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Governance of Water, Sanitation and Hygiene (WASH) in South Africa and Associations with Nutritional Status in Children Between Birth and One Year of Age

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A thesis submitted to the, Faculty of Health Sciences

School of Clinical Medicine

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in fulfilment of the requirements for the degree of

Doctor of Philosophy

Supervisors

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Professor Shane Norris

Johannesburg, South Africa

2020

Declaration

I, Douglas James Momberg, declare that this thesis is my own original, unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other university or institution.



D J Momberg

Date: 12/10/2020

Dedication

Dedicated to the subaltern children who do not yet have a voice.

Acknowledgements

I am deeply indebted to my supervisors, Dr Rihlat Said Mohamed and Professor Shane Norris for the priceless opportunity to pursue my PhD under their supervision. I appreciate the vast knowledge, skills, guidance and input that they contributed to my PhD journey.

In addition to the contribution of my supervisors, I will be forever grateful for the support I received from a number of experts who have contributed to my PhD from conceptualisation of the study, to data analysis and interpretation, to drafting and revision of the various manuscripts that culminated in this thesis: Lee Voth-Gaeddert, Julian May, Pinky Mahlangu, Christian Ngandu, Linda Richter, and Karina Cardoso Ribeiro.

This study would not have been possible without the continued support and assistance of a great research team; Karabo Moloi, Hazel Pemba, Lutricia Moagi, Nonthuthuko Dube, Bongiwe Nkambule, Sostina Matina, and Yonela Kumbi. In addition to the research team of course, I am incredibly grateful to the respondents who participated in our interviews and panel discussions, and to the women and children that volunteered to be part of the prospective cohort study and welcomed us into their homes.

This series of studies, and my PhD as a whole, would not have been possible without the support of the SAMRC/Wits Developmental Pathways for Health Research Unit, the DSI-NRF Centre of Excellence in Food Security, the DSI-NRF Centre of Excellence in Human Development, and the International Atomic and Energy Agency.

My heartfelt thanks and endless gratitude go to my husband, my mother, and all my family and friends for their relentless support and unconditional belief in my capabilities.

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Thesis Material and Contributions

Together with my supervisors, I contributed to the conceptualisation of the new data collection for this thesis. I contributed to the development of the study protocol, which included formulating questionnaires, the standard operating procedures, and data collection. I led the systematic review and conducted the in-depth interviews and the consensus development conference. I assisted with data collection on the infant and maternal anthropometry, water, sanitation, and hygiene questionnaire, morbidity and illness assessment, deuterium dilution technique, infant abdominal ultrasound, and other survey instruments. In addition, I contributed to the project management, quality control and data management for the surveys, as well as statistical analysis of the results presented.

Funding and Awards

This study was made possible through the support of the SAMRC/Wits Developmental Pathways for Health Research Unit, DSI-NRF Centre of Excellence in Food Security (Grant Number: 160502), DSI-NRF Centre of Excellence in Human Development (Grant Number: ACC2017007), International and Atomic Energy Agency (Grant Number: 22420). The support of the DSI-NRF Centre of Excellence in Human Development, DSI-NRF Centre of Excellence in Food Security, SAMRC/Wits Developmental Pathways for Health Research Unit, and International and Atomic Energy Agency, towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at are those of the author and not necessarily to be attributed to the Centre of Excellence in Human Development, Centre of Excellence in Food Security, the SAMRC/Wits Developmental Pathways for Health Research Unit, or the International Atomic and Energy Agency.

Publications and Presentations

In the process of completing this PhD thesis, part of the work was reported and published in a series of scientific publications in international, peer-reviewed journals. Results from this study were also presented in the form of oral and poster presentations at various academic and scientific conferences.

Peer Reviewed Publications:

Paper 1 (Chapter 3)

Momberg D, Ngandu B, Voth-Gaeddert L, Cardoso Ribeiro K, May J, Norris S, Said-Mohamed, R. Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: A systematic review. *Journal of Developmental Origins of Health and Disease*: 1–27 (*Published Online 6 January 2020*). DOI: https://doi.org/10.1017/S2040174419000898 (Appendix Q).

Paper 2 (Chapter 4)

Momberg D, Mahlangu P, Ngandu B, May J, Norris S, Said-Mohamed R. Intersectoral (in)activity: towards an understanding of water, sanitation, and hygiene (WASH), and childhood undernutrition in public sector departments in South Africa. *Journal of Health Policy and Planning*: 1-41 (*Published Online 14 June 2020).* DOI: 10.1093/heapol/czaa028 (Appendix R).

Paper 3 (Chapter 5)

Momberg D, Voth-Gaeddert L, Ngandu B, Richter L, May J, Norris S, Said-Mohamed R. Water, sanitation, and hygiene (WASH) factors associated with growth between birth and one year of age in children in Soweto, South Africa: Results from the Soweto Baby WASH study. *Journal of Water and Health* (*Published Online 21 September 2020).*DOI: https://doi.org/10.2166/wh.2020.085 (Appendix S).

Conference Proceedings:

Developmental Origins of Health and Disease World Congress, Rotterdam, The Netherlands (2017). Poster Presentation: Governance of water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with nutritional status in children under five years of age: A systematic review.

Global Food Security Conference, Cape Town, South Africa (2017). Oral Presentation: Water, sanitation and hygiene (WASH) in sub-Saharan Africa: A challenge for childhood nutritional status?

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Nomenclature

AU: African Union

ACRWC: African Charter on the Rights and Welfare of the Child

CBO: Community Based Organisation

CHBAH: Chris Hani Baragwanath Academic Hospital

CS: Community Survey

CVD: Cardiovascular Disease

DHS: Demographic and Health Surveys

DOHaD: Developmental Origins of Health and Disease

DPHRU: SAMRC/Wits Developmental Pathways for Health Research Unit

EED: Environmental Enteric Dysfunction

FHI: Food Hygiene Index

GHS: General Household Survey

GINA: Global Database on the Implementation of Nutrition Action

GLAAS: Global Assessment of Sanitation and Drinking-Water

GRADE: Grading of Recommendations, Assessment Development and Evaluation

HI: Hygiene Index

HHI: Household Hygiene Index

HREC: Human Research Ethics Committee

IGO: Inter-governmental organisation

JMP: United Nations Joint Monitoring Programme

LCS: Living Conditions Survey

LMIC: Low and middle-income countries

LRTI: Lower Respiratory Tract Infections

MCR: Maternal Case Record

MDG: Millennium Development Goals

NCD: Non-Communicable Diseases

NDP: National Development Plan

NGO: Non-governmental organisation

NIDS: National Income Dynamic Survey

PHI: Personal Hygiene Index

RHC: Road to Health Card

SANHANES: South African National Health and Nutrition Examination Survey

SD: Standard Deviation

SDG: Sustainable Development Goals

SES: Socio-Economic Status

SSA: sub-Saharan Africa

UN: United Nations

UNICEF: United Nations Children's Fund

WASH: Water, Sanitation, and Hygiene

WHO: World Health Organisation

Abstract

Background:

The realisation that infant and childhood linear growth cannot be completely improved by optimized diet and reduced diarrhoea has led to the hypothesis that linkages between different forms of undernutrition and water, sanitation, and hygiene (WASH) factors, may contribute towards persistently poor child health outcomes. The policy environment in South Africa advocates for multi-sectoral approaches, with a number of policies being adopted over the past three decades in order to address WASH, and child growth and nutritional status. However, most indicators of early childhood nutritional status show disappointing results and efforts have not been sufficient to shift the prevalence of stunting still affecting a third of children under three years of age.

Aim:

The aim of this thesis is to examine the governance landscape of WASH, and links between WASH and nutritional status in early childhood.

Methods:

This thesis undertook 3 objectives, firstly a systematic review was conducted, surveying the literature linking WASH, childhood nutritional status and governance in sub-Saharan African settings. Secondly, through purposive sampling, mapping of the various departments and associated policies that are responsible, for the provision of WASH facilities, and for the nutritional status of children was conducted; in-depth policy review conducted of 3 key policies containing reference to children, WASH, and nutrition. Expert interviews, and a consensus development conference were conducted with experts at the intersection between WASH and nutrition. Thirdly, a longitudinal cohort study from birth to 1 year of age was designed to explore associations between WASH and nutritional status of children living in Soweto. At delivery, 156 mother-infant pairs, were recruited from Chris Hani Baragwanath Academic Hospital and followed-up weekly from birth to 6 months, and fortnightly from 6 months to 1 year, where anthropometric measurements and data pertaining to feeding practices, WASH, socio-economic status, and morbidity and illness were collected. Hierarchical regression analyses were used to assess associations between WASH factors: water index, sanitation, hygiene index, and growth: height-for-age (HAZ), weight-for-age (WAZ), weight-for-height (WHZ) at 1, 6, and 12 months postpartum.

Results:

In sub-Saharan Africa, results from recent trials show disappointing results in the attempt to address infant growth and nutritional status through WASH. In addition, existing studies do not explore the role of governance of WASH in their design, nor describe if and how actors in the field of WASH are incorporated into the research process.

In the context of Soweto, household access to sanitation facilities that were not safely managed was associated with a decrease in HAZ scores at 1 month (β= -2.24) and 6 months (β= -0.96); a decrease in WAZ at 1 month (β= -1.21), 6 months (β= -1.57), and 12 months (β= -1.92); and finally, with WHZ scores at 12 months (β= -1.94). Counterintuitively, poorer scores on the hygiene index were associated with an increase at 1 month for both HAZ (β= 0.53) and WAZ (β= 0.44).

Conclusion:

The public sector would benefit from better integration of the concept of WASH into their policy, planning, and implementation frameworks, whereas too few WASH sector plans consider their impact on nutrition in children. More trials are needed to determine and evaluate which WASH interventions are effective at which stages in early childhood development. Provision of safely managed sanitation at household and community levels may be required before improvements in growth related outcomes are obtained, while continued efforts in the promotion of exclusive breastfeeding and provision of social support are integral to achieving local and international nutrition targets.

Preface

My journey to this PhD began with a mild obsession about the role that water plays in shaping societies. Water is one of humanity's most indispensable resources. It influences every part of our existence; from its unique molecular properties to the fundamental role it plays in meteorological, geological, as well as biological processes. Water has, without exception, contributed to the forging of societies and civilisations across the globe.

Politically, militarily, and economically, control of hydrological wealth has stimulated societies to build cities on its shores, provide passage for goods and people on its arteries, utilise its latent energy as a vital input for agriculture and industry, and ultimately to exact political advantage from it. By contrast, failure to adequately govern and manage this precious lifeblood has been indicative of societal decline and stagnation, and at worst, collapse.

Where water resources, infrastructure, or sanitation have been insufficient, diseases have spread, and people have fallen sick or died prematurely. The history of sanitation and hygiene is intertwined with the history of epidemiology, medicine, and public health, as well as that of urbanisation. What is clear in the progression of human history, is the importance of this interdependent relationship between water, sanitation, and hygiene. Some of the most significant advances in human health have been attributed to improvements in the provision of water and sanitation, and better understandings of how hygiene acts as a barrier to the transmission of pathogens.

My early work focussed on hydropolitics and transboundary governance of shared water resources, however, through a series of fortunate coincidences I ended up at the Developmental Pathways for Health Research Unit. It was here, managing paediatric research projects, that I was sensitised to the importance of undernutrition during early childhood, and the long-term consequences thereof. At the same time, in 2015, the emergence of the Sustainable Development Goals along with a report from the United Nations Children's Fund, brought the role that water, sanitation, and hygiene plays in early childhood growth and development, and the importance of improving nutrition outcomes with better water, sanitation and hygiene to the fore. Links between governance and health related outcomes further surfaced as integral to ensuring the health and well-being of children, early in their lives in order to optimise growth and development, safeguard human capital, and the future, which is in the hands of those exact children.

This planted the seeds that would culminate in this venture and as such, I became interested in exploring the interactions between the biological factors and social environmental

exposures on child growth, in low-and-middle-income settings like South Africa, and how governance is integrated into the realm of epidemiology.

The outline of this thesis is illustrated below:

Part 1: Introduction

Chapters 1 and 2 include the background of the study comprising the problem statement and conceptual framework, literature review and methods for this series of studies.

Part 2: Empirical Chapters

Chapters 3-5 contain details of the studies undertaken; utilising data collected over the course of this PhD.

1: Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: A systematic review.

2: Intersectoral (in)activity: towards an understanding of water, sanitation, and hygiene (WASH), and childhood undernutrition in public sector departments in South Africa.

3: Water, sanitation, and hygiene (WASH) factors associated with growth between birth and one year of age in children in Soweto, South Africa: Results from the Soweto Baby WASH study.

Part 3: Integrated Discussion and Conclusion

Chapter 6 comprises an integrated discussion of the thesis, synthesising the main research findings, a re-evaluation of the conceptual frameworks used in this thesis and concludes with an evaluation of the study strengths and limitations, the relevance and implications of these findings, as well as future research considerations.

Part 1: Introduction

Our children are the rock on which our future will be built, our greatest asset as a nation. They will be the leaders of our country, the creators of our national wealth who care for and protect our people - Nelson Mandela

1 Chapter 1: Background and Literature Review

1.1 Undernutrition and Water, Sanitation, and Hygiene (WASH)

In 2018, global estimates put the number of children that were stunted at 150.8 million (22.2% of the world's children under five years of age) (1). While stunting among children in Africa has decreased in percentage terms from 38.3% (2000) to 30.3% (2017), over the same period, due to population growth, the actual number of stunted children has risen (1). At the same time, in percentage terms, stunting has declined twice as quickly in Asia, Latin America, and the Caribbean as it has in Africa (2).

The World Health Organisation (WHO) defines three main forms of undernutrition as being below 2 standard deviations (SD) from the reference population; for height-for-age (stunting), weight-for-age (underweight), and weight-for-height (wasting) (3). Among the three primary forms of undernutrition – stunting (HAZ <-2 SD), wasting (WHZ <-2SD), and underweight (WAZ <-2SD) – stunting is the most prevalent in children under five years of age (4).

Undernutrition is a major public health concern because of associations with adult health and disease risk later in life, including among others, obesity, hypertension, and diabetes, and furthermore acts as a predictor of physical, mental and cognitive child development (5–9). Stunting, in particular, is of concern because it leads to irreversible impairment, including shorter adult height, lower schooling attainment, reduced adult income, and decreased offspring birthweight. Additionally, children who are stunted, and who put on weight rapidly in later childhood and adolescence, are at high risk of chronic diseases related to nutrition, including obesity, hypertension, and diabetes (6).

Pooled data from Brazil, Guatemala, India, the Philippines, and South Africa suggest that promoting better nutritional status during the first 1000 days – from conception to 2 years, leading to increased birthweight and linear growth velocity in children in developing countries, is likely to reduce morbidity and mortality and provide substantial increases in human capital, with only modest trade-offs (10,11).

The developmental origins of health and disease (DOHaD) paradigm helps elucidate this by exploring how environmental factors during early life (especially during pregnancy and infancy) interact to change individual trajectories that may increase or decrease risk for health conditions in later life. The scientific evidence of DOHaD overwhelmingly demonstrates that the environment in which the embryo, foetus and child grows and develops, influences health

and well-being, both in the short-term, in terms of stunting risk, as well as longer-term, in the form of non-communicable diseases (NCD) and human capital (12).

Undernutrition is linked to the environment in which children live, which encompasses familial, cultural, socio-economic, as well as biological factors. Integral in this continuum is the underlying structural determinant of undernutrition, poverty (13). A recent systematic review reported that in sub-Saharan Africa (SSA), lower maternal education, maternal unemployment and lower household wealth index were the socio-economic status (SES) factors most commonly associated with adverse birth outcomes and infant undernutrition (14). The aetiology of undernutrition disproportionately affects the poor and those that are facing food insecurity and poor environmental conditions that lead to increased infections and diarrhoeal diseases. Diarrhoea is closely linked to socio-economic status and has the most adverse effects in impoverished communities (15,16).

Undernutrition is therefore the result of an intergenerational cycle of poverty, reduced human capital, and nutrition and environmental related disease that is difficult to break (6,10,12). While stunting, wasting, and underweight emanate from a variety of structural circumstances and determinants, including antenatal, intra-uterine, and postnatal malnutrition (5,17), observational studies have found associations between the frequency of open defecation and the prevalence of undernutrition (7). An analysis of data from 140 demographic and health surveys (DHS) in 65 countries reported that over half of the variation in child height between countries was explained by the frequency of open defecation. Another analysis of 171 surveys in 70 low- and middle-income countries (LMIC) found that increasing access to and use of improved water sources reduced the risk of stunting (7,8,18).

The realisation that physical growth cannot completely be improved by optimised diet and reduced diarrhoea has led to the hypothesis that linkages between different forms of undernutrition and environmental conditions, including water, sanitation, and hygiene (WASH), may contribute towards persistently poor child health outcomes (19).

WASH is in and of itself a composite concept comprised of three individual components, namely water, sanitation, and hygiene. While each represents a separate field of work, each is contingent on the presence of the other. For example, without toilets, water sources become contaminated, without clean water, basic hygiene practices are not possible (20). Each component is further concerned with a subset of factors that are implicated, for instance, aspects of water include focus on the quantity and biological and chemical quality, as well as type of, and distance to, infrastructure; while sanitation includes focus on the access to, type

of, and distance to, infrastructure; finally, the hygiene component emphasises access to handwashing facilities with soap, as well as nurturing good hygiene practices (20).

The United Nations (UN) Joint Monitoring Programme for Water Supply and Sanitation (JMP) is coordinated through a partnership between the WHO and United Nations Children's Fund (UNICEF). The JMP produces national, regional and global estimates of progress on drinking water and sanitation and reports progress towards Sustainable Development Goals (SDG) 6: Universal and equitable access to safe water and adequate sanitation (21). The JMP classifies drinking water sources into 4 categories; (1) Safely Managed; (2) Basic; (3) Unimproved; and (4) Surface Water (22). Sanitation is categorised into 5 classifications; (1) Safely Managed; (2) Basic; (3) Shared; (4) Unimproved; and (5) Open Defecation (22). Finally, hygiene is separated into 3 groups; (1) Basic; (2) Unimproved; and (3) No Facility (21,22). The JMP collates infrastructure and monitoring data at population and institutional levels, from various sources including household surveys and censuses, and leverages that data, in conjunction with their partners the WHO and UNICEF, to promote intersectoral collaboration, through strong consensus in the WASH and nutrition sectors that WASH is an essential nutrition-sensitive intervention to address undernutrition (23).

1.2 WASH, Nutrition, and Conceptual Frameworks

The link between WASH and nutritional status is not one that should come as a surprise. WASH has long been part of the UNICEF Conceptual Framework, which provides a lens through which maternal and child undernutrition can be examined (Figure 1). This is achieved through providing a scalar model that incorporates immediate causes such as disease and dietary intake, underlying causes including household environment, food security, and health services, as well as basic causes, referring to socio-economic and political context (24).

In applying this framework we see that undernutrition is directly caused by inadequate dietary intake and/or disease and indirectly related to many factors, including contaminated drinking-water and poor sanitation and hygiene (7,24).

Underlying causes such as the quality and quantity of water, as well as the sanitation facilities available to households, play a significant role in the confluence between WASH and nutritional status. Inadequate feeding practices, such as early weaning and introduction of complementary foods, and poor food hygiene, contribute to both short- and long-term consequences of maternal and child undernutrition. Food security, in terms of access to food,

as well as food diversity at both household and community levels, are also particularly noteworthy in this regard (7,23–25).

Basic and systemic causes include access to resources such as education, employment and income, technology, and land. Inadequate financial, human and social capital is underpinned by the social cultural, economic and political context that exists in the various regions of the world (24).

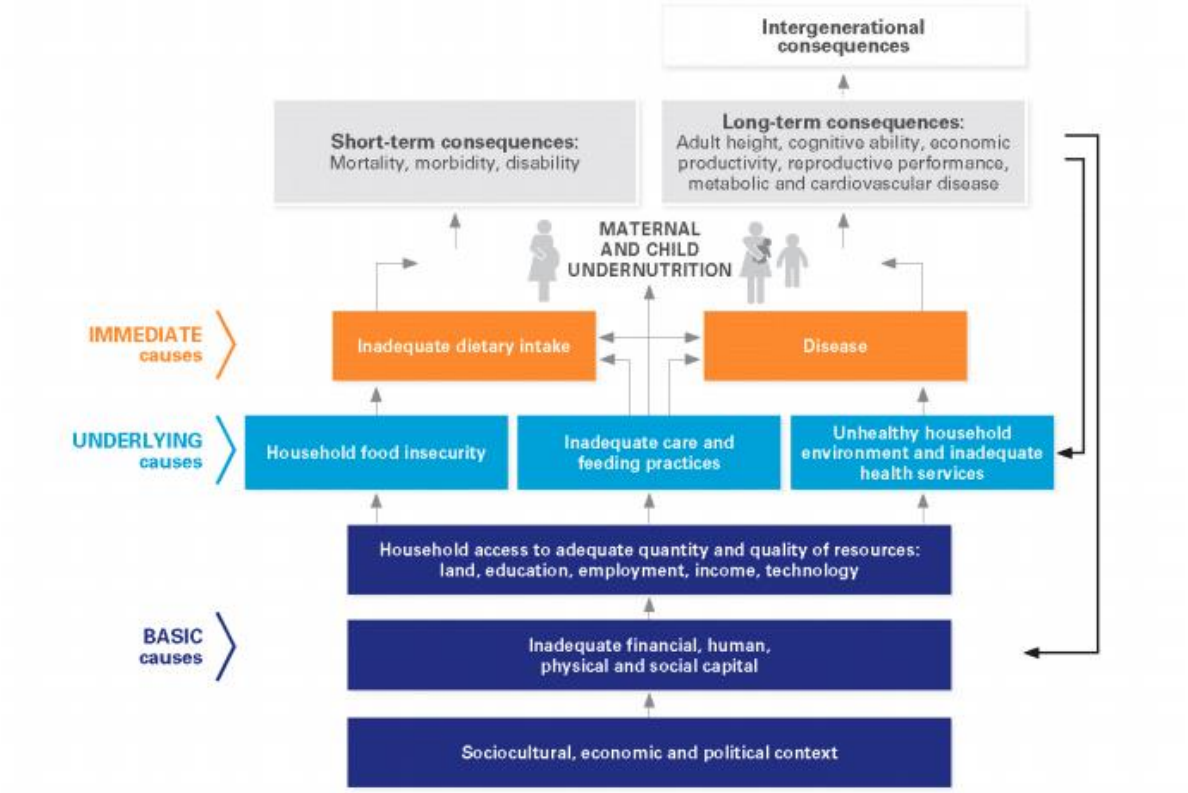


Figure 1: UNICEF Conceptual Framework for Maternal and Child Undernutrition (24)

Psychosocial factors have been found to impact on child growth. Maternal postnatal depression and stress were found to affect child physical growth (higher risks of stunting were reported) and mental health (26,27). Poverty and inequalities are the cornerstone of poor housing, overcrowding, sexual risky behaviour, food insecurity, psychosocial stresses, lack of education, poor access to health care, inadequate WASH are all critical factors of the majority of the determinants of stunting (28).

In addition to the aforementioned, specific pathways are proposed by the so-called 5-F diagram, which describes the faecal-oral transmission route, adapted here to pertain to both individual and community levels (29). The proposed transmission route is that faeces and associated pathogens are transmitted via fluids, fields/floors, flies, and fingers to foods, and then to the infant which causes disease and infection which in turn leads to growth faltering

(Figure 2). Of particular relevance for this study, rather than examining each of the suggested pathways, will be to look at the specific barriers to transmission, namely the latrine, safe water, and hygiene barriers.

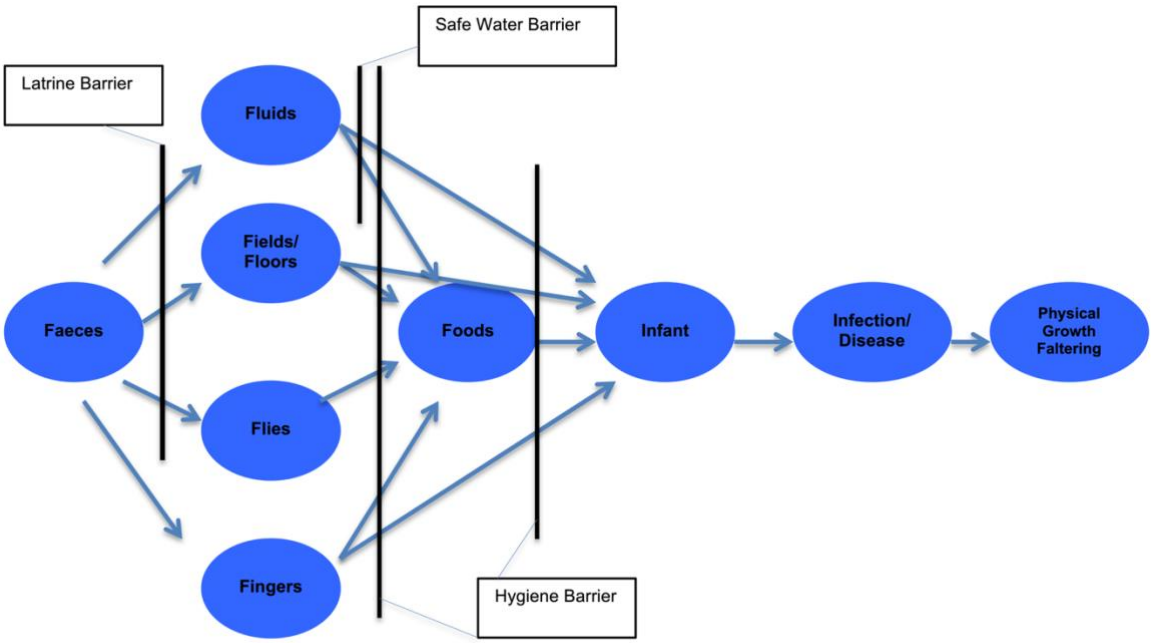


Figure 2: 5-F Diagram (29)

The Lancet series on Maternal and Child Nutrition launched in 2008 again highlighted the link between WASH and nutritional status by reviewing evidence-based interventions that affect maternal and child nutrition-related outcomes, emphasising the importance that WASH plays in preventing undernutrition (30,31). The 2013 follow-up series built on this and provided an updated framework for maternal and child nutrition which included recommendations for inter-sectoral approaches to the challenges of malnutrition in LMIC settings, including an emphasis on WASH. In particular, water, sanitation, and a safe hygienic environment were highlighted in the resultant framework for programmatic action in order to achieve optimum foetal and child nutritional status and development (4,32).

In addition, the 2016 Lancet series on Early Childhood Development, considered new scientific evidence for interventions, building on the aforementioned findings and recommendations (33,34). The importance of this was that it integrated evidence and knowledge from the previous series' and framed the role that these interventions play in terms of early childhood development with an emphasis on the continuum of nutritional status, growth, and cognitive

development. Once again WASH was included in the framework to promote young children's development through a multi-sectoral approach that advocated for ensuring access to clean water, creating sanitation infrastructure, and promoting hygiene behaviours, while stressing the fact that WASH interventions are integral across the life-course (33).

Political rhetoric about the challenges of undernutrition have increased at national and international levels and have led to itemised commitments from many national governments, international organisations, and donors. Agreement among stakeholders, has increased with regard to their understanding of the main causes of undernutrition and the various options for addressing it (35). Among the main challenges are enhancing and expanding the quality and coverage of nutrition-sensitive interventions, including water, sanitation, and hygiene. However a critical level of action relating to the environments and processes that underpin and shape political, governance and policy processes is sorely neglected (35).

1.3 The Role of Governance in WASH and Nutrition

To accelerate progress in addressing the burden of undernutrition, broader efforts are needed, that extend beyond the nutrition sector and that explicitly address the underlying determinants of undernutrition (29). Reflecting on the governance of WASH by disentangling the various actors, role players and stakeholders at various levels, while unravelling the policy environment in comparison to particular health related outcomes is imperative to the understanding, design and implementation of WASH initiatives targeted at addressing the burden of maternal and child undernutrition in various contexts (25,36,37).

The notion of governance is a complex concept, which is in part dealt with in this thesis, however there are a myriad of definitions, with each tending to mean different things to different institutions and/or actors. The Commission on Global Governance defines governance as; the sum of many ways, individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting and or diverse interests may be accommodated, and cooperative action may be taken. It includes formal, as well as informal arrangements that people and institutions have agreed to or perceive to be in their interest (38).

Important elements that are often highlighted pertaining to governance are accountability, state capacity, strong skills and competence, and responsiveness, things that enable government to deliver services to its people efficiently (39). In this sense the extent to which actors, including the state, are held accountable is integral to ensuring implementation and

monitoring and responsiveness to deviations. Where transparency and accountability mechanisms are weak or lacking, people's needs are often marginalised (39). Strengthening accountability requires capacity in government and institutions outside central government, such as parliament, civil society, media, and local communities, as well as an enabling environment in which these stakeholders can operate responsibly and effectively. Even when opportunities for governance reform at the national level are limited, there may be entry points at the local level. In some settings, the entry point might be bottom-up participatory reform, such as community-driven development, especially when it also supports the development of local government transparency, capacity and accountability (39).

Figure 3 presents a modified typology of some of the actors in the global health system, divided into four overarching groups and their types of actors. This shows a growing plurality of actors and the emergence of non-state actors (philanthropic organisations, private industry, civil society organisations, global health initiatives) alongside state actors (donor country governments, UN organisations, multilateral development banks). Involvement of Development Financial Institutions (DFIs) such as the International Monetary Fund and World Bank; Governmental Organisations (GOs) such as the United States Agency for International Development (USAID), as well as regional organisations such as the African Union (AU); and Small and Medium Enterprises (SME) are becoming more evident (40).

Important in this regard is the distinction that governance is not exclusively government. The latter referring to activities that are backed by formal authority to insure the implementation of duly constituted policies. The former is therefore extended to include non-governmental (NGO), inter-governmental organisations (IGO), community based organisations (CBO) (38).

An NGO is a non-profit, voluntary citizens' group which is organised on a local, national or international level. Driven by people with a common interest, NGOs perform a variety of services and humanitarian functions. They convey citizen concerns to governments, advocate and monitor policies. Some are organized around specific issues, such as human rights, environment or health. IGOs on the other hand are entities that are created by a treaty between two or more nations to work on issues of common interest. They are subject to international law and have the ability to enter into enforceable agreements among themselves or with states (38). Finally, a CBO is a public or private non-profit organisation that is representative of a community, or significant segment thereof, and works to provide services in order to meet community needs (41).



Figure 3: Typology of Governance Actors (40)

The challenges governments face are far from uniform and include, among others, that interventions and policies to reduce health inequities often limit themselves to intermediary determinants, but don't include policies specifically crafted to tackle the social mechanisms that systematically produce inequitable distribution of the determinants of health among population groups (42,43). Collaboration with relevant sectors offers distinctive opportunities, while also raising specific behavioural and structural challenges. Behavioural elements concern individual attitudes and comportments among those being asked to work collaboratively across sectoral boundaries. Structural influences include political factors (e.g. political backing, political style, values and ideology), policy issues (such as consensus on the nature of problems and their solutions), and specific technical factors related to the policy field(s) in question (43). Strong national institutions, or lack thereof are furthermore an effective and long-term solution to governance and corruption challenges and to mitigating fiduciary risk for all public money (42).

Broadly defined, social determinants of health represent economic and political structures, social and physical environments, and access to health services (44). Social and economic policies have a determining impact on whether a child can grow and develop to its full

potential and live a flourishing life, or whether its life will be blighted (45). Many existing models of the social determinants of health may need to be modified in order to help the policy community understand the social causes of health inequalities (43).

In this regard, intersectoral action, in terms of the integration of health considerations into the policies and work of other government sectors is of particular relevance when considering the link between WASH and nutrition. It is often noted that normal government processes are not facilitating intersectoral action in a satisfactory way for achieving social and health equity. The need for recognizing the dual political and technical nature of the changes required for better health equity governance is well documented (42,43). Currently however, the health sector's approach to intersectoral action is frequently siloed, and intersectoral processes for health equity are therefore fragile (43).

The Millennium Development Goals (MDG) were established in 2000 to address the world's major development challenges, with health, and its related areas, among the prime foci.

Eight goals were framed with the goal to (1) eradicate extreme poverty and hunger; (2) achieve universal basic education; (3) promote gender equality and empower women; (4) reduce child mortality; (5) improve maternal health; (6) combat HIV/AIDS, malaria, and other diseases; (7) ensure environmental sustainability; (8) develop a global partnership for development (46). The MDGs played an important role in uplifting people from poverty, hunger, death and illness, and illiteracy. However, to address shortcomings in achieving these goals and confront the emerging challenges of a globalised society, the SDGs emerged from the UN Conference on Sustainable Development, Rio+20, in 2012. The SDGs concentrated on creating more focussed, concrete, measurable, and universally agreed objectives and indicators, resulting in 17 SDGs and 169 associated targets (46,47).

Parallel to this, the UN formally declared the right to water in November 2002 and noted that the right to water was indispensable to leading a life of human dignity and was furthermore a prerequisite for the realisation of other human rights. The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use. This also provided the first implicit reference to the responsibilities that governments and stakeholders have in delivering clean water and sanitation to everyone (48). The primary responsibility for service delivery of water and sanitation, as both a basic service and a human right, lies with the state, however, even if the state holds ultimate responsibility, a number of stakeholders take part in the implementation.

In this regard scalability and sustainability depend on good governance and technical factors such as infrastructure and improved knowledge, and the availability of financial resources. Governance issues including limited managerial capacity, poor financial resource administration, corruption and weak institutions, all limit the capacity of the national sector to deliver sustainable results at scale (23).

Findings from studies of nutrition governance and policy processes, broadly concur on three factors that shape enabling environments: knowledge and evidence, politics and governance, and capacity and resources. The international community needs to identify and establish a new global governance structure that can provide greater accountability and participation for civil society and the private sector. Furthermore, linkages with national-level processes need to be significantly enhanced, so that priorities that are felt at country level are better reflected in international normative guidance, donor funding, research, and advanced training (35,49).

Much concern about the governance of WASH has been dedicated to disaster management and mitigation, However, recent research shows that technical aspects surrounding WASH are often not the constraint, but rather it is the lack of good governance which compromises public-service delivery (50)

Many countries in Asia and SSA are rapidly moving to decentralised political, administrative, and financial systems, transferring authority from central to local government, which necessitates building of commitment and capacity at the various political and bureaucratic levels at which decisions are made and resources allocated (35).

Ultimately, national governments, national and global civil society, international and regional organisations, including UN agencies, development banks, and the AU, charitable foundations, international research organisations, academia, and private-sector companies all have a role in the global institutional architecture for WASH and nutrition.

1.4 WASH, Nutrition, and Governance in sub-Saharan Africa (SSA)

In the African context, Article 14 of the African Charter on the Rights and Welfare of the Child (ACRWC) (51) ensures the provision of adequate nutrition and safe drinking water; and that all sectors of society are informed and supported in the use of basic knowledge of child health and nutrition, and the importance of hygiene and environmental sanitation. Countries in SSA continue to make headway in terms of increased access to WASH services, financial resources however remain a critical issue (52). Current levels of WASH financing are not sufficient to fund the achievement of SDG 6, estimated to cost an approximate $122 Billion between 2016

and 2030 (53). Important gaps in financing still exist with SSA countries, on average, committing 0.52% GDP to WASH expenditures. When excluding South Africa, this figure drops to a mere 0.27% GDP. Aid commitments for WASH to SSA have also declined from US$ 3.8 billion to US$ 1.7 billion from 2012 to 2015, and continue to decline (52).

At the closing of the MDG cycle, some 663 million people globally (9% of the world's population) still lacked access to improved drinking water, while 2.4 billion (32% of the world's population) lacked access to basic sanitation services. The situation is most critical in SSA, where, in 2015, 311 million people lacked a safe water source, and the portion of people relying on untreated surface water for drinking was eight times higher than in any other region. In 2015, over 70% of the SSA population were living without adequate sanitation (53). Moreover, the absolute number of people practising open defecation actually increased over the MDG period.

The MDGs had a single nutrition target: to reduce underweight in children under five years of age by 50% by 2015 and by the end of the MDG cycle in 2015, failing to meet these targets in SSA, an estimated 36.6% of children under five were still stunted, 8.6% wasted, and 19.5% underweight (54).

Over this period, nearly all African countries did however show a reduction in the absolute levels of stunting, wasting and underweight in children under five. Stunting was the most prevalent form of undernutrition while wasting, more sensitive to external environmental fluctuations, such as crop yields and food availability, and more likely to affect children over the course of months rather than years, has led to short-term events driven by uneven temporal patterns of decline, compared to the more consistent decreases seen in stunting and underweight (54).

In the post-2015, SDG agenda, SDG 6: Universal and equitable access to safe water and adequate sanitation; and SDG 2: End all forms of malnutrition, by 2030 are of particular importance and can be seen as interrelated with many of the other SDG child health ambitions (36,47,54).

Current nutrition indicators show that some countries are on track to meet the WHO Global Nutrition Targets (25), however, large tracts of the SSA continent will need to significantly increase their efforts. Inland areas of central Africa and the Sahel will require the most marked improvement while some areas, such as southern and western coastal Africa, are on target to meet the 40% reduction of stunting rates. The reduction of child wasting, to less than 5% is likely to be met in most countries in south-eastern Africa based on current trajectories, but

much of central SSA and the entire Sahel will require pronounced improvements to match these targets (54).

Regionally, the AU, under the auspices of the Malabo Declaration (2014) commits to improve nutritional status, and in particular, the elimination of child undernutrition in Africa with a view to bringing down stunting to 10%, and underweight to 5% by 2025 (55).

Despite these commitments, stunting rates in children under five years of age in Africa are increasing with significant disparities in progress at subnational level. Notwithstanding the decrease in stunting prevalence in Africa, the number of stunted children has steadily increased from 50.6 million (2000) to 58.7 million (2017) (1). In addressing nutritional status through WASH, particular emphasis is placed on the role that financing, governance, and policy interventions will need to play in achieving these targets (25). In addition, although country-level estimates are useful for international comparisons and benchmarking, they mask disparities in undernutrition at the lower administrative levels where most health and nutrition policy planning and implementation occur. Without comparable, robust subnational information on stunting, wasting and underweight, health authorities face sizeable challenges to precisely target and thus optimally fund relevant nutrition interventions (54).

1.5 South African Context

South Africa is constituted on a quasi-federal system with three spheres of government at national, provincial and local levels (56–58). South Africa is administratively divided from the national level, across 9 provinces (Figure 4), and between either metropolitan councils, or district or local municipalities, with varying degrees of legislative and executive authority (59). National government is responsible for developing policy frameworks, defining norms and standards for service provision, and distributing revenue in an equitable manner while provincial and local governments are responsible for implementing most public functions and service delivery and for putting policies developed at national level into effect (56,58,60).

The policy environment in South Africa advocates for multi-sectoral approaches for addressing nutritional status through WASH and is, among others, informed by the National Food and Nutrition Security Plan for South Africa (61), the National Sanitation Policy (62), and the Integrated Early Childhood Development Policy (63). South Africa has adopted a number of policies over the past three decades in order to address child undernutrition, however most indicators show disappointing results. Provision of social protection, free basic healthcare and services, food fortification, promotion of breastfeeding, improved food safety standards, as

well as micronutrient supplementation during pregnancy and infancy, have not been sufficient to shift the prevalence of stunting (5,13,64).

The South African context is further characterized by various political, economic, demographic, and nutrition transitions resulting in a triple burden of malnutrition whereby the population faces under- and over-nutrition, as well as micronutrient deficiencies (5,65). This is closely related to the fact that South Africa emerged from the oppressive apartheid regime at a critical juncture in global history. The dramatic geopolitical shifts that occurred as a result of the ending of the Cold War, as signalled by the fall of the Berlin wall in 1989, had far reaching consequences for the provision of basic services and healthcare, and transformed the dynamics of economics and health development at global, regional, and national levels (66,67). The rise of civil society and the movement on social justice, equity, and rights significantly reshaped governance of health at all levels (67,68).

As South Africa emerged as a fully-fledged democracy in 1994, the country was faced with a number of immediate challenges, the epidemiological consequences of which are now becoming evident. South Africa has one of the highest levels of urbanisation in Africa, reflecting a long history of mining and industrialisation (56,69,70). During much of the 20th century it resulted in draconian controls on people's movements causing a widening economic gap between urban and rural areas (56,69,70). A fragmented urban environment structured against arbitrary racial lines has had damaging psychosocial, economic and environmental consequences (56,69,70). Fractured cities that favour road-based private transport, making access to basic services and employment opportunities difficult, have created poverty traps and kept those most vulnerable on the periphery (70). As a result, South African cities are amongst the most unequal and visibly divided in the world, with some of the most affluent neighbourhoods juxtaposed with some of the most neglected, unhealthy and dangerous (70). In 2018, approximately 63% of South Africans were already living in urban areas and the numbers are projected to rise to 71% by 2030 and by 2050, 8 in 10 people are expected to be living in urban areas, thereby increasing demand on basic infrastructure requirements (71).

In 2020, South Africa's national unemployment rate was reported at 29.1%. Provincially the rates were reported as follows: Western Cape (20.9%); Eastern Cape (39.5%); Northern Cape (26.9%); Free State (35%); KwaZulu-Natal (25%); North-West (28.8%); Gauteng (30.8%); Mpumalanga (33.6%); and Limpopo (23.1%) (72).



Figure 4: Map of South Africa and Provinces

Historically, from 1994, unemployment rates for African workers have been much higher than for other groups and the experience of unemployment by gender and location is well known, with the most significant point being the substantially higher unemployment rate amongst rural African women, than for any other group (73). Properly calculating employment and unemployment across the full population is really a new activity with many changes in the measurement instruments having been made over the 1990s as Stats SA has sought to make improvements. The October Household Survey (OHS) conducted between 1994 and 1999 and its successor, the Labour Force Survey (LFS) conducted from 2000 onwards, is currently by far the most reliable source of information (73). Historically, the choice to include data from 1994 onwards is due to the skewed nature of the records prior to the transition to democracy.

These shifts are further typified by changes in lifestyle and diet. Nutrition transitions are characterised by shifts to highly refined diets high in fat, salt and caloric sweeteners while

being low in fibre, especially seen in rapidly growing economies (74,75). Dietary shifts occur concurrently with demographic and epidemiological transitions, urbanisation and industrialisation and together contribute to increased prevalence of nutrition related NCDs. Demographic transitions are the shift from a pattern of high fertility and mortality to one of low fertility and mortality, while epidemiological transition is the shift from a pattern of high prevalence of infectious diseases, associated with malnutrition, periodic famine and poor environmental sanitation, to one of high prevalence of chronic and degenerative diseases, associated with urban-industrial lifestyles (75).

The emergence of the nutrition transition in South Africa has been seen through examining anthropometric, NCD prevalence, and food consumption data. The findings reveal a growing prevalence of, amongst others, overweight and obesity, and hypertension (76,77).

South Africa is no different in terms of global trends, where 88% of countries face multiple forms of malnutrition, ranging from childhood stunting, to anaemia in women of reproductive age, and/or overweight in adult women, often occurring in the same household (65,78,79). The probability of reaching the internationally agreed nutrition-related targets for stunting by 2025 is unlikely, due to slow progress (1,25,79,80). The current average annual rate of reduction of 2.3% is below the required rate of 3.9% (1).

The South African Health Review thus emphasises the need for a multi-sectoral approach in combating malnutrition, stating that action on nutrition is needed to achieve goals across the SDGs (79).

In contrast to other countries in SSA, South Africa has a long history of recording nutrition data through studies and national surveys, and is also in an advanced stage of nutrition transition associated with these political, economic and demographic transitions (17). Important in this regard, is the substantial level at which stunting persists (17). In South African children, the prevalence of stunting generally increased between the ages of 8 and 23 months, remaining very high (>40%) between the ages of 18 and 27 months, before declining around three years of age (17,79,81). In children under five years of age, in 2016, the prevalence was 27.4%, with 29.8% of boys and 25% of girls being stunted (81). Provincially the stunting rates were reported as follows: Western Cape (22.9%); Eastern Cape (24.8%); Northern Cape (21.4%); Free State (33.5%); KwaZulu-Natal (28.5%); North-West (27.4%); Gauteng (34.2%); Mpumalanga (21.5%); and Limpopo (21.9%) (79). Over the same period, 5.9% of children under the age of five were underweight and 2.5% were wasted (79,81).

With respect to access to water in South Africa, in 2015, the percentage of households with

access to piped or tap water, by province, were reported as follows: Western Cape (99.2%); Eastern Cape (74.9%); Northern Cape (96.5%); Free State (96.1%); KwaZulu-Natal (84.2%); North-West (86.1%); Gauteng (97.7%); Mpumalanga (85.5%); Limpopo (78.8%); South Africa (89.4%) (82,83). At the same time, in terms of the type of infrastructure at national level, 45.8% of households, had access to piped water in their dwellings, a further 27% accessed water on their property, while 14% relied on communal taps, and 2.7% relied on neighbours' taps (82,83). Although household access to water generally improved, 4.4% of households still had to fetch water from rivers, streams, stagnant water pools, dams, wells and springs (82,83). Furthermore, the National Development Plan (NDP) (84) aims to achieve an increase in the percentage of households with access to a functional water service in compliance with SDG 6 by 2030 (82).

In terms of sanitation coverage, the percentage of households who reported living more than 200 meters away from the outside yard toilet facility increased from 1.3% in 2014 to 6.1% in 2015 and over the same period approximately 270 000 South African households still relied on buckets (82). Table 1 displays the national and provincial percentage of households with access to improved sanitation between 2001 and 2018, displaying data from the national Census, the General Household Survey (GHS), and Community Survey (CS) (85).

The most recent South African GHS (2018) pointed out that progress has stalled, with the final 20% proving to be the most difficult to address.

		2001 Census	2002 GHS 2018	2004 GHS 2018	2006 GHS 2018	2007 CS	2008 GHS 2018	2010 GHS 2018	2011 Census	2012 GHS 2018	2014 GHS 2018	2016 CS	2016 GHS 2018	2017 GHS 2018	2018 GHS 2018
National		58,5	61,7	65,9	68,3	64,4	70,0	75,4	68,9	77,0	79,5	75,6	81,0	82,4	83,0
Province	EC	38,8	33,4	38,5	49,4	45,3	54,9	63,6	56,8	70,0	78,2	74,4	85,1	85,8	88,0
	FS	53,6	64,7	69,7	71,8	68,1	76,4	83,4	75,6	83,5	83,8	79,0	83,2	85,2	85,5
	GP	83,6	88,9	89,8	89,1	86,9	91,3	91,2	87,8	91,1	90,9	88,5	90,5	90,7	91,8
	KZ	51,6	50,9	58,5	63,0	56,8	62,8	72,7	59,6	68,0	75,9	65,1	77,2	81,1	81,4
	LP	26,2	26,9	34,6	33,9	28,4	32,1	41,1	37,0	49,8	54,0	51,5	57,1	59,3	58,9
	MP	48,2	50,7	55,3	53,1	54,5	54,4	55,4	55,9	62,4	64,4	60,4	67,5	67,8	68,1
	NC	71,9	75,5	75,9	76,9	80,6	76,2	83,7	74,7	84,6	83,9	78,6	82,6	88,1	90,0
	NW	47,7	54,1	57,8	54,4	50,9	58,1	66,5	56,9	72,2	67,0	64,6	69,0	71,7	70,6
	WC	87,1	92,2	91,8	95,2	92,6	93,7	96,7	90,1	95,5	94,5	93,5	94,3	94,2	93,8

Table 1: Percentage of Households with Access to Improved Sanitation (85)

In light of the various transitions that South Africa is undergoing and the aforementioned factors associated therewith, the South African National Health and Nutrition Examination Survey (SANHANES-1) specifically points to the importance of the urban informal

environment, as the largest percentage of participants actually experiencing food insecurity, and having the largest percentage of participants with the highest risk of food insecurity (13). The relationship between WASH and infant growth at household level has received little attention in the South African context, which drastically limits our understanding of what installations and caregiver practices expose infants to such risks (64). The aim of this thesis is therefore to address this by examining the governance landscape of WASH, as well as the links between WASH and nutritional status.

1.6 Literature Review

In terms of the literature linking WASH and nutritional status in children, the Lancet series on Maternal and Child Nutrition (2008, 2013) and on Early Childhood Development (2016) have helped summarize the knowledge, gaps and actions needed to reduce infant morbidity and mortality, favouring, amongst others, physical growth.

The 2008 (30) and 2013 (32) series specifically highlighted that hand washing, water quality, treatment, sanitation and hygiene, were suggested to reduce incidence of diarrhoea by 30% and hence reduce the odds of stunting, with each additional episode assumed to increase the odds of stunting by 4% (OR 1.04). A pooled analysis of several concurrent interventions, which included data from seven studies in children younger than 5 years suggested a decrease in diarrhoea episodes (pooled estimate of RR 0·67, 95% CI 0·59–0·76; random effects) (30,32). Evaluating the evidence for the effects of disease prevention strategies, the series reported that for the age-groups 1-12 months and 12-59 months there were significant decreases in diarrhoea reported (handwashing vs. control: RR 0.70, 95% CI 0.56 – 0.89; random effects), although the direct effect of hand washing on preventing deaths due to diarrhoea was not modelled. Analysis of demographic and health surveys (DHS) data from 65 countries suggested significant effects associated with open defecation explaining 54% of variation in child height. A reduction of 20 percentage points in open defecation was associated with 0.1 SD increase in child height (30,32). However, improvements to WASH alone are not enough to address the burden of childhood undernutrition.

The outcome of these results was the inclusion of WASH in the Lancet Maternal and Child Nutrition frameworks to promote young children's development through a multi-sectoral approach advocating for access to clean water, creating sanitation infrastructure, and promoting hygiene behaviours, while stressing the fact that WASH interventions are integral across the life-course (4,30–32). The DOHaD paradigm further points to the first thousand

days as one of the most critical periods in childhood development (30,32), emphasising the necessity to reduce the risks of infectious diseases and to improve infant nutrition and nutritional status (6,11,12,30,32).

A 2013 Cochrane Review on the effect of WASH interventions on nutritional status in children highlighted the low number of studies and low methodological quality of studies conducted in the past (86). The quality of the evidence is noted as being generally poor with the overall estimates presented being based on meta-analyses of data from interventions of relatively short duration. The meta-analysis conducted identified no evidence of an effect of WASH interventions on WAZ (MD 0.05; 95% CI -0.01 to 0.12); no evidence of an effect of WASH interventions on WHZ (MD 0.02; 95%CI -0.07 to 0.11); and identified only a borderline statistically significant effect of WASH interventions on HAZ (MD 0.08; 95% CI 0.00 to 0.16) (86). The review also identified and emphasized the lack of rigorous evidence evaluating the effect of WASH interventions on child nutritional status. Additionally, despite the fact that evidence for SSA is sorely lacking, a 2015 Cochrane Review assessing the effect of hand washing on diarrhoea prevention, concluded that hand washing promotion in LMIC settings may reduce incidence of diarrhoea by about 30% (87).

A package of baby-WASH interventions to interrupt faeco-oral transmission in the first two years of life was proposed in 2016 and included emphasis on reduction of faecal load in the living environment, reduction of faecal transmission via hands, exclusive breastfeeding, improvement of drinking-water quality, avoidance of child faecal ingestion during mouthing and exploratory play, and hygienic handling and preparation of complimentary foods (19).

Recent results from randomised controlled trials on the effect of WASH interventions have however demonstrated only a marginal effect of WASH interventions on linear child growth (86–89). In a community-led total sanitation (CLTS) cluster-randomised controlled trial in Mali, where communities committed to building latrines and stop the practise of open defecation; open defecation free certification was achieved in 58 (97%) of 60 villages assigned to receive the CLTS intervention, and access to a private latrine also almost doubled in CLTS villages (88). Children in the intervention villages were taller, and less likely to be stunted, than children in control villages, and were also less likely to be severely underweight in intervention villages than in control villages (88). On the other hand, the WASH Benefits trial set in Bangladesh and Kenya, where interventions included household visits to promote target behaviours; drinking chlorinated water, safe sanitation consisting of disposing faeces in an improved latrine, handwashing with soap, and combined water, sanitation, and handwashing, counselling on

appropriate maternal, infant, and young child feeding plus small-quantity lipid-based nutrient supplements, reported no effect of WASH interventions on linear child growth (89,90). Compared with the control group, children in the nutrition intervention arm, and combined water, sanitation, handwashing, and nutrition intervention arm, were taller by year two. The individual water, sanitation, and handwashing groups, and combined water, sanitation, and handwashing group, had no effect on linear growth (89).

The Sanitation Hygiene Infant Nutrition Efficacy (SHINE) trials conducted in Zimbabwe combined intervention of sanitation, water chlorination, and handwashing with soap (89,91,92). Both studies concluded that more comprehensive WASH interventions may be needed to achieve a major impact on child health, and that these results do not show that WASH cannot influence child linear growth, but rather emphasise that these specific interventions had no influence in settings where stunting remains an important public health challenge (93).

Further exploration of the data from these, and forthcoming trials, most notably the Maputo Sanitation (MapSan) trial (94), will hopefully provide a more nuanced perspective on what does and does not work.

An important distinction is, that it is in fact not WASH that will improve nutrition but rather that WASH, through various pathways including infections, will improve growth which is in this case a marker of nutritional status. In addition, low-cost WASH interventions often fail to improve health because they require much more user effort, time, and compromise than is required from residents of high-income countries for WASH services (95). In addition, studies have suggested that the smallest deviations from recommended behaviour can have disproportionate effects on health related outcomes (96). For instance, a decline in adherence to water treatment from 100% to 90% reduces predicted health gains, expressed as disability-adjusted life-years, by up to 96% (96).

In the South African setting, a recent study to determine WASH status and practices in ECD centres located in low socio-economic areas of Nelson Mandela Bay in the Eastern Cape, found that despite improved water sources being available in 91% of the facilities, hygiene was poor (97). Results confirm that while most of the ECD centres in the study area have access to improved water sources, they lack adequate sanitation facilities and overall safe hygiene standards and behaviour are low with only 11% of the study population washing their hands hygienically under a running tap or tippy tap (97).

The results shown pose broader questions as gaps emerge in the literature such as, while the microbial quality of drinking water available may be improved, the quantity of water, long argued to be a key driver in water-related health gains, remains an important consideration (90,98). Population density and proximity to sanitation facilities are significant drivers in improving environmental conditions around children, while delivering community wide interventions are important for showing an effect of sanitation on linear growth (88). Other pathways, such as nutrition, animal waste, and complementary foods as pathways for enteric infection cannot be overlooked. The precise timing of specific WASH interventions tailored to best respond to childhood developmental stages and growth require further exploration.

Another major gap, and one especially pertinent to this thesis, is the lack of literature including components of governance into the scientific studies looking at the links between WASH and nutritional status, linking governance to health-related outcomes.

These results show how little we know about the transmission of enteric pathogens, the causes of symptomatic infections and the significance of asymptomatic infections while at a policy level, business as usual in the WASH sector will not be enough to significantly improve child growth (90).

1.7 Overall Aim

This thesis intends to examine two separate yet interrelated foci. Firstly, the governance landscape of WASH and secondly, links between WASH and nutritional status. The governance landscape will be contextualised through examining the sub-Saharan African and South African settings while a longitudinal prospective cohort study from birth to one year of age was designed to address knowledge gaps surrounding links between WASH and nutritional status in urban South Africa.

1.7.1 Study Objectives

Three specific objectives emerged as a way of achieving the aforementioned. The first objective (Paper 1 - Chapter 3) was to conduct a systematic review of the governance of WASH in sub-Saharan African settings and associations with undernutrition in children under five years of age. This systematic review examined the literature linking governance, WASH and childhood nutritional status, in sub-Saharan African settings.

The second objective (Paper 2 - Chapter 4) was to map the institutional and regulatory frameworks for WASH in South Africa and the Gauteng Province. In-depth interviews and

expert panel discussions were conducted with key informants at the confluence between WASH and nutrition to examine the governance of WASH in relation to nutritional status in South Africa.

The third objective (Paper 3 - Chapter 5) was to assess the association between WASH components and childhood nutritional status at contrasted time points, namely, delivery and 1, 6, and 12 months postpartum, and associated factors, such as socio-economic status (SES), while characterising children's nutritional status.

1.7.2 Research Questions and Hypotheses

Research Question 1: How is WASH managed in relation to child nutrition in SSA settings?

Hypothesis: Literature pertaining to WASH and nutritional status in children in SSA do not explicitly integrate governance into their study design, and findings.

Research Question 2: What is the governance landscape of WASH in South Africa in relation to nutritional status of children under five years of age?

Hypothesis: Actors and policies surrounding WASH in South Africa do not explicitly attempt to improve child growth and nutritional outcomes.

Research Question 3: What are the associations between WASH components and nutritional status of children between birth and one year of age?

Hypothesis: Water, Sanitation and Hygiene are risk factors for growth delay between birth and one year of age.

2 Chapter 2: Methodology

This chapter describes the study setting and study design, data measurement and management techniques used, and the ethical considerations related to this thesis. This series of studies proposed three objectives and three distinct, yet complimentary methodologies. Using mixed-methods, qualitative and quantitative techniques were employed to address the specific objectives. Traditionally, efforts to combine qualitative and quantitative methods have often lacked a solid methodological basis in research practice and have frequently combined quantitative and qualitative methods without providing a clear rationale for the choice of methods. Using a mixed-methods approach is however especially useful in understanding contradictions between quantitative results and qualitative findings. This in turn, tends to provide a more complete understanding of the problem, and yields a deeper, more comprehensive body of evidence. Use of both qualitative and quantitative methods for the studies in this thesis were therefore combined to overcome the specific limitations inherent in both methodological approaches, in order to compensate for their mutual and overlapping weaknesses. In light of this, the methods selected in this series of studies were largely informed by the substantive research questions that emerged, and not exclusively by methodological and epistemological considerations alone.

Further detailed methodology for each of the objectives are presented in chapters 3 to 5. Data for the analyses that follow were collected between 2017 and 2019.

2.1 Study Setting

Each of the objectives in this thesis sought to characterise a different scale. Objective 1 for instance sought to explore literature concerned with WASH, governance, and nutritional status in children under five years of age, at the regional level of sub-Saharan Africa. Situating the importance of the topic of this thesis in relation to the SSA context and associated literature was imperative to establishing the *raison d'être* for this study at large and framing the subsequent objectives that sought to concentrate attention at national, sub-national and local levels.

Gauteng, Figure 5, is the smallest province in South Africa in terms of land coverage, accounting for only 1.5% of the total land area of the country and is almost exclusively urban and has the highest population and population density and near universal water and sanitation coverage (82,99). Gauteng is the economic and financial hub of South Africa

producing 34% of South Africa's gross domestic product and approximately 10% of the GDP for the African continent (99,100), however, despite the economic advantages of the province, Gauteng has the 4th highest unemployment in South Africa (72).

Gauteng is also home to the City of Johannesburg (CoJ), the largest city in South Africa (70,99). Johannesburg emerged as an industrial and mining centre in the latter half of the 19th century after the discovery of gold. The discovery of gold and platinum led to the need for vast amounts of labour in order to extract the precious metals from the alluvial and reef deposits. Soweto had its origins in 1905 when the slum yards of Newtown in central Johannesburg were razed to the ground and African residents were moved to what was to become the South-Western Township (SO-WE-TO) (101).

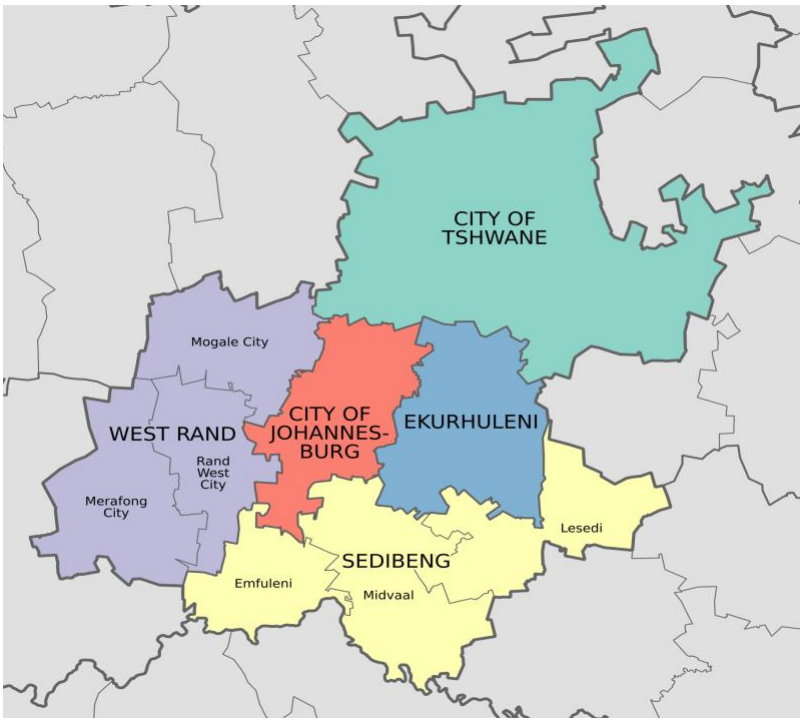


Figure 5: Map of Gauteng Province

Figure 6. Soweto is the largest township in South Africa with a population estimated at approximately 1.3 million, accounting for approximately one third of Johannesburg's population, with between 600 000 and one million people regarded as living in extreme poverty (101).

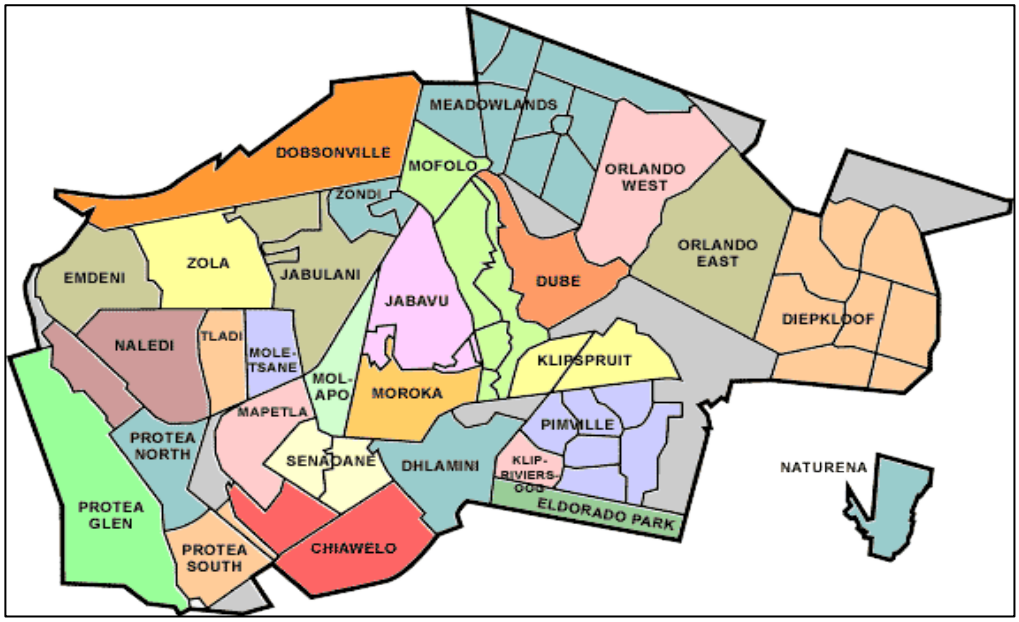


Figure 6: Map of Soweto

The South African Demographic and Health Survey, reported that in Gauteng between 2011 and 2016 the prevalence of children under the age of five that were wasted was 1.3%, 5.8% were underweight, and 34.2% were stunted, representing the highest prevalence of stunting in the country (79,81). In addition to this the SANHANES-1 data points to the importance of the urban informal environment, where the highest prevalence of stunting is seen (13). The aforementioned acted as the impetus to investigate the national and sub-national levels explored in objectives 2 and 3 of this thesis. Objective 2 concentrates on the governance and South African setting in order to elucidate the landscape of WASH in South Africa in relation to nutritional status of children under five years of age in the national, South African, and sub-national, Gauteng, and City of Johannesburg contexts. Objective 3 in turn sought to explore the local setting by examining the specific environmental postnatal factors related to water, sanitation, and hygiene and subsequent associations with growth faltering and nutritional status from birth to 1 year of age in infants who were *a priori* born healthy, in Soweto.

2.2 Objective 1: Systematic Review

2.2.1 Study Design

A systematic review was conducted to examine the literature surrounding the governance of WASH in sub-Saharan settings and associations with nutritional status in children under five

years of age. The PRISMA Statement (102), was utilised while this systematic review has also been registered with PROSPERO (CRD42017071700) (103).

2.2.2 Data Collection

The systematic review was conducted in 2017. Peer-reviewed articles published between January 1990 and October 2017, sourced from PubMed Central, Science Direct, and ProQuest Social Science databases, reporting governance or policy, water, sanitation and/or hygiene and associations with nutritional status in children in sub-Saharan Africa were included. Studies pertaining to children with known chronic and acute diseases or abnormalities affecting growth, and not in either English or French, were excluded. Data pertaining to the governance or policy mechanism were extracted along with nutritional status as defined by the WHO Multicentre Growth Reference Study (3), and water, sanitation, and hygiene metrics as defined by the JMP (21). Study design, date of data collection, country, participant age and sex, as well as sample size, aims and results or outcomes were also extracted.

In addition, a survey of government websites, the Global Database on the Implementation of Nutrition Action (GINA) (104) and, where possible, the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) (105) was conducted to source water and/or sanitation policies for countries in SSA and investigated if they included any links to health and/or nutrition. Excerpts pertaining to the country, policy and date, as well as links to health and/or nutrition were extracted using a standard data extraction form.

2.3 Objective 2: WASH and Childhood Undernutrition in South Africa

2.3.1 Study Design

This component, initiated in 2019, used an exploratory qualitative study design (106,107) to reflect on the nexus between water, sanitation, and hygiene, and nutritional status in children, in the public sector in South Africa focusing on the Gauteng province, and the City of Johannesburg (CoJ). The authors detailed the national and provincial public sector departments and through purposive sampling proceeded to map the various departments and associated policies that are responsible, for the provision of water, sanitation, and hygiene facilities, as well as the nutritional status of children. Finally, a set of expert interviews were conducted, and a consensus development conference convened, with experts at the intersection between WASH and nutritional status.

2.3.2 Study Participants

Key informants identified through institutional mapping and policy review processes, located at national, provincial, and local levels, in government departments, CBOs, NGOs, and IGOs with unique insight and experience of the confluence between WASH and nutrition as it relates to nutritional status in children in South Africa were invited to participate in individual in-depth interviews and a consensus development conference. The information and consent sheet for respondents who agreed to participate is attached as Appendix A.

2.3.3 Data Collection

The institutional mapping, policy review, expert interviews, and consensus development conference were all conducted, during the course of 2019. Following the collation of all the national and provincial government departments in South Africa, purposive sampling (106), and an institutional analysis and development framework (108) were used to select and include public sector departments that are responsible for the provision of water, sanitation, and hygiene facilities, as well as the nutritional status of children, in a mapping exercise. Current policies within each of the departments included were identified and assessed using a document review guide for whether any explicit link between WASH and nutritional status in children was present. The key informants identified were invited for individual in-depth interviews (Appendix B) reflecting upon: (1) the perceived links between WASH and nutritional status; (2) barriers to implementation of strategies designed to address the link between wash and nutritional status; (3) and solutions and/or recommendations to the aforementioned barriers.

2.4 Objective 3: Longitudinal Prospective Cohort Study

2.4.1 Study Design

This study used interdisciplinary approaches to identify specific environmental postnatal factors related to water, sanitation, and hygiene and subsequent associations with growth faltering and nutritional status from birth to 1 year of age in infants *a priori* born healthy in Soweto, Johannesburg. Due to the stochastic nature of growth and in an attempt to better characterise the effects of exposures on growth at regular intervals, a longitudinal prospective cohort study was designed which followed mother-infant pairs up on a weekly basis (from 0-6 months postpartum) and then fortnightly (from 6-12 months postpartum). All the participants were screened and recruited at the maternity services of the Chris Hani

Baragwanath Academic Hospital (CHBAH) in Soweto, Johannesburg. Recruitment commenced from January-March 2018 and the data collected for this particular study ended when the last infant recruited turned 1 year of age (March 2019).

2.4.2 Study Participants

A total of 1289 mothers were screened (Appendix C) 1-3 days post-delivery at the maternity wards at CHBAH. Of those screened, 156 mother-infant pairs were consented (Appendix D) and enrolled. Given the exploratory nature of the study, funding limitations, the timing and age range of infants, in conjunction with the multitude of outcomes being examined, it was not feasible to conduct sample size and power calculations that were able to take all the objectives into account. Despite sample sizes being limited in-lieu of collecting more routine and detailed data, home-visits allowed the study team to limit biases in participant answers by probing and having first-hand experience of the household.

2.4.2.1 Eligibility Criteria

To better identify which, and when, determinants affect growth, we recruited infants who *a priori* had a better start in terms of physical growth and development.

2.4.2.2 Inclusion Criteria:

Mother and infant pairs who fulfilled the following characteristics were eligible for inclusion in the study: ≥18 years of age at time of screening; Singleton pregnancy; Appropriate size for gestational age at birth: birthweight of ≥2500g and <4000g; Term pregnancy of ≥38 weeks and <42 weeks gestational age; Living in formal or informal dwellings in Soweto; Planning to stay in Soweto for the first 12 months after birth; Willing and able to give informed consent for participation in the study.

2.4.2.3 Exclusion Criteria

Mother and infant pairs with the following characteristics were not included in the study: Infants diagnosed with physical, mental or congenital disorders at birth; Mothers living with HIV/AIDS.

2.4.3 Data Collection

Data collection for this objective commenced January 2018, and ended March 2019. Questionnaires and anthropometric measurements, as described below, were administered by trained multi-lingual research assistants. Questionnaires (Appendices F-K) (3,21,115–117,22,105,109–114) we collated using existing tools validated for the South African context and were piloted in the Soweto setting before commencing. The piloting commenced between. The surveys were administered in the participants' home and conducted in the language of their preference.

2.4.4 Measures and Procedures

This section provides information regarding the WASH exposures, the outcome growth measures as well as the maternal and household covariates used in these analyses. Further details on the respective exposure and outcome variables used to address each of the thesis objectives are presented in chapters 3 to 5.

2.4.4.1 Enrolment and Follow-up

For objective 3, once enrolled, data on maternal health, potential complications during pregnancy and the mode of delivery were collected from the Maternal Case Record. Date of birth, length, and head circumference at birth was collected from the infant Road to Health Card. Infant anthropometry (weight, length, mid-upper arm circumference, and head circumference) was then independently measured by study research assistants. Visits, where possible, were made weekly from week 1 to 6 months and fortnightly from 6 months to 11.5 months at the participants' homes. Women and their infants were invited to come to the SAMRC/Wits Developmental Pathways for Health Research Unit (DPHRU) facilities at CHBAH for data collection visits at 6 and 12 months postpartum. The schedule of the data collected at each time point is presented in the attached Sample Collection Table (Appendix E).

2.4.4.2 Outcomes

2.4.4.2.1 Infant Anthropometry

Longitudinal growth measures from birth to 12 months were collected (Appendix F). Anthropometric measurements were performed using standardised techniques by trained research assistants in accordance with the WHO Growth References (3,109). Infant weight was measured to the nearest 0.01kg using an infant scale (seca 367) and recumbent length to the nearest 0.01cm using an infantometer (seca 416). Infant head circumference and mid-

upper arm circumference were measured to the nearest 0.01cm using paediatric measuring tape (Chasmors). Tricep, bicep and sub-scapular skinfold measurements to the nearest 0.01cm were measured using skinfold calipers (Holtain Tanner/Whitehouse Skinfold Caliper).

2.4.4.3 Exposures

2.4.4.3.1 Maternal Anthropometry

Maternal height, to the nearest 0.1cm, was measured using a wall-mounted stadiometer (Holtain), and weight, to the nearest 0.1kg using a digital scale (seca 877), was measured by trained research assistants using standardised techniques, from which maternal Body Mass Index (BMI) was calculated as (kg/m^2) (110). Tricep, bicep and sub-scapular skinfold measurements to the nearest 0.01cm were measured using skinfold calipers (Holtain Tanner/Whitehouse Skinfold Caliper) (Appendix G).

2.4.4.3.2 Household WASH

Household WASH was assessed using a questionnaire (Appendix H) adapted from the World Health Organisation/UNICEF (Core Questions on Drinking-Water and Sanitation for Household Surveys) (118), the JMP (21,22), and the Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) (105). The JMP classifies drinking water sources into 4 categories; (1) Safely Managed - A basic drinking water source, which is located on the premises available when needed and free of faecal and priority chemical contamination; (2) Basic - Piped water, boreholes or tubewells, protected springs, and rainwater, provided collection time is no more than 30 minutes for a roundtrip including queuing; (3) Unimproved - Drinking water from unprotected dug wells, unprotected springs, carts with small tank/drum, tanker trucks or basic sources with a total collection time more than 30 minutes for a roundtrip including queuing; and (4) Surface Water - River, dam, lake, pond, stream, canal or irrigation channel (22). Sanitation is categorised into 5 classifications; (1) Safely Managed - A basic sanitation facility, which is not shared with other households and where excreta are safely disposed in situ or treated off-site; (2) Basic - Flush/pour flush to piped sewer system, septic tank or pit latrine, ventilated improved pit latrine, composting toilet or pit latrine with a slab not shared with other households; (3) Shared - Sanitation facilities of an otherwise acceptable type shared between two or more households; (4) Unimproved - Pit latrines without a slab or platform, hanging latrines and bucket latrines; and (5) Open Defecation - Human faeces disposed of in fields, forest, bushes, open bodies of water, beaches or other open spaces or disposed of with

solid waste (22). Finally, hygiene is separated into 3 groups; (1) Basic - Facility with soap and water in the household; (2) Unimproved - Facility without soap or water; (3) No Facility - No facilities.

Three indices to assess hygiene behaviours were also included namely, Food Hygiene Index (FHI), Personal Hygiene Index (PHI), and Household Hygiene Index (HHI). The FHI included 1 item; food hygiene practices, constructed by combining two variables pertaining to the cleaning of the breast and cleaning of utensils prior to feeding. The PHI included 2 items; the first pertaining to when hands were washed; the second relating to the detergent used for handwashing. The HHI included 2 items; the first, reporting the type of house, and the second, whether there were animals on the property. A water index was also constructed incorporating the discreet variables pertaining to water source, access, treatment, and supply. Each of the aforementioned items was scored as either 0 or 1, with 1 representing a positive behaviour or circumstance. Positive behaviour or circumstance was defined as an activity or condition that is protective towards or acts as a barrier to the transmission of pathogens (21,22,29,111). Both the water and hygiene indices were calculated as the simple sum of the items, and the composite Hygiene Index (HI) was calculated as the sum of the three individual hygiene indices, FHI, PHI, and HHI (111).

2.4.4.4 Covariates

2.4.4.4.1 Infant Breastfeeding and Complementary Feeding Practices

Infant breastfeeding and complementary feeding questionnaire (Appendix I) was adapted from the WHO/UNICEF Infant and Young Child Feeding questionnaire (113,114). This questionnaire has previously been used at the DPHRU in the Soweto setting (112).

2.4.4.4.2 Household Socio-Economic Status and Demographics

A household demographic and socio-economic questionnaire (Appendix J) was developed for the study integrating aspects of the National Income Dynamic Study (NIDS) (115), as well as the Living Conditions Survey (LCS) (116).

2.4.4.4.3 Maternal and Infant Illness, Morbidity, Healthcare Access

Maternal and infant, morbidity, illness, and healthcare access were assessed using an interviewer-administered survey (Appendix K), validated in the study setting, and confirmed against clinic records (117).

2.5 Data Management

Details of the precise analytical approaches used for these analyses are described in each of the chapters 3 to 5, however additional information about specific analytical and data management components is provided in this section.

Data collected in this series of studies was captured onto the Research Electronic Data Capture (REDCap) data management platform (119,120), hosted by the University of the Witwatersrand, and is stored on a secure server at the DPHRU research facility with all information and files kept in locked premises. The data manager at the research facility is the gatekeeper and requests for access and usage of the data were submitted in accordance with research unit processes. Data that was collected and extracted for this PhD was evaluated by a data committee comprised of relevant stakeholders of this project.

Data from the mapping exercise, document review and consensus development conference for objective 2 including all minutes and recordings from the in-depth interviews were collated, coded and stored on a secure password protected computer, with all personal identifiers kept separate. Data were analysed by myself and the findings from the analysis further discussed and reviewed with supervisors and co-authors.

Variables pertaining to outcomes, exposures and covariates used in the analyses for objective 3 were extracted and merged using participants' identification numbers. Checks were implemented to validate that the datasets were merged correctly. Data management by the author included conducting cleaning and quality checks on data pertaining to all key variables at relevant time points for this study. Data were evaluated for consistency, accuracy and outliers. Checks of all of the original response forms were conducted when missing or improperly defined data was detected. Recoding errors were corrected and where data was incorrectly captured from the original response forms, data were re-entered correctly. Data manipulation for the study included the creation of new variables (e.g. dummy variables and composite variables) and the recoding of existing variables (e.g. reverse coding), as well as converting or transforming variables (e.g. continuous variables to categorical variables). The cleaned datasets were then imported into the statistical software used for analysis, Stata version 13.1 (121).

2.6 Ethical Considerations

Objective 3 of this PhD forms part of a larger study titled “Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age” with Dr Rihlat Said-Mohamed as the Principal Investigator (HREC Clearance: M170753 – Appendix L and Appendix O). An application was submitted to the University of the Witwatersrand’s Human Research Ethics Committee (Medical) for approval of the PhD protocol specifically (HREC Clearance: M170872 – Appendix M) while the SES questionnaire is covered by (HREC Clearance: M170955 – Appendix N). All questionnaires were coded to ensure that participant names were not used, and confidentiality maintained. All the information collected in this study is only to be used for scientific purposes.

Part 2: Empirical Chapters

Some of the best indicators of a country developing along the right lines are healthy mothers giving birth to healthy children who are assured of good care and a sound education that will enable them to face the challenges of a changing world - Aung San Suu Kyi

3 Chapter 3: Paper I

Momberg D, Ngandu B, Voth-Gaeddert L, Cardoso-Ribeiro K, May J, Norris S, Said-Mohamed, R. Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: A systematic review. *Journal of Developmental Origins of Health and Disease*:1–27 (*Published Online 6 January 2020*) Appendix Q.

3.1 Introduction

Undernutrition is a major public health concern because of associations with adult health and disease risk later in life, including among others, diabetes, hypertension, and cardiovascular disease, and furthermore acts as a predictor of physical, mental and cognitive child development (5–9). Experiencing poor nutrition in utero or during early childhood is furthermore associated with chronic diseases later in life. During the first 1000 days of growth and development, specific cells, organs, and systems may be differentially affected by undernutrition (122). Among the three primary forms of undernutrition – stunting, wasting, and being underweight – stunting is the most prevalent in children under five years of age (4) and is defined as having a height-for-age z-score less than two standard deviations of the median of the World Health Organisation (WHO) Child Growth Standards (3,17).

Undernutrition emanates from a variety of circumstances and determinants, including antenatal, intra-uterine, and postnatal malnutrition. The realisation that physical growth cannot completely be improved by optimised diet and reduced burden of infection, has led to the hypothesis that linkages between different forms of undernutrition and environmental conditions, including water, sanitation, and hygiene (WASH), may contribute towards persistently poor child growth and nutritional status (19). Specific pathways are proposed by the so-called 5-F diagram, which describes the faeco-oral transmission route whereby faeces and associated pathogens are transmitted via fluids, fields/floors, flies, and fingers to foods, and then to the infant which causes disease and infection which in turn leads to growth faltering (29). Exposure to poor WASH during early childhood has been associated with higher risks of infections and poor nutritional status, including stunting (123,124). Repeated infections in early life is associated with chronic low-grade inflammation (125,126) and associated Cardiovascular Disease (CVD) risks in adulthood (127).

Data from 140 demographic and health surveys (DHS) in 65 countries reported that over half of the variation in child height between countries was explained by the frequency of open defecation. Another analysis of 171 surveys in 70 low- and middle-income countries (LMIC) found that increasing access to and use of improved water sources reduced the risk of stunting (7,8,18). The situation is most critical in sub-Saharan Africa (SSA), where at the closing of the Millennium Development Goals (MDG) cycle in 2015, the portion of people relying on untreated surface water for drinking was eight times higher than any other region. Furthermore, over 70% of the SSA populations were living without adequate sanitation and the absolute number of people practising open defecation actually increased (53).

In response to these observations a number of trials, in various phases, have explored the effects of WASH interventions on nutritional status in children (88,91,94,128). Initial results have indicated that there is only a marginal effect of drinking water, sanitation, and hygiene (WASH) interventions on linear child growth (86,88,89). In 2012, The WHO set ambitious global nutrition targets to reduce the number of children under the age of five that are stunted by 40% by 2025 with particular emphasis being placed on the role that WASH, financing, and policy interventions will need to play in achieving these targets (25).

The United Nations (UN) formally declared the right to water in November 2002 and noted that the right to water was indispensable to leading a life of human dignity and was furthermore a prerequisite for the realisation of other human rights. The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use. This also provided the first implicit reference to the responsibilities that Governments and stakeholders have in delivering clean water and sanitation to everyone (48). In the post-2015 agenda Sustainable Development Goals (SDG) have been established, most notably in this regard SDG 6: Universal and equitable access to safe water and adequate sanitation (WASH); and SDG 2: End all forms of malnutrition, by 2030 (36,47). A key challenge to achieving the above SDGs is the unique combination of governance systems, stakeholder dynamics, and institutional structures found in each country which manifest various problems and subsequent priorities (50). Governance of WASH in this regard is the set of systems that are involved in decision-making about management and service delivery. Investigating the governance of WASH by disentangling the various actors, role players and stakeholders at various levels, while unravelling the policy environment is imperative to the understanding, design and implementation of WASH initiatives targeted at addressing the burden of childhood undernutrition (25,36,37). The authors chose to conduct the review from 1990

onwards primarily due to the introduction of the UNICEF conceptual Framework (24) which proposed a causal framework for maternal and child undernutrition which included WASH. In addition to this, the dramatic geopolitical shifts that occurred as a result of the ending of the Cold War, as signalled by the fall of the Berlin wall in 1989 had far reaching consequences for the provision of basic services and healthcare, and transformed the dynamics of economic and health development at global, regional, and national levels (66,67). The rise of civil society and the movement on social justice, equity, and rights significantly reshaped governance of health at all levels (67,68). Furthermore the Lancet Series on Maternal and Child Nutrition in 2013 provided an updated framework for maternal and child nutrition, as well as, recommendations for inter-sectoral approaches to the challenges of malnutrition in LMIC settings, including WASH (4,32). In order to explore this nexus, this systematic review aims to examine the literature linking WASH, childhood nutritional status, and governance in sub-Saharan African settings.

3.2 Methods

3.2.1 Protocol and Registration

A systematic review has been conducted to examine the governance of WASH in sub-Saharan settings and associations with nutritional status in children under five years of age. The PRISMA Statement (102), was utilised while this systematic review has also been registered with PROSPERO (CRD42017071700) (103).

3.2.2 Eligibility Criteria

Peer-reviewed articles published between January 1990 and October 2017 reporting governance or policy, water, sanitation and/or hygiene and associations with nutritional status in children in sub-Saharan Africa were included. Studies pertaining to children with known chronic and acute diseases or abnormalities affecting growth were excluded along with publications not in English or French. In addition, a survey of Government websites, the Global Database on the Implementation of Nutrition Action (GINA) (104) and, where possible, the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) (105) was conducted to investigate whether countries in SSA had water and/or Sanitation policies and if they included any links to health and/or nutrition.

3.2.3 Study Identification and Selection

Data was sourced from electronic databases. All combinations of the following keywords were used to select publications from PubMed Central, Science Direct, and ProQuest Social Science databases published between January 1990 and October 2017: Governance, Policy, Management; Water, Sanitation, Hygiene, WASH; Undernutrition, Under-Nutrition, Under Nutrition, Malnutrition, Stunt-ed/ing, Underweight, Wast-ed/ing; Children, Infant, Under Five Years of Age, Preschool, Pre-school; Africa. The authors opted for selecting papers that reported governance, WASH and nutritional status irrespective of links between the various components. With regards to water and sanitation policies in SSA, Government websites, the Global Database on the Implementation of Nutrition Action (GINA) (104), and where possible, the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) (105) were searched for relevant policies. The authors searched grey literature databases including, the Grey Literature Report in Public Health (129), African Index Medicus (130), the WHO Virtual Health Sciences Library (131), as well as conference proceedings and websites, the authors furthermore reviewed reference lists and where appropriate contacted experts and authors.

3.2.4 Data Extraction

Using a standard data extraction sheet for all studies included in the systematic review, data pertaining to the governance or policy mechanism were extracted along with nutritional status as defined by the WHO Multicentre Growth Reference Study (3), and water, sanitation, and hygiene metrics as defined by the United Nations Joint Monitoring Programme (JMP) (21). Study design, date of data collection, country, participant age and sex, as well as sample size, aims and results or outcomes were also extracted. In terms of the policies that were sourced, excerpts pertaining to the country, policy and date, as well as links to health and/or nutrition were extracted using a standard data extraction form.

3.2.5 Quality Assessment and Data Analysis

For studies that were included, the strength of the individual articles and body evidence were assessed using the GRADE approach (The Grading of Recommendations, Assessment Development and Evaluation) (132,133). All studies were graded concerning their quality and summary data regarding data extraction fields, compiled. The studies included were assessed and classified to be of very-low, low, moderate, or high quality.

A synthesis of the eligible studies was compiled and health policy and systems research - exploratory and descriptive frameworks utilised (106,107). These sought to incorporate the context, content, and processes surrounding knowledge production and act as a model for analysis.

3.3 Results

3.3.1 Description of Publications

The search terms returned a total of 15351 articles for screening as reflected in the flow diagram (Figure 7), through which a total of 47 articles were identified for full-text review. Publications were excluded because: nutritional status was not reported (*n*=3636), metric for water, sanitation, and/or hygiene was not reported (*n*=3609), comorbidities such as acute and chronic infections, congenital abnormalities or any condition that could affect growth was not reported (*n*=2864), participant was >5 years of age (*n*=791), publications did not geographically pertain to sub-Saharan Africa (*n*=2102), publication or date of study was not between 1990 and 2017 (*n*=257), governance or policy mechanism were not reported (*n*=13), publications were not in English or French (*n*=3), the type of document was a newspaper, correspondence, or book review (*n*=1394), miscellaneous reasons (*n*=635). One article could not be procured; thus 46 articles were included in the qualitative synthesis. For the purposes of this systematic review, the quality assessment yielded 3 publications of high quality (4,28,32), 19 of moderate quality (17,29,134–150), 24 of low quality (151–174), and none of very-low quality.

Table 2 delineates the observational studies included in this systematic review while Table 3 indicates the reviews included. A total of 24 cross-sectional household surveys (122,135–137,140–142,147,151,152,154–159,162–165,167–169,172), 14 reviews (4,17,28,29,32,134,145,146,150,153,166,170,173,174), 4 cohorts (143,144,148,160), 3 meta-analyses (138,161,171), and 1 case-control (149), studies were included (Figure 8). The first publication documented dates from 1993 (170) (Figure 9). However, the period from 1993 to 2012 is characterized by a consistently low number of publications with a brief spike in 2008. There is a significant increase in the number of studies from 2013 to 2017.

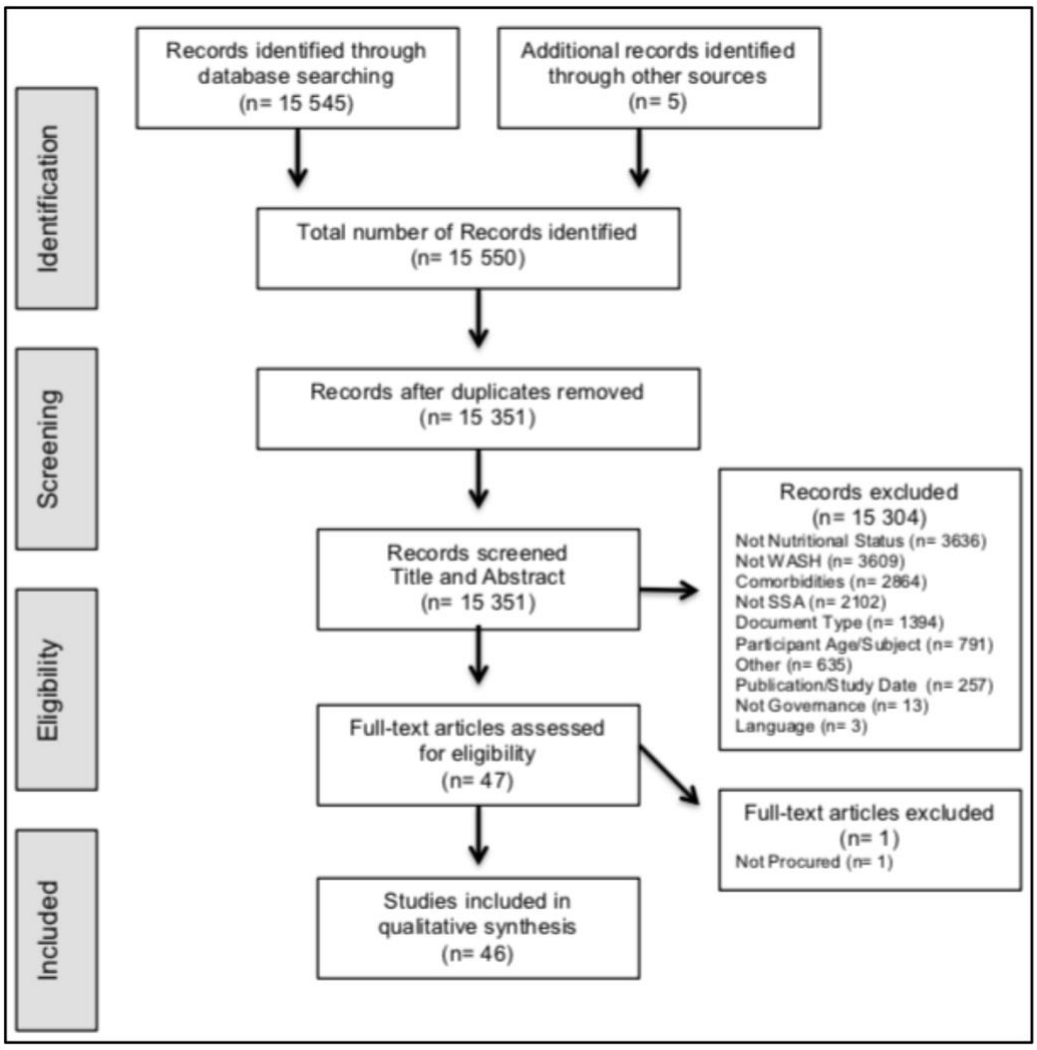


Figure 7: Systematic Review Description of Publications Flow Diagram

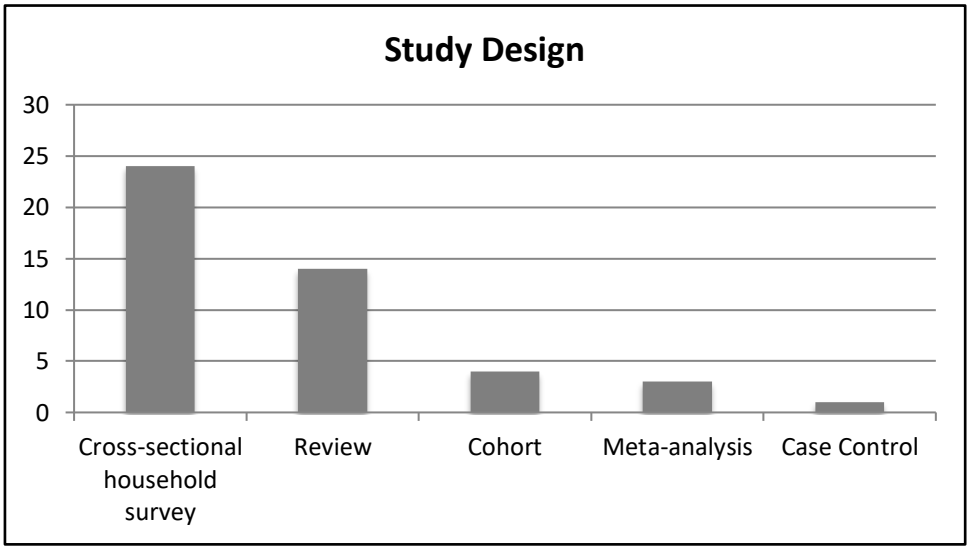


Figure 8: Systematic Review Study Design of Publications

Of the observational studies included, 30 (135–144,147,149,151,152,154–157,159–165,167–169,171,172) aimed at assessing nutritional status and associated factors, while 2 (148,158) were concerned with assessing the association between WASH and child growth. Water, either in terms of source, type of infrastructure, or access, was reported as a significant risk factor in 21 (135–137,142–144,148,151,154–156,159,161–165,167,169,171) of the observational studies, and access to sanitation, or type of sanitation infrastructure, as a significant risk factor in 15 of the studies (136,138–141,143,147–149,158,160,162,164,169,171). Hygiene, considered here as multiple forms of hygiene, or hygiene as an integrated concept was reported as a significant risk factor in 1 study (149). All significant risk factors are in the expected direction, i.e. associations in the direction typically hypothesised e.g. improved wash conditions predict reduced stunting. No association between WASH and nutritional status was reported in 4 papers (152,157,168,172). With regards to the observational studies assessing the association between WASH and child growth, in unadjusted models, that didn't control for child, household, parent, and community characteristics, household access to improved water and toilets was associated with reduced stunting risk. After adjusting for child, household, parent, and community variables, access to improved water was associated with reduced stunting at 1 and 5 years of age (relative risk ratios from 0.55 to 0.57) (148). In adjusted models, those that controlled for child, household, parent, and community characteristics, open defecation externalities were important for child height-for-age z-scores where people lived in close proximity to one another. One study found that a one log-unit increase in population density was associated with lesser height-for-age z-score by about 0.04 SD (158).

In terms of the 14 review articles included, 3 papers (29,32,150) aimed at assessing WASH interventions, while 4 (4,17,28,173) were concerned with assessing trends in nutritional status. A total of 7 articles (134,145,146,153,166,170,174) aimed at reviewing evidence between environmental enteric dysfunction (EED) and nutritional status, with EED as a mediating factor between poor WASH conditions and nutritional status. Results of the reviews highlighted water either in terms of source, type of infrastructure, or access, was reported as a significant risk factor in 12 (4,17,28,29,134,145,146,150,166,170,173,174) of the papers while the importance of access to sanitation, or type of sanitation infrastructure was emphasised in 13 (4,17,28,29,32,134,146,150,153,166,170,173,174) articles, and hygiene in 9 (28,29,32,134,146,150,170,173,174) of the reviews.

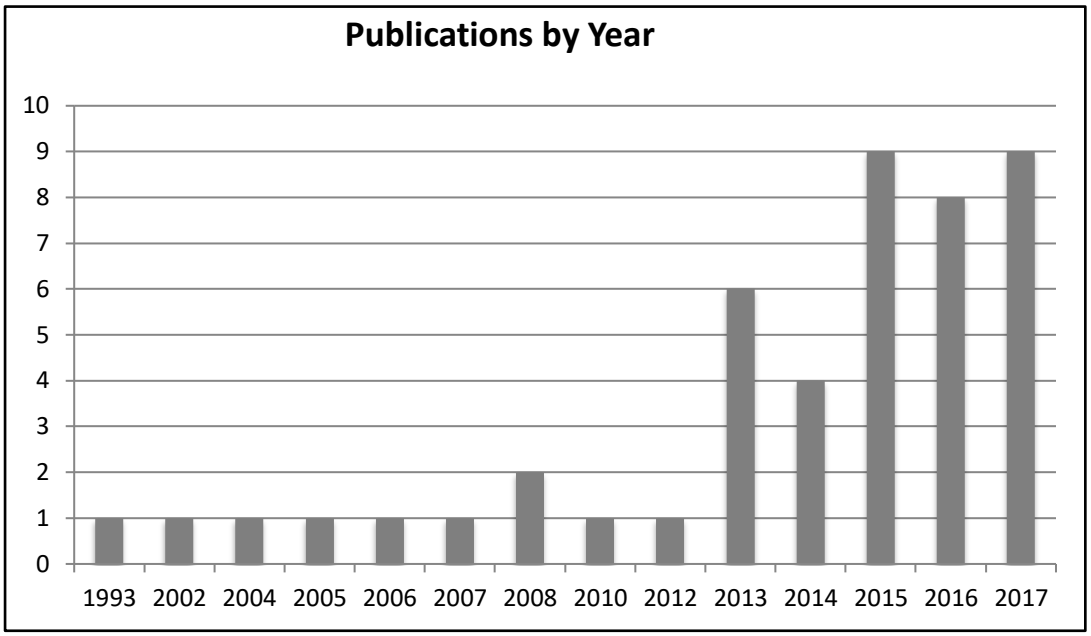


Figure 9: Systematic Review Publications by Year

Table 2: Studies Included in Systematic Review

Ref #	Country	Design	Age	Sample	Nutritional Status	WASH	Governance	Aim	Results
(135)	Nigeria	DHS	0–59 months	24529	HAZ	Water (Source and Type); Sanitation (Type)	Policy; Intervention Planning	To determine the factors associated with stunting and severe stunting in children 0-23 months and children 0-59 months.	Significant risk factors for stunting and severe stunting, among children aged 0–23 months and 0–59 months, included children who were reported to have had diarrhoea in the 2 weeks prior to the survey [(AOR) for stunted children 0–23 months = 1.22 (95%CI: 0.99, 1.49)]; [AOR for stunted children 0–59 months = 1.31 (95%CI: 1.16, 1.49)], [AOR for severely stunted children 0–23 months = 1.31 (95%CI: 1.03, 1.67)]; [AOR for severely stunted children 0–59 months = 1.58 (95%CI: 1.38, 1.82)].
(165)	Ethiopia	Cross-sectional survey	0–59 months	605	HAZ; WAZ; WHZ	Water (Source and Type); Sanitation (Type)	Policy	To assess the nutritional status and associated factors in children <5 years of age.	Stunting was predicted by, households where water was taken from unprotected sources (AOR, 2.13; 95% CI, 1.09–4.14).
(156)	Ethiopia	Cross-sectional survey	6–59 months	3108	HAZ	Water (Treatment); Sanitation (Access)	Policy	To review socio-demographic characteristics, and child anthropometry on potential immediate, underlying and basic individual and community level determinants of child undernutrition using the UNICEF conceptual framework.	Household level water treatment practice was associated with higher child height-for-age Z score by 0.25 SD ($p < 0.05$) compared to households that did not treat water at household level.

(155)	Tanzania	Cross-sectional survey	6–59 months	3280	HAZ	Water (Source and Type); Sanitation (Access)	Intervention Planning	To explore factors associated with stunting among pre-school children.	Stunting was associated with access to improved water source (AOR: 0.70; CI: 0.52-0.93) and to a functioning water station (AOR: 0.63; CI: 0.40–0.98).
(164)	Congo; Ivory Coast; Ethiopia; Gambia; Mali; Mozambique; Namibia; Niger; Nigeria; Sierra Leone; Uganda; Zambia	DHS	0–59 months	Not Available	HAZ; WAZ; WHZ	Water (Source and Type); Sanitation (Type)	Intervention Planning	To explore the major question about the association between different household environment conditions with child survival and health.	Improved water sources were significantly associated with lower odds ratio of stunting (0.77) and wasting in Uganda (0.50) while it was found significantly associated with lower odds ratio of underweight in Mali (OR = 0.768) compared to the use of non-improved water sources. Use of improved sanitation significantly associated with lower risk of underweight in the Congo Republic (OR = 0.821), Ethiopia (OR = 0.811), and Mali (OR = 0.768). It was also associated with lower risk of stunting in Cote d'Ivoire (OR = 0.709) and Ethiopia (OR = 0.854).
(168)	SSA	DHS	12-36 months	33000	HAZ; WAZ	Water (Source); Sanitation (Access)	Policy	To consider the relationship between child malnutrition and selected bio-physical and macro-demographic variables combined with anthropometric data via geographic location.	In unadjusted regression models, increased usage of well water and decreased usage of surface water were associated with a high share of underweight children. A complete lack of toilet and lack of flush toilet facilities were associated with a high share of underweight children. However, neither the infrastructure of water nor of sanitation were significantly

									associated with underweight in adjusted models.
(137)	Tanzania	Cross-sectional household survey	0–59 months	7324	HAZ	Water (Source)	Intervention Planning	To assess the determinants of stunting and severe stunting in children aged 0-23 months and 0-59 months.	Most consistent significant risk factors for stunted and severely-stunted children aged 0-23 and 0-59 months were: unsafe sources of drinking water [AOR for stunted children aged 0-23 months = 1.37; 95% CI: (1.07, 1.75)]; [AOR for severely stunted children aged 0-23 months = 1.50; 95% CI: (1.05, 2.14)], [AOR for stunted children aged 0-59 months = 1.42; 95% CI: (1.13, 1.79)] and [AOR for severely stunted children aged 0-59 months = 1.26; 95% CI: (1.09, 1.46)].
(138)	SSA	Meta-analysis	0–59 months	Not Available	HAZ	Water (Type and Source); Sanitation (Type)	Policy; Intervention Planning	To determine the risk factors for childhood stunting.	Unimproved water and sanitation had the second largest estimated impact on stunting in sub-Saharan Africa. Unimproved Sanitation; OR 1.37: 95% CI (1.33, 1.41). Unimproved water source; OR 1.09: 95% CI (1.06, 1.12).
(172)	Ghana	DHS	0–59 months	2379	HAZ	Water (Source); Sanitation (Type)	Policy; Intervention Planning	To examine the correlates of stunting.	Source of drinking water and kind of latrine were used as independent variables in intermediate (environmental) factor model, however only descriptive statistics were reported.
(148)	Ethiopia	Cohort	0–59 months	7715	HAZ	Water (Access and Type); Sanitation	Policy; Intervention Planning	To understand associations between water, sanitation, and child growth.	In unadjusted models, household access to improved water and toilets was associated with reduced stunting risk. After

						(Type); Hygiene (Non-specific)			adjusting for child, household, parent, and community variables, access to improved water was associated with lower prevalence (?) of stunting and thinness at 1y and 5y. However, access to improved sanitation is more frequently associated with reduced stunting risk than access to improved water.
(147)	Ethiopia	Cross-sectional household survey	6-24 months	587	HAZ; WHZ	Sanitation (Access)	Intervention Planning	To assess stunting, wasting and associated factors among children aged 6–24 months.	Unavailability of latrine was significantly associated with higher odds of stunting [AOR = 1.76; 95% CI: 1.17, 2.66].
(161)	SSA	Meta-analysis	0–59 months	Not Available	WHZ	Water (Access)	Policy	To understand how social context affects the nutritional status of populations, as reflected by the prevalence of wasting in children under five years of age. To present a systematic way of building models for wasting prevalence, using a conceptual framework for the determinants of malnutrition; and to examine the feasibility of using readily available data collected over time to build models of wasting prevalence in populations.	Low birth weight (LBW), measles incidence, and access to a safe water supply explained 38% of wasting in Africa.
(140)	Ghana; Malawi; Tanzania; Nigeria; Zambia; Zimbabwe	DHS	1-35 months	Not Available	WAZ	Water (Type); Sanitation (Type)	Policy; Intervention Planning	To compare individual and household predictors of underweight among young children.	At the household level, type of toilet facilities was associated with lower weight for age z-scores.

(141)	Uganda	Cross-sectional household survey	0–59 months	104	HAZ; WAZ; WHZ	Sanitation (Access)	Policy	To investigate factors associated with malnutrition among under-five children.	Proximate variables mediate demographic and socio-economic factors like the duration of breast feeding, sanitation and mothers health seeking behaviours to influence under-five malnutrition.
(162)	Ethiopia	Cross-sectional household survey	0–59 months	1723	HAZ	Water (Access); Sanitation (Access)	Intervention Planning	Aims at exploring the spatial distribution of stunting at meso-(district) scale, and evaluates the effect of spatial dependency on the identification of risk factors and their relative contribution to the occurrence of stunting and severe stunting.	Underlying factors for child undernutrition also include household and family related factors such as food security, childcare, access to water and sanitation and lack of basic health services.
(169)	Zambia	DHS	0–59 months	12714	HAZ	Water (Source and Type); Sanitation (Type)	Policy; Intervention Planning	To investigate changes in socioeconomic inequality in stunting and fever.	Improved water source and improved toilet were not associated with a higher likelihood of stunting.
(158)	SSA	DHS	0–59 months	Not Available	HAZ	Water (Type); Sanitation (Access)	Policy	To assess whether the importance of dense settlement for infant mortality and child height is moderated by exposure to local sanitation behaviour. Is open defecation worse for infant mortality and child height where population density is greater? Is poor sanitation an important mechanism by which population density influences child health outcomes?	Open defecation externalities are more important for child health outcomes where people live more closely together. A one log-unit increase in population density increases the corresponding decline in height-for-age by about 0.04 SD of a height-for-age z-score.
(139)	Kenya; Zambia	DHS	0-48 months	2500	HAZ; WHZ	Sanitation (Access)	Intervention Planning	To determine the prevalence and determinants of stunting.	There was a higher risk of stunting in both Kenya and Zambia, for those with no formal toilet [OR = 0.80; 95% CI: 0.55, 1.15].

(143)	Kenya	Cohort	0–59 months	3335	HAZ; WAZ; WHZ	Water (Access); Sanitation (Access)	Policy; Intervention Planning	To investigate associations between nutritional status and individual level factors, maternal factors, and feeding practices.	The double burden of malnutrition in the urban slums may be occasioned by prevailing adverse conditions in these settings including poor livelihoods and low socio-economic status, high levels of food insecurity, poor access to water and environmental sanitation and health care services, high prevalence of infections (especially from diarrhoea, respiratory diseases), and poor child feeding practices in these settings
(159)	Somalia	Cross-sectional household survey	6–59 months	73778	HAZ; WAZ; WHZ	Water (Source)	Policy	To assess the spatial co-distribution of wasting, stunting and underweight and investigate their shared correlates.	Access to foods with high protein content and vegetation cover, a proxy of rainfall or drought, were associated with lower risk of wasting and stunting. A 1-unit increase in enhanced vegetation index was associated with a 38 %, 49 % and 59 % reduction in wasting, stunting and low mid-upper arm circumference, respectively. Children who had diarrhoea and acute respiratory infection in the past 2 weeks had a higher risk of wasting, stunting and underweight.
(154)	Somalia	Cross-sectional household survey	0–59 months	73778	HAZ	Water (Source)	Intervention Planning	To test a Bayesian hierarchical space-time model to forecast stunting by using the relationship between observed stunting and environmental covariates.	Rainfall and vegetation cover were significant in forecasting stunting. Rainfall (OR = 0.994, 95% Credible Interval (CrI): 0.993, 0.995) and vegetation cover (OR = 0.719, 95% CrI: 0.603, 0.858)

									were significant in forecasting stunting.
(151)	Somalia	Cross-sectional household survey	6–59 months	73778	HAZ; WHZ	Water (Source)	Policy; Intervention Planning	To investigate the predictors of wasting, stunting and among children aged 6–59 months.	Effects of distal environmental covariates associated with vector-borne diseases, on child growth outcomes were examined. These were rainfall, enhanced vegetation index (EVI), mean temperature, distance to water features and urbanization. Fever, diarrhoea, sex and age of the child, household size and access to foods were significant predictors of malnutrition.
(167)	Sierra Leone	Cross-sectional household survey	0–59 months	604	HAZ; WHZ	Water (Access); Sanitation (Access and Type)	Intervention Planning	To assess the changing patterns of stunting and wasting in children 0-59 months.	Stunting is associated with a number of immediate factors including (e.g., environmental, economic, and socio-political factors) restricting access to safe and sufficient food and water.
(160)	Ethiopia	Cohort	0-12 months	1065	HAZ; WAZ; WHZ	Sanitation (Type)	Intervention Planning	To determine the prevalence and predictors of undernutrition among infants aged six and twelve months.	Significant and consistent predictors of infant underweight, stunting and wasting, in both logistic and linear multiple regression models were poor household sanitary facilities.
(144)	Gambia	Cohort	0-24 months	3659	HAZ; WAZ; WHZ	Water (Source); Sanitation (Access); Hygiene (Non-Specific)	Intervention Planning	To assess trends in growth faltering in children younger than 2 years.	Underweight, stunting and wasting were markedly seasonal, with greater deficits occurring in the rainy season when infections are more common. Amplitude of seasonal Z-score fluctuation between birth and 2 years. HAZ [–0·09 (95% CI: –0·10 to –0·08)]. WAZ [–0·15 (95% CI: –0·16 to –

									0·14). WHZ [–0·16 (95% CI: –0·18 to –0·14)].
(136)	Cameroon	DHS	0–59 months	1923	HAZ; WAZ	Water (Type); Sanitation (Type)	Intervention Planning	To assess the association between explanatory factors and nutritional status and to estimate the net effects of both household and community factors.	Improved household water and sanitation were associated with better HAZ and WAZ.
(149)	Zimbabwe	Case-Control	0-24 months	14110	HAZ	Water (Type); Sanitation (Type); Hygiene (Non-Specific)	Intervention Planning	To test the effects of a single high-dose vitamin A supplement given to mothers and/or infants during the immediate postpartum period on several infant health outcomes.	Non-exclusive breastfeeding has been associated with faeco-oral transmission of bacteria among infants living in conditions of poor sanitation and hygiene; frequent exposure to potentially pathogenic organisms likely drives the T-cell mediated enteric inflammation that characterizes Environmental Enteropathy.
(163)	Tanzania	Cross-sectional household survey	0–59 months	678	HAZ	Water (Access and Source)	Intervention Planning	To determine the prevalence and determinants of stunting.	Time to water source was associated with stunting. [OR = 0.69; 95% CI: 0.48–1.01].
(171)	SSA	Meta-analysis	0–59 months	Not Available	HAZ; WAZ	Water (Type); Sanitation (Type)	Policy;	To explore trends in mild, moderate, and severe stunting and underweight.	Children's growth was associated with infection and suboptimal nutrition. Hence, food insufficiency, poor water and sanitation, and restricted access to high-quality primary care, all associated with household and community poverty, was associated with poor growth outcomes.
(152)	SSA	DHS	0–59 months	Not Available	HAZ; WAZ	Water (Source); Sanitation (Access)	Policy	To report on socioeconomic inequality in childhood malnutrition and to provide evidence for an association between socioeconomic	An indicator of socioeconomic status, including clean water and a toilet, was developed using principal component analysis. After correcting for the

								inequality and the average level of malnutrition.	concentration index's dependence on mean malnutrition the median Concentration Index for SSA was -0.15, where negative values imply that malnutrition is more concentrated among poorer children. There was thus a marginal association between average stunting and socioeconomic inequality
(157)	Ghana	DHS	0–59 months	3061	HAZ	Water (Access); Sanitation (Access)	Policy; Intervention Planning	To summarize inequality in children's height-for-age z-scores across the entire socioeconomic distribution and decompose this inequality into different contributing factors.	Access to sanitation in terms of having a toilet and access to safe water was not associated with malnutrition.
(142)	SSA	DHS	0-6 months	Not Available	Stunting	Water (Access)	Policy	Examine the independent association of six different types of food (exclusive breastfeeding, non-exclusive breastfeeding, infant formula, milk liquids, non-milk liquids, and solid foods) with five measures of infant health (length, weight, diarrhoea, fever, and cough).	Study shows that for an infant younger than 6 months old, following current guidelines and exclusively breastfeeding instead of giving the infant solid foods was associated with higher length by 0.75cm and weight by 0.25 kg and lesser diarrhoea, fever, and cough prevalence by 8, 12, and 11%, respectively. Authors were unable to control for access to sanitary water: a necessary ingredient in infant formula, without which, the results could be biased upward.

Table 3: Review Articles Included in Systematic Review

Ref #	Country	Design	Age	Sample	Nutritional Status	WASH	Governance		Results
(32)	SSA	Review	0–59 months	Not Available	HAZ; WAZ; WHZ	Water (Source and Type); Sanitation (Type); Hygiene (Hand Washing)	Policy; Intervention Planning	To assess nutrition specific interventions across the lifecycle for evidence of benefit.	WASH Interventions with significant effects: reduced risk of diarrhoea with hand washing with soap (RR 0.52, 95% CI 0.34–0.65), with improved water quality, and with excreta disposal. Open defecation explained 54% of international variation in child height by contrast with GDP, which only explained 29%. A 20-percentage point reduction in open defecation was associated with a 0.1 SD increase in child height.
(4)	SSA	Review	0–59 months	Not Available	HAZ; WAZ; WHZ	Water (Access); Sanitation (Access)	Policy; Intervention Planning	To review maternal and child undernutrition and overweight in low-income and middle-income countries.	Studies have consistently shown that diarrhoea is the most important infectious disease determinant of stunting. A framework for actions to achieve optimum child nutrition and development require nutrition sensitive programmes and approaches including water and sanitation is proposed.
(166)	South Africa	Review	0–59 months	Not Available	Stunting	Water (Source); Sanitation (Access); Hygiene (Food and	Policy	To profile the current food hygiene and safety needs of children under the age of five in South Africa. To reflect the importance of domestic hygiene, access to water and sanitation in	Two studies reported that water source and sanitation were correlated with linear growth in children. In addition, latrine ownership was associated with lesser risk of stunting.

						Domestic Hygiene)		reducing the transmission of gastrointestinal pathogens while feeding infants and young children. To highlight the need for collaboration between healthcare professionals and the local authorities who provide basic services.	
(146)	SSA	Review	0–59 months	Not Available	Stunting	Water (Source and Type); Sanitation (Access and Type); Hygiene (Hand Washing and Food Hygiene)	Policy; Intervention Planning	To review the evidence linking WSH measures to faecal-oral diseases in children.	While the relationship between diarrhoeal disease and malnutrition is complex, reviewing the evidence linking WASH measures to faecal-oral diseases in children suggests stunting in children aged 24 months was associated with five or more diarrhoeal episodes experienced in the first 2 years of life.
(153)	SSA	Review	0–59 months	Not Available	HAZ; WAZ; WHZ	Water (Source); Sanitation (Access and Type); Hygiene (Non-Specific)	Intervention Planning	To provide a narrative review of the current understanding of EED: epidemiology, pathogenesis, therapies, and relevance to child health.	Environmental Enteric Dysfunction (EED) is established during infancy and was associated with poor sanitation, certain gut infections, and micronutrient deficiencies.
(29)	SSA	Review	0-24 months	Not Available	HAZ	Water (Source and Type); Sanitation (Type); Hygiene (Hand Washing)	Policy; Intervention Planning	This review article considers two broad questions: (1) can WASH interventions make a significant contribution to reducing the global prevalence of childhood stunting, and (2) how can WASH interventions be delivered to optimize their effect on stunting and accelerate progress?	The evidence reviewed suggests that poor WASH conditions have a significant detrimental effect on child growth and development resulting from sustained exposure to enteric pathogens.

(28)	SSA	Review	0–59 months	Not Available	HAZ	Water (Source); Sanitation (Access); Hygiene (Non-Specific)	Policy	To assess the global trends in stunting.	Action to reduce stunting requires improvements in WASH.
(134)	SSA	Review	0–59 months	Not Available	HAZ; WAZ	Water (Type); Sanitation (Type)	Intervention Planning	This review documents the evidence that intestinal infections lead to malnutrition and that malnutrition worsens intestinal infections. Also reviewed are the mechanisms by which enteric infections lead to undernutrition and by which malnutrition worsens enteric infections, with implications for potential novel interventions.	Authors suggest that a substantial proportion of global malnutrition is due to impaired intestinal absorptive function resulting from multiple and repeated enteric infections. The economic, human and societal impact of repeated and prolonged enteric infections, is far greater than ever calculated Thus any effective interventions, ranging from targeted antimicrobial therapy and key micro- and macronutrient approaches to improved water and sanitation, have far greater cost-benefit effects than ever adequately appreciated.
(145)	SSA	Review	0–59 months	Not Available	HAZ	Water (Source)	Policy; Intervention Planning	To summarize what we do and do not know about these very early alterations in intestinal digestive function, discuss their potential impact on childhood growth, and examine the policy implications for interventions to interrupt this pathway to stunting.	A number of factors have been proposed to underlie altered function of small bowel mucosa, including a combination of microbial contamination of water and food. In young infants and children, environmental enteric dysfunction may precede and dispose to malnutrition of varying degrees, which in turn contributes to an increased

									incidence of infectious disease, especially diarrhoea.
(170)	SSA	Review	0–59 months	Not Available	Stunting; Wasting	Water (Type); Sanitation (Type); Hygiene (Food Hygiene)	Policy; Intervention Planning	Aims to demonstrate that weaning foods prepared under unhygienic conditions are frequently heavily contaminated with pathogens and thus are a major factor in the cause of diarrhoeal diseases and associated malnutrition.	Weaning foods prepared under unhygienic conditions are frequently heavily contaminated with pathogens and thus are a major factor in the cause of diarrhoeal diseases and associated malnutrition. To prevent foodborne diseases, a multidisciplinary approach is needed. Environmental conditions need to be improved, including the provision of safe water supplies and sanitation.
(150)	SSA	Review	0-36 months	Not Available	HAZ	Water (Source, Type, and Treatment); Sanitation (Access and Type); Hygiene (Hand Washing and Domestic Hygiene)	Policy; Intervention Planning	To review evidence on the links between clean water, sanitation, and hygiene (WASH), and stunting and anaemia, which are known risk factors for child developmental deficits, and highlight how current WASH interventions fail to adequately protect children in the first 3 years of life.	In order to address stunting and anaemia as key risk factors for early childhood development, this review leads the authors to conclude that baby WASH interventions require baby hand washing at key times and creation of a hygienic and protective play environment, in addition to hygienic infant feeding and household hand washing and sanitation interventions in order to interrupt key faecal-oral vectors while paying attention to animal and human faeces.
(17)	South Africa	Review	0-72 months	Not Available	HAZ	Water (Access and Type); Sanitation	Policy	To investigate the changes in the prevalence of stunting.	Stunting is highly correlated with poorer socio-economic status and environmental conditions especially in rural provinces with

						(Access and Type)			poor access to water and sanitation.
(173)	SSA	Review	0–59 months	Not Available	HAZ; Underweight ; Wasting	Water (Type); Sanitation (Access); Hygiene (Hand Washing)	Policy	To discuss the burden and trends of global under-5, infections, and nutrition conditions; aetiology and associated risk factors; biological plausibility and the interrelation between infections, nutrition, and growth; and existing interventions and strategies to reduce major childhood infections and improve nutrition and growth and implications.	Infection-specific risk factors include poor water quality, unhygienic excreta disposal, unwashed hands, and consequent undernutrition. WASH strategies (hand washing with soap, improved water quality, and excreta disposal), can reduce diarrhoea morbidity in children by 42%, 37%, and 31%, respectively; however, a recent meta-analysis suggests a small benefit of WASH interventions on length growth in children <5 y of age.
(174)	SSA	Review	0–59 months	Not Available	HAZ	Water (Access); Sanitation (Access and Type); Hygiene (Non-Specific)	Policy; Intervention Planning	To review the existing literature regarding the underlying causes of and potential interventions for EED and poor growth in children, highlighting the epidemiology, clinical and histologic classification of the entity, as well as discussing novel biomarkers and possible therapies.	Improving WASH, as well as the child's macro- and micro-nutrient intake, may be the primary means of preventing or mitigating environmental enteropathy and undernutrition.

3.3.2 Geographical Coverage

Nineteen publications dealt with SSA as a region, while 3 articles dealt with more than one country in SSA (139,140,164). Individually, Ethiopia had the most publications with 6 (147,148,156,160,162,165), Tanzania (137,155,163) and Somalia (151,154,159) had 3 articles each while Ghana (157,172) and South Africa (17,166) had 2 articles each, and Cameroon (136), Gambia (144), Nigeria (135), Kenya (143), Sierra Leone (167), Uganda (141), Zambia (169) and Zimbabwe (149) had 1 publication each (Figure 10).

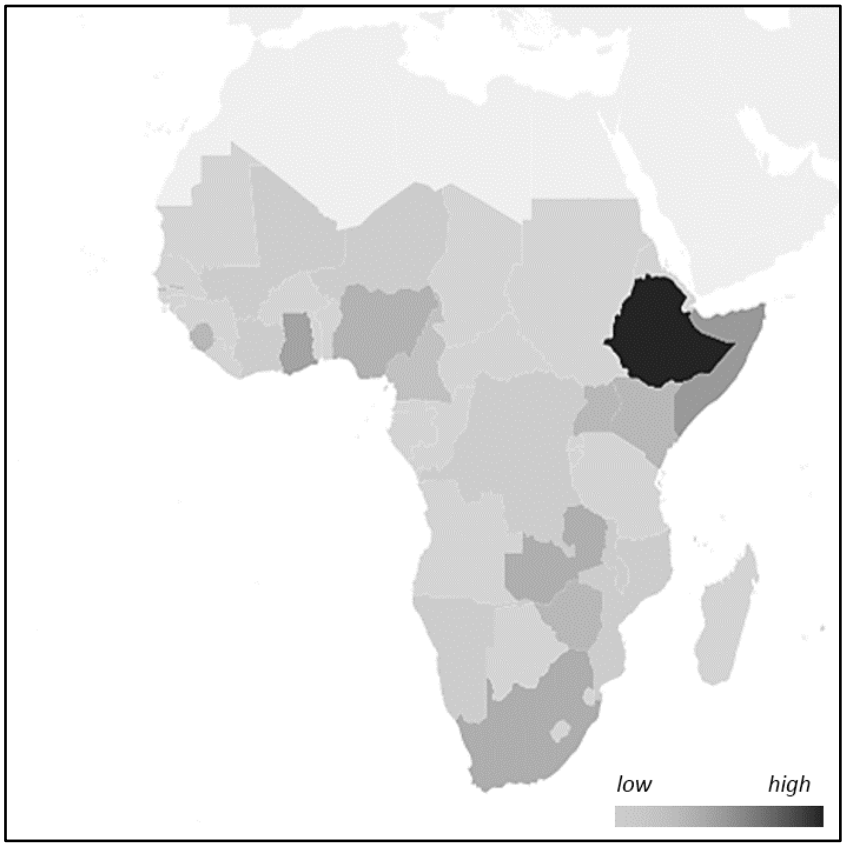


Figure 10: Systematic Review Geographical Distribution of Publications

An electronic survey of specific policies related to Water-only, Sanitation-only, and WASH and subsequent links to health and/or nutrition in individual SSA countries was also conducted (Table 4). Of the 49 countries surveyed, policies relating to water could not be found for 6 countries (Angola, Djibouti, Central African Republic, Equatorial-Guinea, Gabon, and Somalia). The authors could not access the specific water policy documents for 12 countries (Angola, Djibouti, Central African Republic, Comoros, Republic of Congo, Equatorial-Guinea, Gabon, Gambia, Guinea-Bissau, Mauritius, Seychelles, and Somalia). For 9 countries (Central African Republic, Republic of Congo, Equatorial-Guinea, Mauritius, Somalia, South Sudan, Swaziland,

Tanzania, and Zambia) no sanitation policy was found. The sanitation policy documents could not be accessed for 10 countries (Central African Republic, Republic of Congo, Equatorial-Guinea, Seychelles, Somalia, South Sudan, Swaziland, Tanzania, and Zambia). For 4 countries there were no other policy documents reviewed that linked WASH and health/nutrition (Angola, Equatorial-Guinea, Mauritius, and Swaziland). No WASH policies were found.

In terms of the content of the policies, some 16 countries (Burkina Faso, Burundi, Eritrea, Ethiopia, Gambia, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Namibia, Nigeria, Sudan, and Zimbabwe) made reference to hygiene in their respective policies. A total of 4 countries (Burundi, Mauritania, São Tomé and Príncipe, and Uganda) linked water and nutrition in general. A further 2 countries (Liberia and Zimbabwe) linked water and child health in general, while 2 countries (Rwanda and South Africa) linked water and nutritional status in children. Some 14 countries (Burundi, Cape Verde, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Gabon, Guinea-Bissau, Kenya, Niger, Rwanda, São Tomé and Príncipe, Senegal, and Togo) linked sanitation and nutrition in general. A total of 6 countries linked sanitation and child health in general, and 3 countries (Cameroon, Malawi, and Uganda) made reference to the importance of the link between sanitation and nutritional status in children.

Table 4: Water, Sanitation, and Hygiene Policies in sub-Saharan Africa

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Angola National Sanitary Development Plan (2012) (175)	Angola	N/A	N/A	Angola National Sanitary Development Plan (2012).	The PNDS has ambitious objectives in all areas of the National Health System, including strengthening the fight against priority diseases, which currently frame communicable diseases and chronic non-communicable diseases, mother and childcare, improved proximity to services.	N/A
National Water Policy (2008) (176); National Action Plan for the Integrated Management of Water Resources (2011) (177); National Heath Policy (2009) (178); National Sanitary Development Plan (2009) (179).	Benin	National Water Policy (2008); National Action Plan for the Integrated Management of Water Resources (2011).	Ensuring the public health protection with impacts on both public health and the socio-economic development of the country.	National Sanitary Development Plan (2009).	Recognizing the prominent role of health research in decision-making. The nutritional situation of women of childbearing age and their children is also worrying as 9% of them are underweight and 61% are anaemic.	National Health Policy (2009). Policy initiatives for provision of water and sanitation through the Ministry of Mines, Energy and Water; Ministry of Health.
Botswana National Water Policy (2012) (180); Botswana National Health Policy (2011) (181).	Botswana	Botswana National Water Policy (2012).	Safe, affordable and reliable water and sanitation must be provided to all the people of Botswana to promote a healthy population.	Botswana National Water Policy (2012).	Safe, affordable and reliable water and sanitation must be provided to all the people of Botswana to promote a healthy population.	Botswana National Health Policy (2011). Policy initiatives for provision of water and sanitation through the Ministry of Minerals, Energy and Water Resources

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Policy and Strategies on Water in Burkina Faso (1997) (182); Governance Programme for the Water and Sanitation Sector (2016) (183); National Sanitary Development Plan (2011) (184); National Health Policy (2011) (185).	Burkina Faso	Policy and Strategies on Water in Burkina Faso (1997). Governance Programme for the Water and Sanitation Sector Burkina Faso (2016).	The impact of structures and facilities on public health, design of sanitation and irrigation systems to reduce diseases, as well as then to education in hygiene and health. Decentralised technical services (water, health, education) improve the synergy of their actions towards local authorities.	Governance Programme for the Water and Sanitation Sector Burkina Faso (2016). National Sanitary Development Plan (2011).	Decentralised technical services (water, health, education) improve the synergy of their actions towards local authorities. The major diseases of public health importance are malnutrition, diarrheal diseases women and child health. The Burkinabe Government is convinced that health is at the heart of development and has made it one of the priority sectors. Substantial progress has been made in the social sectors, including health and drinking water.	National Health Policy (2011). Policy initiatives for provision of water and sanitation through the Ministry of Health.
National Water Policy (2009) (186); National Sanitation Policy and Operational Strategy Horizon 2025 (2013) (187); National Sanitary Development Plan (2005) (188).	Burundi	National Water Policy (2009).	The contribution of water in the health sector is the improvement of the health of populations through the consumption of quality water, environmental sanitation and hygiene. The agricultural deficit is due, among other reasons, to non-control of water for food production. It results in a high malnutrition, a precarious health situation.	National Sanitation Policy and Operational Strategy Horizon 2025 (2013). National Sanitary Development Plan (2005).	The lack of adequate sanitation constitutes a disaster that is both sanitary, ecological and economic: the impact on the natural environment and on human health amounts to thousands of sick people and deaths. This policy aims to improve the health status of the population through nutrition and food security, as well as the development of an inter-sectoral partnership that could contribute to improvement of health	Policy initiatives for provision of water and sanitation through the Ministry of Water, Environment, Development of the Territory and Urbanism and Public Health Ministry.

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
					indicators - access to drinking water and basic nutritional services.	
National Action Plan for the Integrated Management of Water Resources (PANGIRE) (2009) (189); National Health Technology Policy (2009) (190); Sectoral Health Strategy (2016) (191); Water Solidarity Programme (2013) (192).	Cameroon	National Action Plan for the Integrated Management of Water Resources (PANGIRE) (2009).	It concerns the vital needs of men, economic activities, the protection of the environment, planning and public health. Water for agriculture, livestock and food.	National Health Technology Policy (2009); Sectoral Health Strategy (2016).	The improvement of health services for the entire population of Cameroon through universal access to health care and services, the promotion of healthy behaviours and the development of healthy living environments. The acquisition of health-enhancing skills in the following areas: food and nutrition, nutritional status of children under five nutritional status of adults including women of childbearing age.	Water Solidarity Programme (2013). Policy initiatives for provision of water and sanitation through the Ministry of Water and Energy (MINEE) and Ministry of Public Health.
New Water and Sanitation Code (2015) (193); National Health Policy (2007) (194); National Sanitary Development Plan (2008) (195); National Basic Sanitation Plan (2010) (196).	Cape Verde	New Water and Sanitation Code (2015).	The human right to drinking water and sanitation is closely related to the right to the highest attainable standard of physical and mental health.	National Sanitary Development Plan (2008) National Basic Sanitation Plan (2010); New Water and Sanitation Code (2015).	Among other objectives, health sector reform aims to promote equity in access to health care. Strengthening interventions targeting malnutrition. Environmental sanitation actions should be seen as a basic public health measure.	Policy initiatives for provision of water and sanitation through the Ministry of health and National Water and Sanitation Agency. National Health Policy (2007).
Strategic plan to Strengthen Health Systems in CAR (2007) (197); Health sector	Central African Republic	N/A	N/A	N/A	N/A	Strategic plan to Strengthen Health Systems in CAR (2007); Health sector transition plan in Central African Republic

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
transition plan in Central African Republic (2015) (198); National Health Development Plan (2017) (199).						(2015); National Health Development Plan (2017) The Central African Republic has developed and implemented several strategic documents related to the health sector with a view to improving the health of the people at the grassroots level. Improving the nutritional status of children. Schools and health centres lack sanitary facilities.
The Master Plan for Water and Sanitation in Chad (2003) (200); National Health Policy (2006) (201); National Sanitary Development Plan (2013) (202); National Strategy for Universal Health Coverage of Chad (2015) (203).	Chad	The Master Plan for Water and Sanitation in Chad (2003).	Water impacts on the sustainable improvement of population health.	National Sanitary Development Plan (2013).	The national social protection strategy, in which the health component has been translated into a national strategy for universal sanitation coverage. In the field of malnutrition, there is still much to be done.	Policy initiatives for provision of water and sanitation through the Ministry of Water and Sanitation and Ministry of Public Health. National health Policy (2006). National Strategy for Universal Health Coverage of Chad (2015).
National Water Policy (N/D) (204); Water Code (N/D) (205); National Sanitary Development Plan (2010) (206);	Comoros	National Water Policy (N/D). Water Code (N/D).	N/A	National Sanitary Development Plan (2010).	Protein-energy malnutrition is one of the national health concerns. Development of health services taking charge of health, nutrition.	Policy initiatives for provision of water and sanitation through the Ministry of Production of the Environment, Energy, Industry and Crafts,

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Health Policy (2005) (207).						Ministry of Health. National Health Policy (2005).
Law No. 15/026 concerning water (2015) (208); Sanitary Development Plan (2016) (209); Strategy for strengthening the health system (2006) (210).	Democratic Republic of the Congo	Law No. 15/026 concerning water (2015).	Dealing with the health needs of the public health safety.	Sanitary Development Plan (2016).	Contribute to the improvement of the state of health. Nutritional status: Undernutrition is the most common type of malnutrition in the DRC.	Policy initiatives for provision of water and sanitation through the Ministry of Public Health. Strategy for strengthening the health system (2006).
Water Code (2003) (211).	Republic of the Congo	Water Code (2003).	N/A	N/A	N/A	Policy initiatives for provision of water and sanitation through the Ministry of Energy and Hydraulics; Ministry of Health and Population.
Sectoral Policy for Drinking Water in Ivory Coast (2016) (212); National Sanitary Development Plan (2016) (213).	Ivory Coast	Sectoral Policy for Drinking Water in Ivory Coast (2016).	The overall objective of the program is to contribute to the reduction of poverty and the improvement of population health.	National Sanitary Development Plan (2016).	The overall objective of the program is to contribute to the reduction of poverty and the improvement of population health. The Government of Côte d'Ivoire has made nutrition one of its priorities.	Policy initiatives for provision of water and sanitation through the Ministry of Economic Infrastructure; Ministry of Health and Public Hygiene.
Sanitary Waste Management Plan (2003) (214); Sanitary Code (2007) (215); National Sanitary	Djibouti	N/A	N/A	Sanitary Waste Management Plan (2003); Sanitary Code (2007); National Sanitary Development Plan (2013).	Promotion of nutritional activities. The development of primary health care, health for all. A strong commitment to the fight against malnutrition.	Policy initiatives for provision of water and sanitation through the Ministry of Health.

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Development Plan (2013) (216).						
	Equatorial Guinea	N/A.	N/A	N/A	N/A	N/A
Ministry of Land, Water and Environment (Water Resources Department); Ministry of Health (Nutrition Unit); Eritrean Policy on Infant and Young Child Feeding (2013) (217).	Eritrea	Action Plan for Integrated Water Resource Management (IWRM) in Eritrea (2008).	To improve the health and living condition of rural communities by achieving safe and sustainable sanitation and hygiene practices in relation to water supply and use.	Action Plan for Integrated Water Resource Management (IWRM) in Eritrea (2008).	To improve the health and living condition of rural communities by achieving safe and sustainable sanitation and hygiene practices in relation to water supply and use.	Eritrean Policy on Infant and Young Child Feeding (2013). Recommendations around food hygiene, hand washing and treatment of drinking water.
Ethiopian Water Resource Management Policy (N/D) (218); Ethiopian National Hygiene and Sanitation Strategy (2005) (219).	Ethiopia	Ethiopian Water Resource Management Policy (N/D).	Provision of adequate reliable and clean water supply and sanitation services.	Ethiopian National Hygiene and Sanitation Strategy (2005).	To complement the existing Health Policy and national water sector strategy while placing greater emphasis on 'on-site' hygiene and sanitation.	Ethiopian National Hygiene and Sanitation Strategy (2005). Inter-sectoral collaboration delivered by health, water, education, rural development and agriculture offices.

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Sanitary Development Plan (2011) (220).	Gabon	N/A	N/A	National Sanitary Development Plan (2011).	Bring together the public health priorities accepted by all. Training/retraining health workers in the management of malnutrition cases. Developing cooperation between the Directorate General of Hydraulic Resources and the Ministry of Health.	In 2018, Gabon plans to adopt a code of water and sanitation. Policy initiatives for provision of water and sanitation through the Ministry of Energy and Hydraulic Resources; Ministry of Health, Social Affairs, Solidarity and Family.
Gambia National Water Policy (N/D) (221); The Gambia National Strategy for Sanitation and Hygiene (2011) (222).	Gambia	Gambia National Water Policy (N/D).	N/A	The Gambia National Strategy for Sanitation and Hygiene (2011)	Reduction in the frequency of environmental health and safety-related problems and diseases.	Gambia National Nutrition Policy (2010). Support campaigns on environmental sanitation, including access to safe water supplies, personal hygiene, food hygiene and safety.
National Water Policy (2007) (223); Environmental Sanitation Policy (2010) (224); National Nutrition Policy (2013) (225).	Ghana	National Water Policy (2007)	Improving access to potable water and sanitation is critical to achieving favourable health outcomes, which in turn facilitate economic growth and sustained poverty reduction.	Environmental Sanitation Policy (2010)	Improved environmental sanitation has direct effects on healthcare waste management, vector and waterborne diseases that affect millions of children and women.	Through National Nutrition Policy (2013). The sub-optimal water and sanitation situation in Ghana is a key underlying determinant of health and nutritional status.
Water Code (1994) (226); National Declaration of Commitments of the Republic of Guinea: Water Sector and	Guinea	Water Code (1994). National Declaration of Commitments of the Republic of Guinea: Water Sector and	Health protection, pollution control and the preservation of the environment. Quantities of water needed for human nutrition, hygiene care. Improving the health status of	National Declaration of Commitments of the Republic of Guinea: Water Sector and	Impact on health, and on the economy. Strengthening the national health system, scaling up of high-impact activities - vaccination, nutrition. Essential objectives that contribute to improving	Policy initiatives for provision of water and sanitation through the Ministry of Water and Electricity; Health Ministry. National Health Policy

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Sanitation Sector (N/D) (227); National Health Policy (2014) (228).		Sanitation Sector (N/D).	populations. Impact on health, and on the economy.	Sanitation Sector (N/D).	health. Protection of food and nutritional conditions.	(2014). Public Health Code (N/D).
Water Code (1992) (229); Master Plan for Water Supply and Sanitation (1991) (230); Sanitary Development Plan (2008) (231).	Guinea-Bissau	Water Code (1992). Master Plan for Water Supply and Sanitation (1991).	N/A	National Sanitary Development Plan (2008).	Improving access to health services, equitable distribution of resources. Malnutrition is the first public health problem among non-communicable diseases.	Policy initiatives for provision of water and sanitation through the Ministry of Public Health.
The National Water Services Strategy (2007) (232); Kenya Environmental Hygiene and Sanitation Policy (2016) (233); National Food and Nutrition Security Policy (2011) (234).	Kenya	The National Water Services Strategy (2007).	Assured water supply, sewerage services and basic sanitation for all Kenyans for improved health and wealth creation on an individual level and for the nation.	Kenya Environmental Hygiene and Sanitation Policy (2016)	Ensure strong leadership and coordination at all levels to build and sustain governance for sanitation and hygiene across sectors especially water, health, nutrition, education, gender and the environment.	National Food and Nutrition Security Policy (2011). Uptake of critical nutrition and health interventions focusing on child-care practices, dietary choices, improved hygiene, water and sanitation are essential to address all forms of malnutrition.
Lesotho Water and Sanitation Policy (2007) (235); Health Sector Strategic Plan (2013) (236).	Lesotho	Lesotho Water and Sanitation Policy (2007).	Develop and implement programmes aimed at creating public awareness on linkages between water supply, sanitation, health and hygiene.	Lesotho Water and Sanitation Policy (2007).	Develop and implement programmes aimed at creating public awareness on linkages between water supply, sanitation, health and hygiene.	Health Sector Strategic Plan (2013). Sanitation and Hygiene are among the priorities of the health sector. Arrived at by examining contributions to the heaviest burden of disease.

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Water Supply and Sanitation Policy (2009) (237); Nutrition Policy (2008) (238).	Liberia	Water Supply and Sanitation Policy (2009).	Safe water, hygiene practices and sanitation are directly linked to improved public health, especially for vulnerable groups such as children.	Water Supply and Sanitation Policy (2009).	Safe water, hygiene practices and sanitation are directly linked to improved public health, especially for vulnerable groups such as children.	National Nutrition Policy (2008). To improve nutrition case management of childhood diseases and to improve access to quality health services, safe water, environmental sanitation and waste disposal systems.
Water Code (1999) (239); Sectoral Policy Declaration for Water (2009) (240); National Strategy for Water, Sanitation and Hygiene (2013) (241); Policy and National Strategy for Sanitation (N/D) (242). Health Sector Development Plan (2015) (243).	Madagascar	Water code (1999). Sectoral Policy Declaration of water (2009). National Strategy for Water, Sanitation and Hygiene (2013).	The protection of water resources are integral to health and security. It is a necessary condition for poverty eradication, women's empowerment and health protection.	National Strategy for Water, Sanitation and Hygiene (2013). Policy and National Strategy for Sanitation (N/D).	Integral to health and security. It is a necessary condition for poverty eradication, women's empowerment and health protection.	Policy initiatives for provision of water and sanitation through the Water Ministry; Ministry of Energy and Mines; Ministry of Public Health. Health Sector Development Plan (2015).
National Water Policy (2007) (244); National Sanitation Policy (2006) (245); Infant and Young Child Nutrition Policy and Guidelines (2003)	Malawi	National Water Policy (2007)	Improving public health through integration of rural water supply and Participatory Hygiene and Sanitation Transformation.	National Sanitation Policy (2006)	Seeks to increase access to clean water and sanitation, improve the nutritional status of children and ensure food security.	Infant and Young Child Nutrition Policy and Guidelines (2003). Caregivers should be advised to always follow the standard food hygiene rules when preparing food for the child to avoid food

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
(246); Food and Nutrition Security Policy (2005) (247).						contamination. Food and Nutrition Security Policy (2005). Provision of safe water and adequate sanitation, and hygiene to prevent diseases.
National Water Policy (2006) (248); National Water Policy and Code (2012) (249); National Sanitation Policy (2009) (250); Decennial Plan of Development and Health (2014) (251).	Mali	National Water Policy (2006). National Water Policy and Code (2012).	Focus on sanitation, education for health and hygiene. Promote access to basic health, nutrition, clean water and sanitation.	National Sanitation Policy (2009).	Broader vision of sanitation, which is then to make a healthier environment, not dangerous for human health and its environment.	Policy initiatives for provision of water and sanitation through the Ministry of the Environment and Sanitation; Ministry of Health and Public Hygiene. Decennial Plan of Development and Health (2014).
Water Code (2005) (252); Strategy for Development of the Water and Sanitation Sector (2012) (253); National Health and Social Action Policy (2006) (253); National Health Policy (2017) (254).	Mauritania	Water Code (2005).	Ensure the supply of drinking water ensure the protection of water intended for human nutrition decentralised health services for the promotion of autonomous sanitation and hygiene.	Strategy for Development of the Water and Sanitation Sector (2012).	The taking into charge by the State, municipalities and investment associations of collective sanitation in public buildings (schools, health centres and others).	National Integrated Project of the Water Sector in Rural Areas (PNISER) - African Development Bank. Policy initiatives for provision of water and sanitation through the Ministry of Hydraulics; Ministry of Health. National Health and Social Action Policy (2006). National Health Policy (2017).
Water Management Policy (2013) (255).	Mauritius	Water Management Policy (2013).	N/A	N/A	N/A	N/A

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Water Law n.16/91 (1991) (256); Water Policy (2007) (257); National Strategy for Water and Urban Sanitation (2011) (258); Health Sector Strategic Plan (2013) (259).	Mozambique	Water Law n.16/91 (1991). Water Policy (2007). National Strategy for Water and Urban Sanitation (2011).	The purpose of sanitation of population centres is to ensure, conditions compatible with the requirements of public health. To ensure maximum positive benefit for consumers and to avoid potential public health risks. Improving food security. It is urgent to introduce systematic measures to improve sanitation in order to safeguard the health and dignity of the population.	National Strategy for Water and Urban Sanitation (2011).	It is urgent to introduce systematic measures to improve sanitation in order to safeguard the health and dignity of the population. Leading to a single result: improving the health status of the population.	Policy initiatives for provision of water and sanitation through the Ministry of Construction and Water; Ministry of Public Works and Housing; Ministry of Health. Health Sector Strategic Plan (2013).
Water Supply and Sanitation Policy (2008) (260); National Policy on Infant and Young Child Feeding (2003) (261)	Namibia	Water Supply and Sanitation Policy (2008).	The development of adequate extension services for water supply and sanitation, covering the entire range from community management skills through technical training to health and hygiene education, is necessary for the revised WSS sector policy to succeed.	Water Supply and Sanitation Policy (2008).	The development of adequate extension services for water supply and sanitation, covering the entire range from community management skills through technical training to health and hygiene education, is necessary for the revised WSS sector policy to succeed.	National Policy on Infant and Young Child Feeding (2003). Wash hands before preparation. Use clean utensils washed in soap and water and boiled and kept covered. Boil water for 5 minutes and cool to room temperature before mixing.
National Water and Sanitation Policy (N/D) (262); National Sanitary Development Plan (2011) (263); Strategic Plan of National System of Health Information (2012) (264).	Niger	National Water and Sanitation Policy (N/D).	Following fundamental objectives: food security, protect the environment and health.	National Water and Sanitation Policy (N/D). National Sanitary Development Plan (2011).	Following fundamental objectives: food security, protect the environment and health. Revitalization of primary healthcare and halve malnutrition by 2015.	Policy initiatives for provision of water and sanitation through the Ministry of Hydraulics and Sanitation of Niger; Ministry of Public Health. National System of Health Information (2012).

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water Policy (2004) (265); National Water Sanitation Policy (2004) (266); National Policy on Food and Nutrition in Nigeria (2001) (267); National Policy on Infant and Young Child Feeding in Nigeria (2010) (268).	Nigeria	National Water Policy (2004).	The importance of eradicating poverty and therefore to enhance an improve public health through an optimal use of water resources for development remains the main driving force for the Government of Nigeria.	National Water Sanitation Policy (2004)	Sanitation development is essentially multi-sectoral. An integrated approach combining safe sanitation, hygiene education and promotion and safe water supply ensures improved health and livelihood.	National Policy on Food and Nutrition in Nigeria (2001). Malnutrition results from a combination of inadequate food intake lack of access to clean water, and health and sanitation problems. National Policy on Infant and Young Child Feeding in Nigeria (2010). Combat disease and malnutrition, including within the framework of primary healthcare, through, the provision of adequate nutritious foods and clean drinking water.
National Water Supply Policy (2016) (269); National Sanitation Policy (2016) (270); National Food and Nutrition Policy (2013) (271); National Nutrition Policy (2007) (272).	Rwanda	National Water Supply Policy (2016).	Poor water supply and sanitary conditions due to the lack of adequate water supply promote diarrhoea, intestinal parasites and environmental enteropathy, and have complex and reciprocal links to malnutrition in children.	National Sanitation Policy (2016).	The health cross-sector collaboration has to be strengthened to tackle multi-factorial determinants affecting the health of the population (poverty reduction, nutrition and food security, water and sanitation.	National Food and Nutrition Policy (2013). Problems of water, hygiene, and sanitation affect the synergy between malnutrition and infection. High priority for hygiene is justified because improved personal and domestic hygiene practices can reduce diarrhoea. National Nutrition Policy (2007). Scaling up of community-based nutrition programmes requires social mobilization activities for the promotion of safe

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
						water, personal and environmental hygiene.
Participatory Strategy for Water and Sanitation of São Tomé and Príncipe (2012) (273).	São Tomé and Príncipe	Participatory Strategy for Water and Sanitation of São Tomé and Príncipe (2012).	Recognizing that the water and sanitation sector are two important axes for the development of the country, since they contribute positively to the improvement of health and contribute to poverty reduction, in particular in reducing malnutrition.	Participatory Strategy for Water and Sanitation of São Tomé and Príncipe (2012).	Recognizing that the water and sanitation sector are two important axes for the development of the country, since they contribute positively to the improvement of health and contribute to poverty reduction, in particular in reducing malnutrition.	Policy initiatives for provision of water and sanitation through the Ministry of Public Works and Natural Resources.
Integrated Management Action Plan for Water Resources in Senegal (2007) (274); Sanitation Code (2009) (275); National Plan of Health Development (2009) (276); National Policy of Community Health (2014) (277).	Senegal	Integrated Management Action Plan for Water Resources in Senegal (2007).	The issue of water is a national issue given its impact on different sectors of development of the country: health, industry.	Sanitation Code (2009). National Plan of Health Development (2009).	Prevent damage to health. Health policy remains based on primary health care. Developing nutrition policy.	Policy initiatives for provision of water and sanitation through the Ministry of Urbanism, Habitat, Urban Hydraulics, Public Health e Sanitation; National Plan of Health Development (2009). National Policy of Community Health (2014).

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water Policy (2017) (278); Comprehensive and Integrated Sanitation Master Plan (2014) (279); National Health Policy (2016) (280).	Seychelles	National Water Policy (2017).	N/A	Comprehensive and Integrated Sanitation Master Plan (2014).	N/A	National Health Policy (2016). The Constitution of Seychelles ensures free primary healthcare and universal access to safe drinking water, good sanitation and housing provision.
National Water and Sanitation Policy (2010) (281); Sierra Leone National Food and Nutrition Security Policy (2012) (282).	Sierra Leone	National Water and Sanitation Policy (2010).	The Ministry of Health and Sanitation is responsible for public health and sanitation in the country. By its mandate, it is responsible for conducting health studies and reporting incidences of water borne communicable diseases; water quality testing; and investigating sources of water pollution.	National Water and Sanitation Policy (2010).	The main objective is to improve the health of communities and ensure that the majority of the population has access to sanitation services.	Sierra Leone National Food and Nutrition Security Policy (2012). Factors including access to reliable health services and living in sanitary environments with access to potable water are necessary for proper food utilization.
IYCF Strategy and Action Plan Somalia (2017) (283).	Somalia	N/A	N/A	N/A	N/A	IYCF Strategy and Action Plan Somalia (2017). Poor water, hygiene and sanitation practices are common in Somalia and are a key contributor to malnutrition. There is low access to safe water or to sanitation facilities. Hygiene practices such as hand washing at key times with soap or ash are uncommon.

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water Policy for South Africa (1997) (284); National Sanitation Policy (2016) (62); Infant and Young Child Feeding Policy (2008) (285); National Policy on Food and Nutrition Security (2014) (61).	South Africa	National Water Policy for South Africa (1997).	The Right of access to sufficient water promises every child the right to, among other things, basic nutrition and health care services.	National Sanitation Policy (2016).	The public health benefits of improved sanitation are maximised when sanitation is planned and provided in an integrated manner with other basic services.	Infant and Young Child Feeding Policy (2008). Ingestion of contaminated water, fluids, and food may lead to gut mucosal damage and disruption of immune barriers. National Policy on Food and Nutrition Security (2014). Tackling the problems of poverty, inequality and unemployment. It is a roadmap to a South Africa where all will have water, electricity, sanitation, jobs, housing, public transport, and adequate nutrition.
Water Policy (2007) (286); Health Sector Development Plan (2012) (287).	South Sudan	Water Policy (2007).	The provision of safe drinking water, basic sanitation and clean environment at household level can have a major impact on health.	N/A	N/A	Health Sector Development Plan (2012). The widespread water contamination, due to poor sanitation as a result of inappropriate solid & liquid waste disposal systems12, is a major risk factor for diseases.
Water Supply and Environmental Sanitation Policy (2010) (288); National Nutrition Policy (2009) (289).	Sudan	Water Supply and Environmental Sanitation Policy (2010).	The overall goal of the water supply and environmental sanitation policy is to contribute in improving the health status and living conditions of the population and the economic growth of the nation by providing all of	Water Supply and Environmental Sanitation Policy (2010).	The overall goal of the water supply and environmental sanitation policy is to contribute in improving the health status and living conditions of the population and the economic growth of the nation by providing all of	National Nutrition Policy (2009). Nutrition is not adequately mainstreamed into either pre-service or in-service training for wider public health staff, nor for staff in related sectors such as education, water and

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
			the population with adequate and sustainable access to WASH basic services and hygienic practices.		the population with adequate and sustainable access to WASH basic services and hygienic practices.	sanitation and agriculture. As a result, the ability to work together across sectors is limited.
National Water Policy (2009) (290).	Swaziland (Eswatini)	National Water Policy (2009).	Swaziland has a social, moral and economic responsibility to ensure that all its citizens have adequate access to safe water and adequate sanitation to guarantee human dignity and health.	N/A	N/A	N/A
National Water Policy (2002) (291); National Nutrition and Social Behaviour Change Communication Strategy (2013) (292).	Tanzania	National Water Policy (2002).	Safe drinking water and good sanitation practices are basic considerations for human health. Use of contaminated sources pose health risks to the population as evidenced by the incidences of water borne diseases.	N/A	N/A	National Nutrition and Social Behaviour Change Communication Strategy (2013). Higher priorities for behaviour change in relation to provision of food, and attention to critical actions in the area of water and sanitation and hand washing.
National Policy for the Supply of Drinking Water and Sanitation in Rural and Semi-Urban Areas (2006) (293); National Action Plan for the Water and Sanitation Sector (N/D) (294); National Action Plan for Integrated	Togo	National Policy for the Supply of Drinking Water and Sanitation in Rural and Semi-Urban Areas (2006). National Action Plan for the Water and Sanitation Sector (N/D).	Improving the health of users is one of the objectives of this policy. Very significant potential impact in terms of improving public health.	National Action Plan for the Water and Sanitation Sector (N/D); National Plan of Sanitary Development (N/D).	Strengthening the fight against malnutrition and micronutrient deficiencies. Very significant potential impact in terms of improving public health. Based on the vision of a Togo where the highest level of health is ensured to the population.	Policy initiatives for provision of water and sanitation through the Ministry of Mines, Energy and Water; Ministry of water, sanitation and rural hydraulics; Ministry of Health and Social Protection.

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Water Resources Management (N/D) (295); National Health Policy (N/D) (296); National Plan of Sanitary Development (N/D) (297).						
National Water Policy (1999) (298); National Sanitation Policy (1997) (299); Uganda Food and Nutrition Policy (2003) (300); Policy Guidelines on IYCF (2009) (301).	Uganda	National Water Policy (1999).	Promotion of public health and nutrition through reducing public health risks in irrigation and livestock water supply systems and increasing nutritional levels.	National Sanitation Policy (1997)	The high incidence of diarrhoea has remained a leading cause of nutritional stunting. The goal of this policy is to promote and preserve the health of the community through improved sanitation. Attaining and maintaining a good standard of sanitation will greatly contribute to reducing mortality and morbidity from sanitation related diseases, as well as improving the socio-economic status of the community.	Uganda Food and Nutrition Policy (2003). Promote the use of safe drinking water and sanitary means of waste disposal." Policy Guidelines on IYCF (2009). Encourage parents to practice high standards of hygiene when handling the infant's food, and also to maintain sanitation standards and food/water safety.
National Water Policy (2010) (302); National Food and Nutrition Policy (2006) (303).	Zambia	National Water Policy (2010).	The benefits from supply of sufficient quantities and good quality water and sanitation are important for the sustenance of health.	N/A	N/A	National Food and Nutrition Policy (2006). Poor access to adequate quantity and quality of domestic water and poor sanitary conditions contributes to outbreaks of water borne and other diarrhoeal diseases. These

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
						are closely associated with malnutrition.
National Water Policy (2012) (304); National Sanitation and Hygiene Policy (2017) (305); National Nutrition Strategy (2014) (306).	Zimbabwe	National Water Policy (2012).	The Ministry of Health and Child Welfare (MHCW) is a key player in the Rural WASH sub-sector responsible for water quality monitoring, promoting safe water supply and household sanitation. MHCW is responsible for promoting improvements in domestic hygiene, specifically through adoption of safe self-supply drinking water systems, and household investments in improving excreta disposal and safe sanitation.	National Sanitation and Hygiene Policy (2017).	The Ministry responsible for health will be tasked with sanitation and hygiene sub-sector leadership on policy and standards. Poor access to sanitation and hygiene increases the disease burden leading to loss of productive time and increasing health costs.	National Nutrition Strategy (2014). Government is committed to ensuring nutrition security for all through the implementation of evidence-based nutrition interventions that are integrated within a broad public health framework including health services, water and sanitation.

3.3.3 Nexus between WASH, Undernutrition and Governance

In terms of nutritional status 44 articles considered stunting (4,17,28,29,32,94,134–139,141–144,147–160,162–174), 17 articles underweight (4,32,134,136,140,141,143,144,151–153,160,164,165,168,171,173), and 16 articles wasting (4,32,139,141,143,144,147,153,154,159–161,164,165,167,173). A total of 8 articles were concerned with water alone (137,142,145,151,154,159,161,163) while 4 articles dealt solely with sanitation (139,141,147,160). A combination of water and sanitation was reported in 21 articles (4,17,134–136,138,140,143,152,155–158,162,164,165,167–169,171,172) and 13 articles reported on water, sanitation, and hygiene (WASH) (28,29,32,144,146,148–150,153,166,170,173,174). 21 Articles considered water source (28,29,32,135,137,144–146,150–155,159,164–166,168,169,172), 11 were concerned with access to water (4,17,142,143,148,157,161–163,167,174), 19 with type of infrastructure as defined by the JMP (29,32,135,136,138,140,146,148,149,155,158,164,165,169,171) and 2 with water treatment (150,156). 21 articles dealt with access to sanitation (4,17,28,139,141,143,144,146,147,150,152,153,155,157,158,162,166–168,173,174), and 22 with type of sanitation (17,29,32,134–136,138,140,146,148–150,153,160,164,165,167,169–172,174). A total of 6 articles were non-specific in so far as they considered multiple forms of hygiene, or hygiene as an integrated concept (28,144,148,149,153,174), while 3 considered food hygiene (146,166,170), 2 domestic hygiene (150,166), and 5 hand washing (29,32,146,150,173).

14 articles made explicit reference to the sentiment that the results of the research conducted had policy implications (17,28,141,142,151,152,156,158,161,165,166,168,171,173), while a total of 15 articles advocated for the importance of their results for the planning and development of interventions (134,136,137,139,144,147,149,153–155,160,162–164,167). A total of 17 of the articles included, noted the importance of their results for both policy and intervention planning (4,29,32,135,138,140,143,145,146,148,150,157,159,169,170,172,174). None of the articles unfortunately elaborated on neither precise policies nor specific intervention mechanisms but rather remained nondescript in their reports.

3.4 Discussion

In the literature that was included in this review, only 46 articles were included and indicates a relatively limited body of knowledge on the nexus between governance, water, sanitation, hygiene, and nutritional status in children in the sub-Saharan African context. Publications on

this topic have however been increasing, suggesting that this is an emerging and growing field of interest. In conducting this systematic review, there were no scientific studies or evidence specifically focused on linking the governance of WASH and nutritional status in children. All included publications did note some policy implications based on study results, however the precise manner in which this could or should be operationalized was rarely elaborated on.

In terms of the coverage of the literature for each of the individual WASH components, among the observational studies, more articles reported water as a significant risk factor than sanitation. Interestingly, among the reviews, more articles reported sanitation as a significant risk factor than water, with hygiene being the least represented component in both the observational studies, as well as reviews. While some studies are concerned with water or sanitation separately, water and sanitation was reported most, followed by, water, sanitation, and hygiene. Water source was reported most often, followed by type of water infrastructure, access to water, and finally water treatment. Access to sanitation was most reported followed by type of sanitation infrastructure. With regards to hygiene, being the least represented component, hand washing was reported most, followed by food and domestic hygiene respectively.

In terms of geographic coverage, parts of the Horn, East Africa, along with Southern Africa and pockets of West Africa were represented. Governments are also making progress by having water and sanitation policies in place with reference to the importance of water, sanitation, and hygiene have for the health and nutritional status of children. However, for many countries, much work needs to be done in the political sphere to bring new knowledge and evidence to the fore in order to keep policy mechanisms in tune with the requirements of the population. It is important to note that there are no specific health or nutrition outcomes that policies are evaluated against, especially not when it comes to children, and that each component of the WASH triad also have their own unique intricacies.

The link between WASH and nutrition is not one that should come as a surprise. WASH has long been part of the United Nations Children's Fund (UNICEF) Conceptual Framework, which provides a lens through which maternal and child undernutrition can be examined. This is achieved through providing a scalar model that incorporates immediate causes such as disease and dietary intake, underlying causes including household environment, food security, and health services, as well as, basic causes, referring to socio-economic and political context (24).

Advocating for multi- and inter-sectoral approaches are therefore not new (24,30–32,107). Fundamental to these kinds of grand challenges is the integration of various actors and the effective governance of resources and services as a precondition for the effectiveness and sustainability of WASH programmes and services (50). Overwhelmingly it seems that Governments are committed, at least in principle and in policy, to linking water, sanitation and hygiene to health and/or nutritional outcomes (Table 4).

When it comes to dealing with the nexus between governance, WASH, and nutritional status in children in SSA, scalability and sustainability depend on good governance and technical factors such as infrastructure and improved knowledge, and the availability of financial resources. However, while actors and stakeholders at various levels in the policy and governance arena advocate for multi- and inter-sectoral approaches, most nutritional status indicators show disappointing results. In 2013, for example, global estimates put the number of stunted children in low- and middle-income countries at 161 million (28). African prevalence's have stagnated since 1990 at about 40% and current trends suggest little improvement with business as usual (5). Countries in SSA continue to make headway in terms of increased access to WASH services, financial resources however remain a critical issue (52). Current levels of WASH financing are not sufficient to fund the achievement of SDG 6, estimated to cost an approximate $122 Billion between 2016 and 2030 (52,53). Important gaps in financing still exist with SSA countries, on average, committing 0.52% GDP to WASH expenditure. When excluding South Africa, this figure drops to a mere 0.27% GDP. Aid commitments for WASH to sub-Saharan Africa have also declined from US$ 3.8 billion to US$ 1.7 billion from 2012 to 2015 (52).

Governance issues therefore include limited managerial capacity, poor financial resource administration, corruption and weak institutions, which all limit the capacity of the national sector to deliver sustainable results at scale (23). No blueprints for WASH governance exist and no easy answers can be found on what constitutes the best governance model. Every country has its own set of governance systems, stakeholder dynamics and institutional structures, and therefore faces different problems and priorities (50). The primary responsibility for service delivery of water and sanitation, as both a basic service and a human right, lies with the State, however, even if the State holds ultimate responsibility, a number of stakeholders take part in the implementation. The Commission on Global Governance defines governance as follows; "the sum of many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting and or

diverse interests may be accommodated, and cooperative action may be taken. It includes formal […] as well as informal arrangements that people and institutions have agreed to or perceive to be in their interest" (38). Importantly is the distinction that governance is not exclusively government, as it includes non-governmental (NGO), inter-governmental organisations (IGOs), as well as civil society (38). With 2025 WHO Nutrition Targets (25) and 2030 SDG (47) deadlines looming, concerted efforts to actively facilitate the necessary inter-sectoral approaches requires efforts from all stakeholders to engage so that interventions are not logistically and/or financially prohibitive.

One possible model is that of the South African context where a minister in The Presidency is appointed, overseeing the Department of Planning, Monitoring and Evaluation in order to co-ordinate planning, monitoring and evaluation of government programmes aimed at improving service delivery, outcomes and impact on society. The main objective of which is to rally around a common set of objectives and priorities to drive development and crosscutting issues (307). Furthermore, it gathers people from different departments to discuss inter-sectoral issues. Multi- and inter-sectoral approaches require a significant degree of political will, and while gaps across SSA persist in terms of addressing specific socio-cultural and political contexts, on a positive note, for the most part across SSA, there are policies concerned with water and sanitation, which furthermore make explicit reference to health and/or nutrition as seen in Table 4.

Moreover, studies linking governance, WASH, and nutritional status, are increasing, providing a more nuanced perspective on associations on the various components of WASH (Fig. 3). However, much grey literature was not included in this systematic review, most likely due to the peer-reviewed format of scientific publications, thus limiting the body of knowledge included in this review. The authors searched grey literature databases including, the Grey Literature Report in Public Health (129), African Index Medicus (130), the WHO Virtual Health Sciences Library (131), as well as conference proceedings and websites, the authors furthermore reviewed reference lists and where appropriate contacted experts and authors and found that they grey literature concerned with WASH, nutritional status and governance was predominantly located within the IGO and development sector and associated agencies. Examples of this includes the UN through the WHO (7,105), UN Water (52), UNICEF (7,23,24,50), NGOs such as Save the Children (308), and foreign development co-operation agencies such as USAID (7).

Grey literature also tended to be narrowly focussed on a particular WASH component (either water, or sanitation or hygiene - in particular hand washing) and particular disease context, for instance, tuberculosis, HIV, or helminth infections, and while acknowledging the role that nutrition plays, rarely made an explicit link between WASH, nutritional status, and governance. WASH is in itself a composite concept comprising individual components each with its own body of research and associated complexities. Part of the complexity for WASH as a consolidated concept and topic for research, as well as for service delivery, seems to be agreeing upon a common nomenclature and standardised definition of what is being discussed. In this regard, the UN JMP (21,22) and the WHO and UN Water (105,118) have made significant progress in establishing a set of indicators, classifications and units of analysis.

In addition, the bulk of discussions concerned with the nexus between WASH, governance and nutritional status in this systematic review are situated in observational studies and reviews (Figure 8), thus highlighting the need for more in-depth knowledge on the topic in the various SSA contexts. Surprisingly no trials were found to form part of the literature under review. This may, in part, be due to the specificity of the search terms. Involvement of various stakeholders and implications for implementation, scalability, and policy may not have been reported, specifically in a scientific forum. Furthermore, trials are expensive and while not methodologically required to report on the various interactions with stakeholders are perhaps not explicitly focused on the links to governance structures and civil society as oppose to exploring the biological pathways and determinants.

A 2013 Cochrane Review on the effect of WASH interventions on nutritional status in children highlighted the low number of studies and low methodological quality of studies conducted in the past (86). As such, the production of high-quality data, beyond observational associations is a relatively recent development. Despite recent trial results indicating a marginal effect of WASH interventions on linear child growth (86,88,89) further exploration of the data from these, and forthcoming trials (91,94) will provide a more nuanced perspective on what does and does not work. Broader questions emerge from these results such as, while the microbial quality of drinking water available may be improved, the quantity of water, long argued to be a key driver in water-related health gains remains an important consideration (90,98). Population density and proximity to sanitation facilities are significant drivers in improving environmental conditions around children while delivering community wide interventions are important for showing an effect of sanitation on linear growth (88). Other

pathways - such as nutrition, animal waste, and complementary foods as pathways for enteric infection cannot be overlooked. These results show how little we know about the transmission of enteric pathogens, the causes of symptomatic infections and the significance of asymptomatic infections while at a policy level, business as usual in the WASH sector will not be enough to significantly improve child growth (90).

3.5 Conclusion

This systematic review sought to examine the literature linking governance, WASH and childhood nutritional status, in sub-Saharan African settings. The authors found that policy makers would benefit from integrating this emerging evidence-based information into their respective policies in order to better articulate and address the intricacies of water, sanitation, and hygiene in various contexts. Utilising consistent and established terminology when referring to the challenges and recommendations for service provision would allow for a more targeted discussion around which particular aspects of the WASH components require further consideration. The importance of early life exposures and associations with disease risk in adulthood provides further impetus for the tackling WASH from a governance perspective. Neither observational studies nor intervention studies included components exploring the role of governance of WASH in their design nor described if and how actors in the field of WASH were incorporated into the research process. Integrating the role of governance through the involvement of civil society, communities, IGOs, government, as well as development agencies would be a recommendation for future studies on the topic. The scientific and research community could further contribute by considering the manner in which study findings could or should be operationalized and gain real-world application. Incorporating WASH components in line with consistent and established terminology and definitions will make study design, as well as the results that emanate from such studies more pertinent and reproducible. At the same time more trials are also needed to determine and to evaluate more effective WASH interventions to halt the vicious cycle of exposure to poor WASH conditions in early childhood, repeated infections, inflammation and disease risk in adulthood.

Undernutrition has a complex set of political, social, and economic causes, none of which are amenable to easy solutions. Important knowledge gaps still remain concerning critical aspects of child undernutrition, including environmental risks in the neonatal and infant periods, especially in sub-Saharan contexts. Vast differences inevitably occur between communities,

between urban and rural, between socio-economic and political landscapes, and between regional and global contexts. The complexity of this is further compounded with the realization that access to water and sanitation are problematized through an increasingly resource and climate constrained context. Water resources are found in a variety of geographic settings that transcend geopolitical boundaries. Given the complex spatial context and transboundary nature within which water is situated, a number of dichotomies emerge when attempting to analyse national, regional and even continental or global WASH strategies and initiatives.

4 Chapter 4: Paper II

Momberg D, Mahlangu P, Ngandu B, May J, Norris S, Said-Mohamed R. Intersectoral (in)activity: towards an understanding of water, sanitation, and hygiene (WASH), and childhood undernutrition in public sector departments in South Africa. *Journal of Health Policy and Planning*: 1-41 *(Published Online 14 June 2020)* Appendix R.

4.1 Introduction

Undernutrition stems from a range of biological, contextual and structural determinants, including antenatal, intra-uterine, and postnatal malnutrition. Undernutrition is the outcome of inadequate macro- and micronutrient intake and repeated infections, defined as below 2 standard deviations from the median of the reference population, and includes underweight (low-weight-for-age; WAZ <-2SD), stunting (low-height-for-age; HAZ <-2SD), wasting (low-weight-for-height; WHZ <-2SD) (3,31,161). Undernutrition in children is of particular concern from a public health perspective because of its association with health and risk of diseases such as diabetes, hypertension, and cardiovascular disease in adulthood and is also a predictor of physical growth, mental, and cognitive development in childhood (Victora *et al.*, 2008; de Onis *et al.*, 2011; Spears *et al.*, 2013; WHO/UNICEF/USAID, 2015; Piper *et al.*, 2017). In this regard, childhood physical growth is used as a proxy for childhood nutritional status. Studies indicating that growth cannot be entirely improved by optimised diet have shown that environmental factors, including water, sanitation, and hygiene (WASH), contribute to poor child growth and nutritional status (19). The composite concept of WASH is comprised of the three spheres of water, sanitation, and hygiene. While each represents a separate field of work, each is dependent on the presence of the other. For example, without toilets, water sources become contaminated, without clean water, basic hygiene practices are not possible (20). Aspects of water include focus on the quantity and quality, as well as type of, and distance to, infrastructure; while the sanitation component includes focus on the access to, type of, and distance to, infrastructure; finally, the hygiene component emphasises access to handwashing facilities with soap and nurturing good hygiene practices (20). Exposure to poor WASH during early childhood has been associated with higher risks of infections and poor nutritional status, including stunting (123,124). Stunting is the result of a cyclical process of chronic exposure to undernutrition and repeated infections where women who were themselves stunted, are at higher risk of having stunted offspring, creating an

intergenerational cycle of poverty, reduced human capital, and disease that is difficult to break (10,12). Specific faeco-oral pathways are proposed by the so-called 5-F diagram, whereby faeces and associated pathogens are transmitted via fluids, fields/floors, flies, and fingers to foods, and then to the infant which causes disease and infection which in turn leads to growth faltering (Cumming *et al.*,2016). Growth faltering, is one of the physical consequences of undernutrition stemming from an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein, or micronutrients that negatively affect growth and development (144,309–311). An analysis of Demographic and Health Survey data from 70 low- and middle-income countries (LMIC) found that increasing access to and use of improved water sources reduced the risk of stunting in children under the age of five (18).

The United Nations Children's Fund (UNICEF) has advocated for the link between WASH and nutritional status for almost 30 years and through the Conceptual Framework (1990), for Improved Nutrition of Children and Women in Developing Countries (24), provides a lens through which maternal and child undernutrition can be analysed. A scalar model is presented that highlights immediate, underlying, and basic causes, incorporating the circumstances and determinants of maternal and child undernutrition from disease and dietary intake, to household environment and food security, to socio-economic and political context (24). The Lancet Series on Maternal and Child Nutrition (2008) highlighted the link between WASH and nutritional status by reviewing evidence-based interventions that affect maternal and child nutrition-related outcomes, emphasising the importance that WASH plays in preventing undernutrition (30). The 2013 follow-up series provided an updated framework including recommendations for inter-sectoral approaches to the challenges of malnutrition in LMIC settings, including an emphasis on WASH (4,32).

While the WASH concept was permeating the public health arena, from a policy perspective, the United Nations (UN) formally declared the right to water in 2002 and noting it as indispensable to human dignity and a prerequisite for the realisation of other human rights. The right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use (312). This provided the first reference to the responsibilities that Governments and service providers have in delivering clean water and sanitation to everyone (48). In 2010 the UN General Assembly extended this remit and adopted a resolution including and recognising sanitation as a human right (313). In the African context, Article 14 of the African Charter on the Rights and Welfare of the Child (ACRWC) (51) ensures the provision of adequate nutrition and safe drinking water; and that

all sectors of society are informed and supported in the use of basic knowledge of child health and nutrition, and the importance of hygiene and environmental sanitation.

Despite the ACRWC having been ratified by 49 member states, the situation is most critical in sub-Saharan Africa (SSA), where at the closing of the Millennium Development Goals cycle in 2015, the portion of people relying on untreated surface water for drinking was eight times higher than any other region. During this period more than 70% of SSA populations were living without adequate sanitation and the total number of people practising open defecation actually increased (53). Conversely, between 2000 and 2017 the percentage of people in SSA using safely managed sanitation, and drinking water, increased from 20% to 32% and from 18% to 27% respectively (314). However, these improvements did not significantly reflect in the nutritional status of African children. While stunting among children in Africa has decreased in percentage terms from 38.3% (2000) to 30.3% (2017), over the same period, due to population growth, the actual number of stunted children has risen (1,2).

The South African setting is characterized by various transitions resulting in a multiple burden whereby the population faces under- and over-nutrition, as well as micronutrient deficiencies (77). Overnutrition exists when the amount of nutrients exceeds the amount required for normal growth, development, and metabolism.

With regards to WASH infrastructure, in 2015 the national percentage of households with access to piped or tap water in their dwellings was 89.4%. In terms of national sanitation coverage, approximately 270 000 South African households were reliant on buckets, while 1 in 5 households did not have access to improved sanitation facilities (82,83).

National budgetary data suggests spending on water and sanitation is increasing, accounting for 15.3% of public sector expenditure amounting to a total of R132 billion disbursed via various infrastructure grants (315). At provincial level, due to service provision for water and sanitation not being administered at this level, but rather national and local levels, there is sparse budgetary data for this.

Despite the high coverage levels of WASH infrastructure in South Africa, diarrhoeal diseases are the second leading cause of mortality in children under five years of age (79). The aetiology of diarrhoea in the South African context is closely linked to socio-economic status, and illnesses such as HIV/AIDS, access to vaccinations, as well as poor environmental conditions (15). Between 2011 and 2016, in children under five years of age, the prevalence of stunting was 27.4% and over the same period, 5.9% were underweight and 2.5% were wasted (79,81). Worryingly, despite the provision of social grants, free primary health care and vitamin

supplementation, this prevalence rate has been unchanged since 1994 (17,316). The relationship between WASH at household level, and infant growth has received little attention in the South African context, which drastically limits our capacity to disentangle which installations and/or caregiver practices expose infants to such risks (64).

Intergovernmental and regional organisations, national governments, and academic research at global, regional and national levels have recognised the importance of the link between WASH and nutritional status in children. Disappointingly however, continued siloed efforts to reduce the prevalence of undernutrition in SSA, and in particular, South Africa, one of the most economically developed countries of the region, via improving infrastructure and access to WASH, have not been sufficient. Globally, much of the literature concerned with health policy analysis has focused exclusively on the content of policy documents and have neglected the actors involved in policy implementation and reform, while emphasis on health policy analysis in LMIC settings is still lacking (107). In SSA settings, gaps remain in relating governance and public policy analysis to health-related outcomes (317), while in the South African context, there is no clear delineation of roles and responsibilities relating to the integration of WASH and nutritional status, including intergovernmental relations on how to address nutritional status of children.

The aim of this paper is therefore to elucidate the landscape of WASH in South Africa in relation to nutritional status of children under five years of age. While interested in the broader South African context, emphasis is placed on the specific manner in which this manifests in Gauteng, and the City of Johannesburg (CoJ). Of particular interest was to learn which public sector departments were involved at the confluence of WASH and nutritional status in children, their level of coordination, barriers to implementation of strategies designed to address the link between WASH and nutritional status, and finally, make recommendations to address these barriers.

This paper has three interrelated objectives; firstly, to map public sector departments that are responsible for the provision of water, sanitation, and hygiene facilities, as well the nutritional status of children. Secondly, to identify and examine policy documents related to the confluence of WASH and nutritional status to explore the extent to which they address the link between WASH and nutritional status in children; and finally, to engage with experts at the intersection between WASH and nutrition to understand the vertical and horizontal coordination of public sector departments.

4.2 Methods

4.2.1 Study Design

This study, initiated in 2019, used an exploratory qualitative study design (106,107) to reflect on the nexus between water, sanitation, and hygiene, and nutritional status in children, in the public sector in South Africa focusing on the Gauteng province, and the CoJ.

4.2.2 Study Site

The study site, the CoJ metropolitan council, is situated in the Gauteng province and is home to the largest township in South Africa, Soweto. Soweto's population is officially estimated at approximately 1.3 million, with between 600 000 and one million people in the township regarded as living in extreme poverty (101). In 2015 Gauteng had 97.7% piped water coverage and 91.0% sanitation coverage (82,83). The CoJ, in 2016, reported that 99.5% of inhabitants had access to sanitation facilities and 99.9% had access to water (318). The CoJ, which is an urban area, is better resourced as compared to other parts of South Africa, and although the provision of infrastructure is well covered, the provision of operation, maintenance and repair services can become a risk factor for infant nutritional status/growth. In terms of water quality, 2019 data from Johannesburg Water indicates a total of 12 incidents of non-compliance for microbiological safety requirements (presence of *E.coli*), and 10 chemical and physical incidents of non-compliance (related to turbidity). Despite these incidents of non-compliance, overall compliance targets were maintained (319). For the CoJ, spending on water and sanitation infrastructure is decreasing, however so too are the absolute number of people without access to basic water and sanitation services. Spending however, for repair, maintenance, and upgrading of existing infrastructure is increasing (320).The South African Health Review reported that in Gauteng between 2011 and 2016 the prevalence of children under the age of five that were wasted was 1.3%, 4.6% were underweight, and 34.2% were stunted, representing the highest prevalence of stunting in the country (79).

4.2.3 Data Collection

4.2.3.1 Institutional Mapping

The authors detailed all national and provincial government departments in South Africa. South Africa is constituted on a quasi-federal system with three spheres of government at national, provincial and local levels (56–58). National government is responsible for developing policy frameworks, defining norms and standards for service provision, and

distributing revenue in an equitable manner; provincial and local governments are responsible for implementing most public functions and for putting into effect the policies developed at national level (56,58,60). Provincial government enjoys legislative and executive powers concurrent with national government, local government on the other hand can take the form of either metropolitan councils, or district or local municipalities and have varying degrees of legislative and executive authority (59).

Following the collation of national and provincial government departments in South Africa, purposive sampling (106), and an institutional analysis and development framework (108) were used to select and include public sector departments that are responsible for the provision of water, sanitation, and hygiene, as well as nutrition, are both presented in Table 5. The following inclusion criteria were used: participants (the public sector departments tasked with responsibility for the provision of WASH facilities, and those tasked with ensuring the adequate nutritional status of children); scale (level at which the particular departments work, either national, provincial, or local); mandate (the department's responsibility in the provision of WASH facilities, as well the nutritional status of children); and finally, scope for action (the department's agency to act in a coordinating or independent capacity in order to address the link between WASH and nutritional status in children).

4.2.3.2 Document Review

Electronic searches for each of the departments included were conducted to identify and examine current policies and to determine whether any explicit link between WASH and nutritional status in children was present. A document review guide was developed to structure the review process and was informed by the Walt and Gilson (1994) model for health policy analysis, focusing on understanding the content of policy documents, actors, context and process of interaction between public sector departments (107).

Table 5: Institutional and Development Framework for Departments Purposively Sampled

IAD Framework	Purposive Sampling		
Scale	National	Provincial	Local
Participants	National Department of Water and Sanitation (DWS)	Gauteng Provincial Department of Health	Johannesburg Water
	National Department of Social Development (DSD)	Gauteng Provincial Department of Social Development	CoJ Department of Health
	National Department of Health (DOH)		
Scope for Action	National Sanitation Policy		
	Food and Nutrition Security Policy		
	Integrated Early Childhood Development Policy		

4.2.3.3 Expert Interviews

Key informants, informed by the institutional mapping and document review, located at national, provincial, and local levels, in government departments, community-based organisations (CBO), non-governmental organisations (NGO), and intergovernmental organisations (IGO) with unique insight and experience of the confluence between WASH and nutrition as it relates to nutritional status in children in South Africa were identified. The authors approached respondents and, in the process, identified alternative key informants from those that did not consent to participate. Those that were approached were also asked if they themselves were not able to participate if they could recommend others that the authors could contact.

An open-ended interview guide was used to conduct key informant in-depth interviews, as well as a consensus development conference reflecting upon: (1) the perceived links between WASH and nutritional status; (2) barriers to implementation of strategies designed to address the link between wash and nutritional status; (3) and solutions and/or recommendations to the aforementioned barriers.

In addition to key informant in-depth interviews, a modified consensus development conference method (321,322) was convened providing a forum for discussion and deliberation, and was comprised of an expert panel of representatives from academia, public sector departments, CBO, NGO, and IGO. The panel were presented with evidence pertaining to the institutional mapping and document review. The discussion was moderated by an independent chairperson ensuring that all panel members had an opportunity to contribute.

4.2.4 Data Analysis

The authors identified and mapped actors and their respective mandates and identified factors that determine patterns of interaction (108). The information gathered was analysed following the World Health Organisation's methodology for mapping governance and health for well-being (323) outlining the public sector departments included in this study. This provides a graphical representation of the structure and processes within a system, and a map reflecting the relationships between the different components within the system.

Within the policy documents, the content was analysed by identifying actors, both individual, and groups, implicated in the confluence between WASH and nutritional status in children. The processes of how these policies are realised were considered in terms of the particular mechanisms that provide for horizontal coordination between departments on the same

level; and vertical coordination between departments at different spheres of government. Finally, the environment within which these documents came into existence and that which they are meant to address was contextualised. This process was conducted by DJM and BCN and checked by RSM and PM.

Data from the document review was analysed using Walt and Gilson's policy analysis framework which provides information about actors, process, content, and context (107). Data from the key informant interviews and the consensus development conference were minuted and analysed using thematic content analysis. Both the data-driven inductive method and a deductive method drawing from the Christensen framework of coordination were used (324). Christensen's framework was selected because it allows for reflection on coordination vertically between spheres of government, and horizontally between departments as it relates to WASH and nutritional status in children. Data from the *a priori* selected themes were extracted from the document review, expert interviews, and consensus development conference. Theme 1: Link between WASH and nutritional status in government departments; Theme 2: Complexity and lack of cross communication between government departments; and Theme 3: Recommendations. All minutes and recordings were analysed by DJM and the findings from the analysis further discussed and reviewed with RSM and PM.

4.3 Results

4.3.1 Institutional Mapping

Table 6 presents all national and provincial government departments and highlights the various public sectors as delineated by national departments and displays overlaps and/or absence of certain public sector departments in the various provinces. It demonstrates how each province has their own unique constellation of departments and that not all national departments are represented at provincial and/or local level. Responsibility for the provision of water and sanitation does not reside at provincial level but rather directly with local government (59). Thus, responsibility is located with the CoJ metropolitan council rather than the Gauteng provincial government. Health, on the other hand falls under the purview of provincial government, except where the responsibility for service provision is shared, as is the case with metropolitan councils such as the CoJ (56,59).

Nationally, it was determined that the National Department of Water and Sanitation (DWS), National Department of Social Development (DSD), and the National Department of Health (DOH) should be included. At provincial level, the following departments were included;

Gauteng Provincial Department of Health, and the Gauteng Provincial Department of Social Development. Within the Metropolitan Council of the CoJ, Johannesburg Water, and the CoJ Department of Health were identified for inclusion.

The results of the World Health Organisation's methodology for mapping governance and health for well-being (323) are presented in Figure 11 outlining the public sector departments included in this study.

The DSD finds its core legislative mandate in terms of Sections 27 and 28 of the Constitution and aims to ensure protection against vulnerability by creating an enabling environment for the provision of a comprehensive, integrated and sustainable social development service (325). The DWS states its responsibility in terms of the formulation and implementation of policy governing the water and sanitation sector, while striving to ensure that all South Africans gain access to clean water and dignified sanitation (326). Finally the DOH is concerned with improving health status through the prevention of illnesses and the promotion of healthy lifestyles (327).

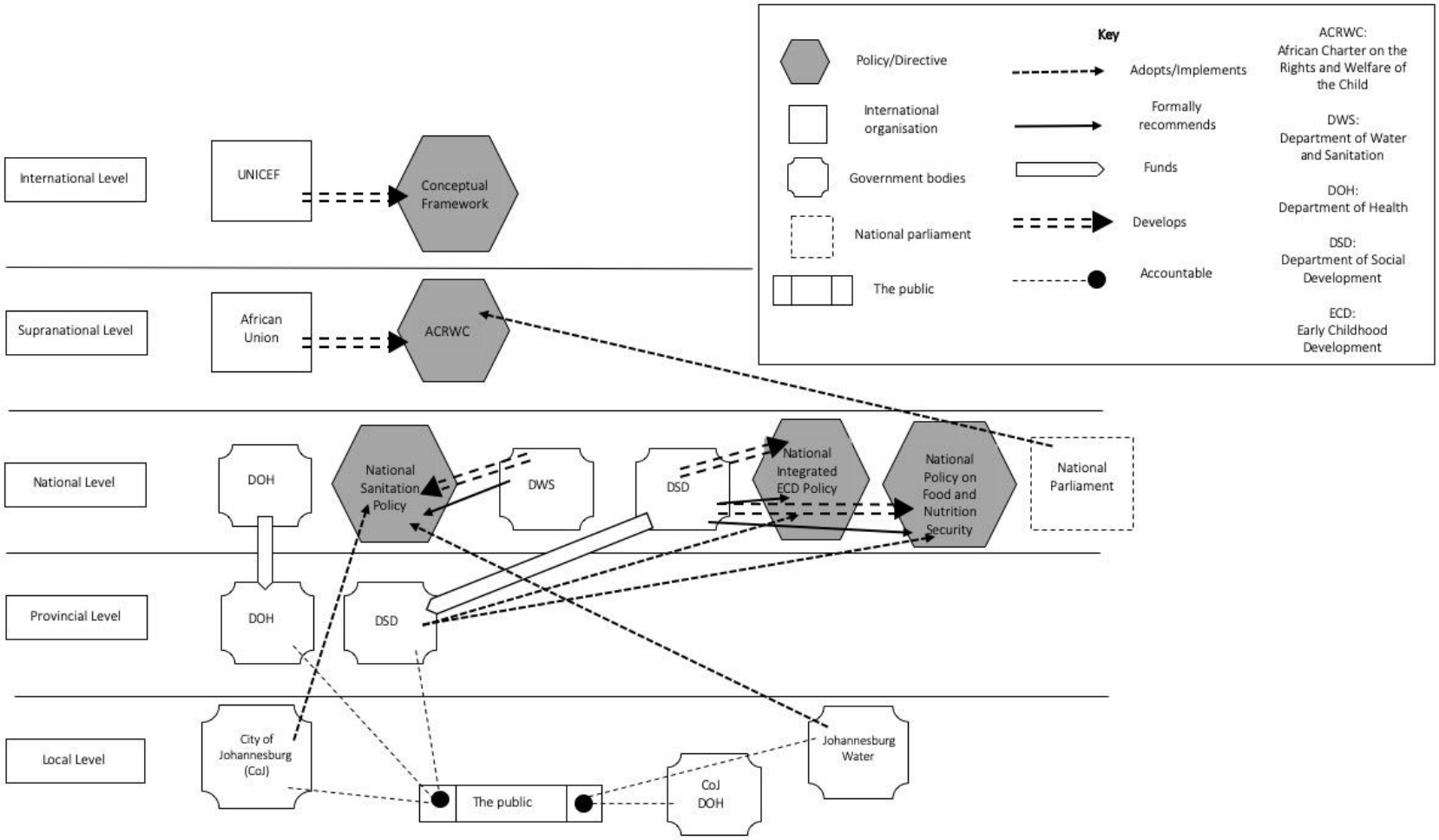
The scope of action, vertical and horizontal, for each of these departments is provided for, in principal, through the 1996 Constitution and the Intergovernmental Relations (IGR) Framework Act of 2005. The Constitution (1996) states that the three spheres of government should function in a cooperative, interrelated and interdependent manner, and ensure that there are intergovernmental relations, formal and informal processes, and institutional arrangements and structures for coordination within and between spheres of government (Government of South Africa, 1996; Butler, 2009; Mahlangu *et al.*, 2018). Chapter 3 of the IGR Framework Act (2005) outlines the process to be followed to ensure coordination in service delivery between national, provincial and local governments. The extent to which this is operationalised was explored through the document review and expert interviews.

Table 6: National and Provincial Government Departments

National Government	Gauteng	Western Cape	Eastern Cape	Northern Cape	KwaZulu-Natal	North West	Limpopo	Free State	Mpumalanga
Health									
Social Development									
Office of the Presidency	Office of the Premier			Office of the Premier					
Human Settlements					Human Settlements	Local Government and Human Settlements		Human Settlements	
National Treasury	Provincial Treasury			Provincial Treasury			Provincial Treasury		
Basic Education Higher Education and Training	Education			Education		Education and Sports Development	Education		
Agriculture, Land Reform and Rural Development	Agriculture and Rural Development	Agriculture	Rural Development and Agrarian Reform	Agriculture and Land Reform	Agriculture and Rural Development	Rural, Environmental and Agricultural Development	Agriculture and Rural Development		Agriculture, Rural Development, Land and Environmental Affairs
Environment, Forestry and Fisheries		Environmental Affairs and Development Planning		Environment and Nature Conservation	Economic Development, Tourism, and Environmental Affairs		Economic Development, Environment and Tourism		
Economic Development		Economic Development and Tourism	Finance, Economic Development, Environmental Affairs and Tourism	Economic Development and Tourism		Finance, Economy, and Enterprise Development			Economic Development and Tourism
Tourism						Tourism			
Public Works and Infrastructure	Infrastructure Development	Transport and Public Works	Roads and Public Works			Public Works, Roads, and Infrastructure	Public Works and Infrastructure		Public Works, Roads and Transport
Transport	Roads and Transport		Transport	Transport, Safety and Liaison	Transport	Community Safety and Transport Management	Transport and Community Safety	Police, Roads and Transport	
Police	Department of Community Safety		Department of Safety and Liaison		Department of Community Safety and Liaison				Community Safety, Security and Liaison
Sports, Arts and Culture	Sports, Arts, Culture, and Recreation	Cultural Affairs and Sport	Sports, Recreation and Arts and Culture	Sports, Arts and Culture	Arts and Culture Sports and Recreation	Culture, Arts, and Traditional Affairs	Sports, Arts and Culture	Sports, Arts, Culture, and Recreation	Culture, Sport and Recreation

Cooperative Governance and Traditional Affairs	Local Government	Cooperative Governance and Traditional Affairs	Cooperative Governance, Human Settlements, and Traditional Affairs	Cooperative Governance and Traditional Affairs		Cooperative Governance, Human Settlements, and Traditional Affairs	Department of Cooperative Governance and Traditional Affairs
Water and Sanitation							
Justice and Correctional Services							
Mineral Resources and Energy							
Communications and Digital Technologies							
Home Affairs							
International Relations and Cooperation							
Employment and Labour							
Defence and Military Veterans							
Public Enterprises							
Science and Technology							
Small Business Development							
State Security							
Telecommunications and Postal Services							
Trade and Industry							
Public Service and Administration							

Figure 11: National Mapping



4.3.2 Document Review

The following key policies were identified, sourced, and reviewed: National Development Plan 2030 (84), National Sanitation Policy (62), National Water Policy (329), National Policy on Food and Nutrition Security (61), National Integrated Early Childhood Development Policy (63), and the National Environmental Health Policy (330).

Of the policies reviewed, three mentioned WASH, nutrition, and children, however none explicitly linked WASH to nutritional status in children. An in-depth review and analysis of these three crucial policy documents was conducted.

With regards to the National Sanitation Policy (62), children, irrespective of age, are mentioned in the policy in so far as sanitation contributes to the fight against child mortality, and that basic sanitation should be safe for children to use. The policy explicitly mentions the link between sanitation, nutrition and health and acknowledges hygiene education and the importance of systematic approaches to encourage the widespread adoption of safe hygiene practices in order to reduce diarrhoeal and other WASH related diseases. Communication and education related activities are delegated to local government. While overall policy coordination is emphasised in order to achieve these objectives, responsibility for coordination and compliance is deferred to the Department of Co-operative Governance and Traditional Affairs as the regulator of local government.

The Food and Nutrition Security Policy (61) acknowledges the constitutional mandate that guarantees every citizen the right to have access to sufficient food and water. With reference to children, no particular age range is proposed however the policy notes that the existence and extent of malnutrition is an important proxy indicator of access to food and in particular that health related measures such as stunting and wasting, are particularly concerning when it comes to urban informal settlements. The policy also states that food and nutrition security, requires well-managed inter-sectoral co-ordination, and the integration of existing policies and programmes in health, education, and environmental protection, and calls for the involvement of CBO and NGO. Furthermore, the policy advocates for a comprehensive Food and Nutrition Security and Vulnerability analysis which would serve as a national data set including health, nutritional status, and sanitation. Water and hygiene are not explicitly included.

The final policy that was reviewed, the Integrated Early Childhood Development Policy (63) states that it aims to provide an overarching multi-sectoral enabling framework of early childhood development services, inclusive of national, provincial and local spheres of

government. The policy covers the period from conception until the year before children enter formal school, or until age six. Essential components that need priority attention as a government obligation include healthcare and nutrition programmes, water, and sanitation. The policy recognises that early childhood development programmes result from a series of mutually dependent partnerships of role players responsible for the well-being and development of children in South Africa, which include different government departments, organisations, agencies and individuals. The national DSD is responsible for policy development; national planning; regulation and development of norms and standards for service provision; and evaluation of efficiency and effectiveness while the provincial DSD are responsible for provincial population-based planning and management of the services described above. The DOH is responsible for the provision of the health and nutrition programmes. The DWS is responsible for formulating and implementing policy governing this sector and has an overriding responsibility for water and sanitation services provided by local government. It is thus responsible for ensuring that national water and sanitation policies and laws securing the rights of young children to access to sanitation and clean piped water. The policy goes so far as to delegate specific roles and responsibilities to all government departments as it pertains to early childhood development.

4.3.3 Expert Interviews

Invitations to 15 respondents from government, NGO, IGO, and academia were extended to participate as key informants. Three of those approached were from academia, 6 were from the government sector, 4 were from NGO, and 2 from IGO.

Of those approached, 2 consented to participate for in-depth interviews, one respondent came from an international NGO, and the other from the governmental health sector.

Important points made by the key informants targeted the need for training around early identification of chronic forms of malnutrition in early childhood through regular clinic visits and that parents need to have a better understanding of the Road-to-Health Card (an instrument used by doctors and nurses to monitor and record growth rate, development, and immunisations - given to mothers when their infant is born) and the anthropometric measurements being conducted. The respondents noted that the policy environment is very complex and that a lack of cross communication between departments both horizontally and vertically hinders planning and implementation. Another key challenge relates to the lack of data sharing, between provinces, as well as between departments. Integration of data with

indicators that are relevant for particular outcomes based on shared concerns was also highlighted. For instance, clinicians may not be immediately concerned with the environmental causes of diarrhoea over and above if the child presents with acute malnutrition. One respondent commented that "there is a lack of agency in tracing and addressing WASH related issues from a clinical standpoint, however from a disease surveillance perspective the incidence of diarrhoea at various scales is important to identify and address potential outbreaks, as well as more pervasive and chronic issues including growth faltering."

A panel for the consensus development conference was convened from a pool of stakeholders and experts comprised of professionals from the public health sector, NGO, IGO, CBO, and academia. Invitations to participate in the consensus development conference were extended to 20 respondents, of which 13 agreed to participate. The panel acknowledged that there is a strong link between WASH and nutritional status in children and that the biological pathways are well defined. The complexity of mapping the public sector departments is however made difficult due to the fact that there is no clearly defined link between the various WASH components in a public sector setting and as such no defined responsibility. The panel highlighted that there is a lack of advocacy for the link between WASH and nutritional status in children due to a survival driven agenda which is more-concerned with childhood mortality than morbidity. The panel noted that the extent that WASH affected nutritional status children and the cost of inaction needed to be quantified at various scales in order to increase the political will around addressing WASH and chronic undernutrition in children. The panel pointed to a number of policies, including those reviewed in this exposition, that include WASH. They highlighted that none clearly define or create a causal link between governance, WASH and nutritional status in children and that there are competing priorities between the various levels of government both in terms of mandate and in terms of party politics. It was furthermore suggested that national government is much better it seems at co-operation than the provinces, however implementation and operationalisation is key at local level.

4.4 Discussion

After the institutional mapping and review of policy documents, key informant interviews and consensus development conference, the study found that the key actors involved in addressing WASH and nutritional status in the study site includes the national DWS, national DSD, and national DOH, Gauteng provincial DOH, Gauteng provincial DSD, Johannesburg

Water, and CoJ Department of Health. The research has also highlighted the limited integration and coordination around service provision of these key areas related to WASH. Departments function in silos and there are limited efforts and implementation of efforts that are meant to allow for coordinated service delivery. Intergovernmental relations between levels of government are also poor, and there is limited harmonisation of efforts between the national, provincial and local levels of government.

The WASH landscape is comprised of a complex set of actors from various sectors that engage with one another on an *ad hoc* basis and while acknowledging that there are biological associations between WASH, morbidity, nutrition and growth, the precise pathways are not well articulated in the policy sphere. The horizontal and vertical intersectoral collaborations are also particularly difficult to delineate.

The South African Constitution provides for the provision of healthcare, food, water, and social security under Section 27 of the Bill of Rights and Section 28 further extends the right to basic nutrition in the case of children, however no explicit mention is made to the provision of sanitation (313,328,331). This has led to the South African Human Rights Commission to link the right to sanitation to the right to human dignity, privacy and the right to a clean environment (313,332,333). Furthermore, the National Development Plan (84) aims to achieve compliance with SDG 6 (clean water and sanitation for all) by 2030 (82). If these are to be achieved, a more co-ordinated effort will need to be leveraged at policy, planning and implementation levels. WASH is furthermore amongst the strategic priorities for the WHO Thrive Agenda 2030 (334). The report details the fact while most countries have a policy for WASH in healthcare facilities or infection prevention and control, less than 25% of these are fully funded and being implemented. As of 2017, 75% of the 75 countries that participate in the UN-Water Global Analysis and Assessment of Sanitation and Drinking- Water (GLAAS) initiative indicated financial data were available and utilized for decision-making around WASH and health issues. Of these countries, over two-thirds indicated the existence of a financing plan or budget for WASH, but fewer than one-third reported a financial plan was in place and consistently followed. The report details the fact while most countries have a policy for WASH in healthcare facilities or infection prevention and control, less than 25% of these are fully funded and being implemented. Thus advocating for the strengthening of sectors that enable improvements in newborn and child health, such as nutrition and WASH (334)

4.4.1 Theme 1: Link between WASH and nutritional status in government departments

WASH is a complex concept, with many components, both individual factors (water, sanitation, and hygiene), as well as within each component (quality, quantity, access, infrastructure, etc.), interacting in the system, while the individual WASH components occur in different governmental spheres. As such, articulation of the link between the various WASH components and nutritional status in children is sparse and although the various components, namely water, sanitation, and/or hygiene are mentioned, the relationship between them is rarely elaborated upon.

The various departments are primarily concerned with their core mandates. As such they are restricted in addressing crosscutting issues that fall outside of their immediate remit. For instance, the DoH (and/or clinicians and allied medical services) are responsible and concerned with direct/acute clinical issues and are not necessarily empowered to address the underlying and environmental causes of clinical conditions that they are confronted with. While the link between WASH and nutritional status is not new and the pathways are well established, given the complex public sector landscape it is difficult to translate these into the policy realm. The public sector would therefore benefit from better integrating a consolidated concept of WASH (20), that coherently incorporates the various individual components namely water, sanitation, and hygiene into their policy, planning, and implementation frameworks, rather than dealing with each component in isolation, as well as ensuring consistent, coordinated and complementary indicators across clinical and service provision sectors may also help coordination between sectors.

4.4.2 Theme 2: Complexity and lack of communication between government departments

The 1996 Constitution provides that the three spheres of government national, provincial, and local should function in a cooperative, interrelated and interdependent manner (Government of South Africa, 1996; Butler, 2009; Mahlangu *et al.*, 2018). The arrangement of government departments is by no means static and has gone through many functional and structural iterations at all levels since the transition to democracy in 1994 (335).

In the South African context, there is a lack of a guiding framework to operationalise and address the link between nutritional status and WASH, and to guide and inform implementation at national, provincial or local levels. There is also a lack of clarity about roles and responsibilities of various sectors, that need to be involved and how the link between

WASH and nutritional status should be monitored. This is perpetuated by a constellation of departments at various levels which complicates vertical and horizontal co-ordination, co-operation and collaboration.

While municipalities hold the mandate to deliver services, politics, both party and personal, intrude into coordination within municipalities (across wards and between departments), between municipalities and the province (and cutting across different departmental mandates), as well as with national government. The impact of politics intensifies the closer the authority is to the councillors and ward committees who are lobbying for resources, and party affiliations matter as much as personal connections. Municipal debt, which across South Africa totalled R72.4 billion in 2019, is another issue that should be mentioned in this regard (336,337). The various wards that cumulatively comprise the municipal jurisdiction are often purchasing utilities from the national service providers and are tasked with recouping those costs from residents. Recent protests about service delivery and the shutting down of services due to mounting municipal debt in the CoJ further demonstrate the tension between the various levels of government and the various levels of service provision (338,339).

On a positive note, the public sector involvement in the HIV and AIDS response in South Africa has had many successes, suggesting that such coordination is possible. Amongst the biggest gains has been the prevention of mother to child transmission and important lessons can be learned as to how best to leverage a multisectoral response (Padarath *et al.*, 2016; Mahlangu *et al.*, 2018; Rispel and Padarath, 2018). Progress in this regard has been achieved through mainstreaming HIV in the public sector, in both health and non-health sector departments (58). In addition, deeper vertical co-ordination at international and supra-national levels could further assist in developing strategies for addressing the burden of undernutrition from a WASH perspective. In recent years, countries such as Brazil, Peru, and Senegal, have found success in reducing undernutrition significantly through tailored multisectoral approaches, ascribing successful interventions by agriculture, healthcare, and WASH to jointly targeted populations and geographic areas (Skoufias *et al.*, 2019).

4.4.3 Theme 3: Recommendations

During the course of this study it became evident that providing recommendations on how best to address the challenges faced by the various public sector departments was not an easy task. However, a few recommendations were echoed through a number of sources. The establishment of a database of tools, policies and implementation strategies around best

practice, relating to successful attempts at combining WASH and nutritional status, at all levels of government would help leverage experience of successful programmes. Use of the National Dashboard of priority indicators was also noted as a powerful tool for driving implementation as there is visible monitoring and accountability for specific indicators (341). Integration of data with indicators that are relevant for particular outcomes based on shared concerns is essential. For instance, clinicians may not be immediately concerned with the environmental causes of diarrhoea over and above if the child presents with acute malnutrition, thus integrating a clear and defined set if indicators will be essential in trying to address the problem of growth from a WASH perspective. Harmonising indicators across clinical and service provision sectors may therefore help coordination across sectors. Using consistent language for both WASH and nutritional status related indicators is integral to harmonising such coordination efforts. Understanding what each of term and indicator means, using them appropriately in the right context, is key to communication between actors but also measuring impact of policies and other interventions. For instance, while the issues underpinning undernutrition could be addressed appropriately, seeing changes in linear growth can be seen at later stages, even in the next generation due to other determinants (including epigenetics) which can take two or three generations to overcome. While results can be seen more quickly if looking at wasting. Underweight is a poor indicator due to the fact that it does not distinguish between weight and height contributions. Furthermore, undernutrition also includes hidden hunger, i.e. micronutrient deficiencies, which are hardly measured in routine or in survey assessments. Of the policies reviewed in this exposition, none clearly define or create a causal link between governance, WASH and nutritional status in children. There are competing priorities between the various levels of government both in terms of mandate and in terms of party politics and because the various WASH and nutritional status components fall under different public sector departments there is no defined responsibility for how WASH should be operationalised to help address the burden of malnutrition in children. The SDG indicators may therefore be of use for synchronising targets from international to local scales, while providing a framework for linking policy to health-related outcomes. Localising the SDGs is critical to align the competing priorities between departments at various levels of government.

Understanding the associations between WASH, growth, and nutrition are integral and the way that these pathways are articulated in the policy sphere have real-world implications. An important distinction is that it is in fact not WASH that will improve nutrition but rather WASH

will improve growth which is in this case a marker of nutritional status. In addition low-cost WASH interventions often fail to improve health because they require much more user effort, time, and compromise than is required from residents of high-income countries for WASH services (95). For instance trial results showed that an intervention testing the effect of a device which automatically chlorinates piped water, on child diarrhoea delivered less-than-perfect disinfection but required no user effort (or even awareness of its presence) significantly reduced child diarrhoea by 23% (92,95). Among the policies reviewed there was little reflection on when during childhood, or at what age, it would be ideal to intervene. Timeous targeting of interventions, especially during the first thousand days is integral. In addition, while a conceptual understanding of what the links are, WASH interventions have had mixed success when it comes to improvements of linear growth. Policy is the first step and in order to take WASH policies to the next level it is important to acknowledge policy gaps but also focus attention on the complexities of implementation and communication, collaboration and co-operation between the various actors and stakeholders. Future studies would benefit from including a SWOT analysis focusing on strengths, weaknesses, opportunities, and threats in the South African and study contexts in order to better understand the dynamics of addressing nutritional status through WASH.

Finally, it is imperative to note that governance is not only for government and private sector involvement is imperative in order to create sustainable solutions at scale. Furthermore, the role that CBO, NGO, and IGO play in the intersection between WASH and nutritional status cannot be overstated.

While intersectoral collaboration is, in principal, facilitated at a national level through policy frameworks there exists a deeper need to ensure that co-ordination around implementation is operationalised at provincial and local level. Unfortunately, this is problematised in the case of metropolitan councils, which are politically highly contested due to the fact that they enjoy legislative and executive authority. In certain cases where the provincial and metropolitan council government are opposing political parties, or competing factions within parties, collaboration and cooperation can be particularly difficult.

While we have highlighted the institutional restraints of the public sector departments, this study has in itself a number of limitations. The authors reached out to a number of key informants within each of the government departments included, however most declined to participate in this study. They indicated an appreciation for the importance of the topic but expressed a lack of confidence in commenting on the intersection between WASH

components and links nutritional status in children. Although they considered the link between WASH and childhood malnutrition to be important, they did not consider themselves sufficiently competent to comment. This reinforces our contention that this is a neglected issue in SA policy and implementation.

While the authors have mentioned the specific mandates of the various government units, explicit indication and discussion about past, present and future programmes was outside the immediate scope of this exposition. The authors remain cognisant about the importance of describing and evaluating such initiatives in the context of the current research and suggest this as a focal point for future research on the topic.

A lack of data at local government level made an analysis across various scales difficult and while this study utilised simplified models to describe complex systems and interactions, based on these findings, future research needs to focus on the barriers to implementation. Experiences may also differ in other municipalities and provinces that emphasise and feature WASH more prominently in their policy and implementation frameworks and as such further research and insight is required. Despite these challenges the authors managed to compile data in each of the proposed fields providing insight into the status quo while presenting a novel use of methods offering critical advantages and strengthening the work conducted from traditional scoping and desk reviews.

4.5 Conclusion

This exposition sought to elucidate the landscape of WASH in South Africa in relation to nutritional status of children under five years of age. The authors found that utilising consistent and established terminology and indicators when referring to the challenges and recommendations for service provision would allow for a more targeted discussion around which particular aspects of the WASH components require further consideration. The public sector would benefit from better integrating the concept of WASH into their policy, planning, and implementation frameworks.

The WASH sector should take stronger action to integrate nutrition; too few WASH plans consider the impact of water, sanitation, and hygiene on nutritional status of children. The various public sector departments involved in WASH service provision, and other WASH stakeholders, including CBO, NGO, and IGO, should be involved in the decision-making, monitoring and evaluation, and implementation of policies and strategies within the nutrition sector.

In addition, further targeted research on the governance of WASH through the identification of the various role players and stakeholders at various levels, while understanding the policy environment in relation to particular health related outcomes is imperative to address the burden of child undernutrition.

5 Chapter 5: Paper III

Momberg D, Voth-Gaeddert L, Ngandu B, Richter L, May J, Norris S, Said-Mohamed, R. Water, sanitation, and hygiene (WASH) factors associated with growth between birth and one year of age in children in Soweto, South Africa: Results from the Soweto Baby WASH study. *Journal of Water and Health* (*Published Online 21 September 2020)* Appendix S.

5.1 Introduction

Children under two years of age are considered as the most at risk group for undernutrition due to their rapid growth, and increased vulnerability to infectious diseases (147). The World Health Organisation (WHO) defines three forms of undernutrition among children – namely stunting, underweight, and wasting - as being 2 standard deviations (SD) below the WHO age and sex adjusted growth standard; for stunting, height-for-age (HAZ); for underweight, weight-for-age (WAZ); and for wasting, weight-for-height (WHZ) (3). Z-scores in this regard referring to a statistical measurement of a score's relationship to the median in a group of scores, measured in terms of a standard deviation from the median of the population.

The first thousand days (from conception to 2 years of age) is an integral phase of childhood development due to developmental plasticity and is amongst the most pertinent periods for interventions aimed at optimising growth and development (11,12,149,310). Developmental plasticity posits that environmental conditions experienced in early life, including nutrition, trigger permanent physiological adjustments that can profoundly influence human biology and long-term health outcomes (342–344).

Inadequate nutrition and frequent illness, especially diarrhoea, are among the most commonly implicated causes of undernutrition (91–93). Nutrition-sensitive interventions to improve undernutrition and child growth have therefore often incorporated water, sanitation, and hygiene (WASH) factors as strategy to prevent disease transmission. However, recent results from large-scale randomized controlled trials (SHINE and WASH Benefits) have found no effect of basic WASH interventions on childhood stunting, and only mixed effects on childhood diarrhoea (93). Both studies concluded that more comprehensive WASH interventions may be needed to achieve a major impact on child health. Further, the authors argue that the results do not show that WASH cannot influence child linear growth, but rather that these specific interventions had no influence in settings where stunting remains an important public health challenge (93).

In terms of specific WASH-related risk factors, a recent systematic review investigating WASH in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age, found that observational studies more often reported water as a significant risk factor while review articles tended to highlight sanitation as a significant risk factor (317). Across both observational and review studies included in the systematic review, hygiene was the least represented component (317).

The South African context is characterised by particularly high rates of stunting for a middle-income country where in 2016, the prevalence of stunting in children under five years of age was 27.4%, while at the same time, 5.9% of children under the age of five were underweight and 2.5% were wasted (79,81). In terms of water infrastructure in South Africa, it was reported in 2015, that 89.4% of South Africans had access to piped tap water, comprised of households having access to either piped water in their dwellings, piped water onto their property, communal and neighbours' taps, the remainder relying on water from rivers, streams, stagnant water pools, dams, wells and springs (82,83,85). With regards to sanitation infrastructure in South Africa in 2018, 83% had access to improved sanitation facilities, with final 17% unimproved sanitation facilities proving to be the most difficult to address (82,83,85). The Gauteng province in particular is reported to have the second highest coverage of access to water (97.7%) and sanitation (91.8%) (82,83,85). In terms of water quality, 2019 data from Johannesburg Water indicates a total of 12 incidents of non-compliance for microbiological safety requirements (presence of *E.coli*), and 10 chemical and physical incidents of non-compliance (related to turbidity). Despite these incidents of non-compliance, overall compliance targets were maintained (319,345). For the City of Johannesburg, spending on water and sanitation infrastructure is decreasing, however so too are the absolute number of people without access to basic water and sanitation services. Spending however, for repair, maintenance, and upgrading of existing infrastructure is increasing (320,345). Soweto is serviced by 3 wastewater treatment works, Goudkoppies, Bushkoppies, and Olifantsvlei wastewater treatment works, which remediate both industrial and household wastewater (346). The precise configuration of sanitation provision across Soweto is quite diverse and ranges from flush toilets to pit latrines, and portable toilets that are typically arranged in latrine banks. The system of waste disposal, maintenance and treatment associated with these facilities is decentralised to different outsourced service providers (345). In terms of water and sanitation infrastructure in South Africa, it was reported in 2015, that 89.4% of South Africans had access to piped tap water, and in 2018, that 83% had access to improved

sanitation facilities (82,83,85). Diarrhoea is still one of the leading causes of morbidity and mortality in South Africa, accounting for approximately 20% of all deaths in children under five years of age (15). Despite a number of initiatives to address the persistently high prevalence of stunting, including near universal water and sanitation coverage in urban settings, the provision of social grants, and free primary healthcare, this prevalence rate has remained largely unchanged since 1994 (17,316).

The relationship between WASH at the household level, and infant growth has received little attention in the South African context, which drastically limits our capacity to disentangle which installations and/or caregiver practices expose infants to such risks (64). Knowledge gaps still exist in terms of which WASH factors are risks for undernutrition, at what time during early childhood development WASH factors are implicated, and precisely when WASH interventions are most effective at improving growth.

This study therefore sought to identify specific WASH factors and subsequent associations with HAZ, WAZ, and WHZ scores in infants *a priori* born healthy in Soweto, Johannesburg. The study hypothesised that inadequate water, sanitation, and hygiene are associated with decrease in HAZ, WHZ, WAZ scores between birth and one year of age.

5.2 Methods

5.2.1 Study Design and Setting

The study is based on cross-sectional data from 4 timepoints (delivery, 1, 6, and 12 months postpartum) drawn from a larger longitudinal prospective cohort study, entitled "Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age." Colloquially referred to as Soweto Baby WASH study, the aim was to document household environment, maternal and infant morbidity and illness, and infant feeding and care practices, and assess the association between these factors and infant growth and development in the first year postpartum. The Soweto Baby WASH study had 37 timepoints over the course of 12 months, with weekly follow-up home visits from birth to 6 months, and fortnightly from 6 to 12 months postpartum. Visits at 6 and 12 months were conducted at the Developmental Pathways for Health Research Unit facilities at Chris Hani Baragwanath Academic Hospital (CHBAH). Data collected included maternal and infant anthropometric and body composition measurements; household WASH; maternal and infant morbidity, illness, and healthcare access; infant feeding practices; household socio-economic status and demographics; maternal social support,

stress, and depression; quality of care in the home; infant temperament; and infant development.

Recruitment commenced in January 2018 and data collection ended when the last recruited infant turned 1 year of age in March 2019. All the participants were screened and recruited at the maternity services at CHBAH in Soweto, Johannesburg.

Soweto is the largest township in South Africa with an estimated population of 1.3 million residents, and is situated in the City of Johannesburg in the Gauteng Province (99,101). In 2018 it was reported that Gauteng had near universal water and sanitation coverage with 97.7% of the population having access to piped tap water in their dwellings, and 91.8% having access to improved sanitation (85,99). Despite the economic and infrastructure advantages of the province, in 2016 Gauteng reported the highest prevalence of stunting in the country at 34.2% (79).

5.2.2 Ethical Considerations

The study received clearance from the University of the Witwatersrand's Human Research Ethics Committee (Medical) (Certificates: M170753, M170872, and M170955). Written informed consent was obtained from all participants.

5.2.3 Participants

In order to identify which determinants affect growth at what time, infants who *a priori* had a better start at birth in terms of physical growth and health were recruited. Women who were 1-3 days postpartum were screened for eligibility. Mother-infant pairs eligible for inclusion were: ≥18 years of age at time of screening; singleton pregnancy; birthweight between ≥2500g and <4000g, and term pregnancy between ≥38 weeks and <42 weeks gestational age. Mother-infant pairs were not eligible for inclusion if infants were diagnosed with physical, mental or congenital disorders at birth or if a mother was living with HIV.

5.2.4 Outcome Variables

5.2.4.1 Infant Growth

Anthropometric measurements were performed by trained research assistants using standardised techniques (3,109). Infant weight was measured to the nearest 0.01kg using an infant scale (seca 367) and recumbent length to the nearest 0.01cm using an infantometer

(seca 416). Anthropometric related data (sex, age, length, weight) were analysed using the WHO Anthro Survey Analyser software to generate HAZ, WAZ and WHZ scores (347).

5.2.5 Exposure Variables

Table 7 summarises the variables and survey questions drawn from the Soweto Baby WASH study, as well as the coding of composite variables created for use in the analyses that follow.

5.2.5.1 Water, Sanitation, and Hygiene (WASH)

Household WASH was assessed using a questionnaire adapted from the WHO/UNICEF Core Questions on Drinking-Water and Sanitation for Household Surveys (118), the WHO/UNICEF Joint Monitoring Programme (JMP) (21,22), and the Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) (105).

Variables pertaining to water source, were aggregated into 2 categories, safely managed and not safely managed. Safely managed water sources were defined as: a basic drinking water source located on the premises (piped into the home/property), available when needed and free of faecal and chemical contamination (22). Not safely managed water sources comprised all other installations. Variables including, access to water source (coded 1 if the water source was on the property, and 0 if not), water treatment and interruptions to water supply were also collected (Table 7). A water index (scored 0-4, with 0 representing the lowest level of water infrastructure and behaviours, and 4 the highest); was constructed as a sum of the items pertaining to water source, access, treatment, and supply (348).

Data on the type of sanitation infrastructure (Table 7) were aggregated into 2 categories, safely managed and not safely managed. Safely managed sanitation facilities were defined as: a basic sanitation facility (flush/pour to piped sewer system) where excreta are safely disposed *in situ* or treated off-site (22). Not safely managed sanitation facilities incorporated all other infrastructure installations.

In order to create a composite hygiene index (scored 0-5: with 0 representing the lowest level of hygiene behaviours and infrastructure, and 5 the highest), three indices to assess hygiene behaviours and circumstances were created (111). Firstly, a Household Hygiene Index (HHI) - scored 0-2, (Table 7) included type of house, and presence of animals on the property (coded 0 if there were animals on the property, and 1 if not). Secondly, a Personal Hygiene Index (PHI) - scored 0-2 (Table 7), included handwashing, and handwashing detergent. And thirdly, a Food Hygiene Index (FHI) - scored 0-1 (Table 7), cleaning of the breast and cleaning of utensils prior

to feeding. The HHI, PHI and FHI were calculated as the sum of the individual items and the overall hygiene index as the sum of the HHI, PHI and FHI (111,348).

For both the water and hygiene indices, each of the items was scored as either 0 or 1, with 1 representing a positive behaviour or circumstance. Positive behaviour or circumstance was defined as an activity or condition that is protective towards or acts as a barrier to the transmission of pathogens (21,22,29,111).

Table 7: Composite variables for water index, sanitation, and hygiene index

Descriptor	Description	Aggregated Variable	Coding	Survey Question
Type of Water Source	Piped into dwelling	Safely managed	1	What are the most common (within past 2 weeks) sources of water you have access to?
	Piped into yard/plot			
	Bottled water	Not safely managed	0	
	Public tap			
	Borehole			
	Protected dug well			
	Protected spring			
	Rainwater			
	Tanker/Cart with small tank			
	Unprotected dug well			
	Unprotected spring			
	Surface water			
Interruptions to Water Supply	Daily	> Once a month	0	How often do you have interruptions to your water supply?
	Once a week			
	Once a month			
	Rarely/Never	Rarely	1	
	Don't know			
Water treatment	Bleach/Chlorine	Treatment	1	What methods do you use to treat your water?
	Boiling			
	Strain it through a cloth			
	Use a water filter			
	Solar disinfection			
	Let it stand/settle			
	Other			
	None	No treatment	0	
Type of Sanitation	Flush/Pour to piped sewer system	Safely managed	1	What type of toilet facilities are available?
	Flush/Pour to septic tank	Not safely managed	0	
	Flush/Pour to pit latrine			
	Flush/Pour to elsewhere			
	Ventilated Improved pit latrine			
	Pit latrine with slab			
	Composting toilet			
	Portable toilet			
	Bucket			

	Pit latrine without slab			
	No facilities (bush or field)			
Type of House	Shack/Zozo	Informal	0	How would you describe the home you are living in?
	Hostel			
	Flat/Cottage	Formal	1	
	House			
	Room/Garage			
	Residence (attached to education or employment)			
	Government housing			
	Other			
Handwashing	Before and after eating	Before/After handling food	1	When do you wash your hands?
	Before preparing food			
	Before and after feeding			
	After using toilet	Before/After using sanitation	1	
	After changing diaper			
	When hands are dirty	Other	0	
	Never/Rarely			
	Other			
Handwashing detergent	Soap and water	Water and soap/ash	1	What do you wash your hands with?
	Water and ash			
	Only water		0	
Cleaning of Breast/Nipple	Yes, Always	Food hygiene practices (Recommended)	1	Do you clean your breast or nipples before feeding? How do you usually clean the utensils used for feeding?
	Yes, Sometimes			
Cleaning of Utensils	Cold Water and Soap			
	Boiled Water			
	Boiled Water and Soap			
	Sterilisation Solution			
Cleaning of Breast/Nipple	No	Food hygiene practices (Not Recommended)	0	
	Don't Know			
Cleaning of Utensils	Cold Water			
	Other			

5.2.6 Covariates

5.2.6.1 Maternal Anthropometry

Maternal height, to the nearest 0.1cm, was measured using a wall-mounted stadiometer (Holtain), and weight, to the nearest 0.1kg using a digital scale (seca 877), was measured by trained research assistants using standardised techniques, from which maternal Body Mass Index (BMI) was calculated as (kg/m^2) (110).

5.2.6.2 Morbidity and Illness

Maternal and infant morbidity, illness, and healthcare access were assessed using interviewer-administered surveys, validated in the study setting, and confirmed against clinic records (117). Incidence of diarrhoea was recorded by 7 day recall from birth to 6 months, and 14 day recall from 6 months to 1 year of age.

5.2.6.3 Infant Feeding Practices

Infant feeding practices were assessed using a locally adapted version of the WHO/UNICEF Infant and Young Child Feeding Questionnaire (112–114). Prevalence of exclusive breastfeeding (EBF) from birth to 6 months was determined using the WHO definition which allows the infant to receive breastmilk (either expressed or from a wet nurse), oral rehydration solution, drops, syrups (vitamins, minerals, medicines), but nothing else (113,114).

5.2.6.4 Household Socio-Economic Status and Demographics

The household socio-economic status questionnaire was developed based on the National Income Dynamics Study (NIDS) (115), and the Living Conditions Survey (LCS) (116). Data pertaining to household crowding, maternal employment, and education were collected. A Household Wealth Index (HWI), was calculated using latent household variables: household assets (bicycle, motorcycle, motor vehicle, fridge, microwave, washing machine, landline telephone, camera, cell phone, television, DVD-player, paid television subscription, computer/laptop, internet access), housing characteristics (home ownership, land ownership, and main type of energy) (349,350). The HWI, was built using principal component analysis (350). Based on the HWI, the sample was divided in half into two categories (the richest and the poorest)

5.2.7 Sample Size

A total of 1289 mothers were screened post-delivery at the maternity wards at CHBAH. Of those screened, 243 were eligible. Because 87 did not consent, 156 mother-infant pairs were enrolled in the study (Figure 12).

5.2.8 Statistical Analyses

The statistical software used for analysis was Stata version 13.1 (StataCorp, 2013). Descriptive statistics, including frequencies, proportions, means and standard deviation, or median and range were used to summarize the variables. The Shapiro-Wilk test for normality, and tests of homogeneity of variance were performed to identify the type of distribution for continuous variables. Differences by sex were assessed using a Pearson's chi squared test, or an independent Student t-test.

Using the social-ecological model (351) informed by the UNICEF Conceptual Framework (24) three hierarchical models were hypothesised in order to assess the associations between WASH components and HAZ, WAZ, and WHZ, while controlling for individual infant and maternal factors, as well as household characteristics at 1, 6, and 12 months postpartum (352). Model 1 (M1) investigated the unadjusted and independent association between WASH factors and growth outcomes. Model 2 (M2) examined effect after controlling M1 for individual infant factors (birthweight, gestational age). Model 3 (M3) explored the effect after controlling M2 for maternal factors (age, height, BMI, employment, education). Finally, Model 4 (M4) investigated the effect after controlling M3 for household factors (crowding, wealth index). Collinearity between variables was tested by assessing the variable inflation factor and covariance correlation matrices. Significance levels were set at $p \leq 0.05$ with 95% Confidence Intervals.

5.3 Results

Over the duration of the study, 73 (46.8%) participants were lost to follow-up. A total of 83 mother-infant pairs exited the study after 12 months of follow-up, comprising the final sample (Figure 12).

At birth (Table 8), despite having been born within normal ranges for birthweight (mean=3.055 grams, SD=0.35) and gestational age (mean=38.9 weeks, SD=1.2), the prevalence of stunting was 9.7%, underweight 0.7%, and wasting 2%. Stunted largely persisted being at higher prevalence than other forms of undernutrition as the study progressed with 10.2 % of

participants being stunted at 1 month, 10.1% at 6 months, and 11% at 12 months (Table 9). Mean maternal BMI values were as follows, 27.5 (SD=5.9) at 1-month, 29.9 (SD=6.1) at 6 months, and 29.9 (SD=6.6) at 12 months (Table 9). At 1 month postpartum, more than two-thirds of mothers were employed, while conversely at 12 months postpartum, approximately two-thirds (65.3%) were unemployed.

Additional participant characteristics are presented in Table 13, supplementary.

The water index did not vary much over the course of the study with the sample mean remaining around 3.11 over a maximum score of 4 across all 3 timepoints (Table 9). With regards to sanitation, more than 90% of participants had access to a safely managed sanitation facility. The hygiene index did also not vary much over the course of the study with sample means remaining around 3.35 (SD=0.87) at 1-month, 3.38 (SD=0.89) at 6 months, and 3.14 (SD=0.97) at 12 months.

Table 10,Table 11, and Table 12 show the results for the hierarchical regression analyses on HAZ, WAZ, and WHZ at 1, 6, and 12 months postpartum respectively. All significant associations for the fully adjusted M4 models are diagrammatically displayed in Figure 13.

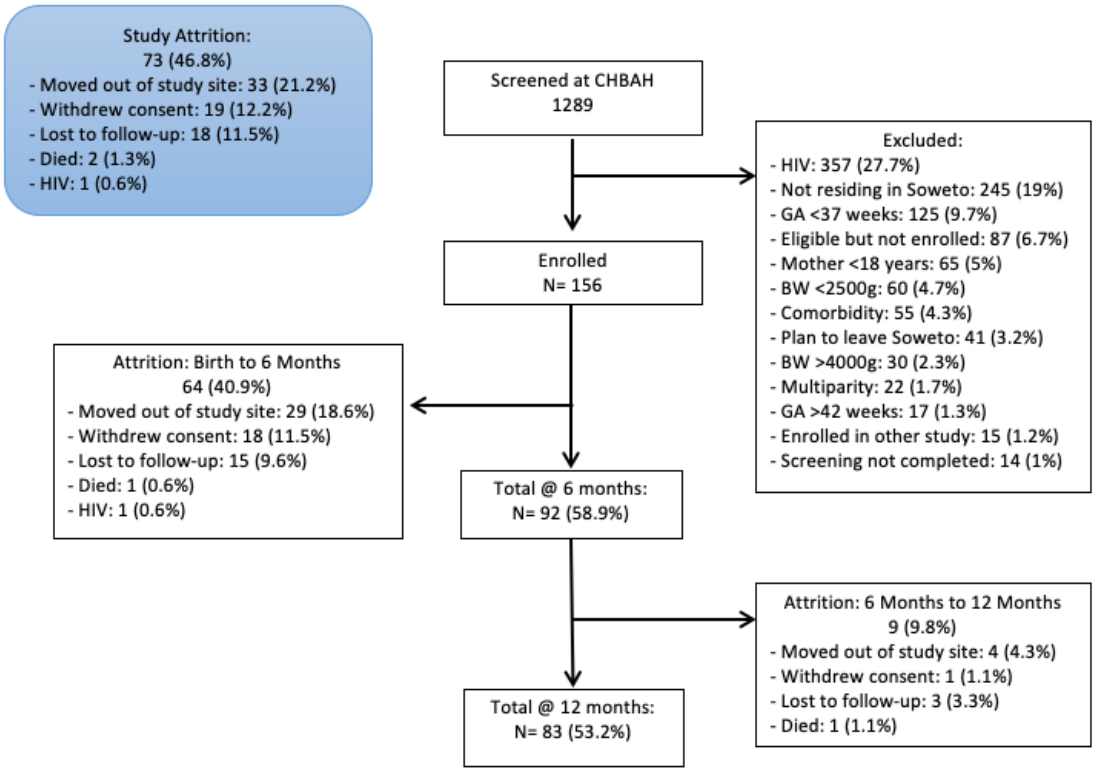


Figure 12: Screening, Follow-up and Attrition Flow Diagram of the Soweto Baby WASH study

Table 8: Maternal and infant characteristics at birth in the Soweto Baby WASH study

		Delivery	
		Total	
		n	Mean, SD, or Percentages
Infant Characteristics			
Sex	Male	76	50.3%
	Female	75	49.7%
Age (mean, SD)	Months	154	0.039 (0.029)
Gestational age (mean, SD)	Weeks	151	38.9 (1.2)
Weight (mean, SD)	Kilograms	151	3.055 (0.35)
Length (mean, SD)	Centimetres	151	48.3 (1.7)
Stunted	Yes	14	9.3%
	No	136	90.7%
Underweight	Yes	1	0.7%
	No	149	99.3%
Wasted	Yes	3	2%
	No	144	98%
Maternal Characteristics			
Age (mean, SD)	Years	153	27.7 (6.1)
Height (mean, SD)	Centimetres	77	157.8 (6.9)

(Table 10) Using a safely managed sanitation facility was associated with an increase in HAZ scores by 2.24 (M4, *p*=0.03), at 1 month, but this effect size decreased to 0.98 (*p*=0.04), at 6 months postpartum and no association was detected at 12 months. An improvement by 1 unit in the hygiene index was associated with a decrease of 0.53 in HAZ scores (M4, *p*=0.04) at 1 month postpartum but no associations were detected at 6 or 12 months. No associations between the water index and HAZ scores were detected at any of the timepoints. At 1 month, 6 months, and 12 months, WASH factors (M1) explained 2%, 10%, and 6% of the variance in HAZ respectively, while infant, maternal, and household characteristics (M4) at the same time points, explained, 56%, 29%, and 28% of HAZ variance, respectively.

With regards to WAZ (Table 11), a 1-unit improvement in the hygiene index was associated with a decrease in WAZ by 0.44 (M4, *p*=0.001) at 1 month, while no associations were detected at either 6 or 12 months postpartum. Use of a safely managed sanitation facility was associated with an increase in WAZ by 1.21 (M4, *p*=0.01) at 1 month, 1.57 (M4, *p*=0.01) at 6 months, and 1.92 (M4, *p*=0.01) at 12 months. No associations between the water index and WAZ scores were detected at either 1, 6, or 12 months in the fully adjusted models (M4). At 1 month, 6 months, and 12 months, WASH factors (M1) explained 1%, 6%, and 19% of the variance in WAZ scores respectively, while infant, maternal, and household characteristics (M4) at the same time points explained, 90%, 34%, and 26% of the variation in WAZ, respectively.

Finally, in terms of WHZ (Table 12), use of a safely managed sanitation facility was associated with an increase in WHZ, at 12 months, by 1.94 (M4, *p*=0.02) while no associations were detected at 1 or 6 months. No associations with WHZ were detected for either the hygiene or water indices at any of the timepoints. At 1 month, 6 months, and 12 months, WASH factors (M1) explained 2%, 4%, and 18% of the variance in WHZ respectively, while infant, maternal, and household characteristics (M4) at the same time points explained 55%, 18%, and 24% of the variation in WHZ, respectively.

Table 9: Maternal and infant characteristics at 1, 6, and 12 months postpartum in the Soweto Baby WASH study

		1 month postpartum		6 months postpartum		12 months postpartum	
		Total		Total		Total	
		n		n		n	
Infant Characteristics							
Sex	Male	76	50.3%	42	52.5%	42	57.5%
	Female	75	49.7%	38	47.5%	31	42.5%
Age (mean, SD)	Months	59	0.961 (0.098)	79	5.752 (0.506)	73	11.931 (0.654)
Weight (mean, SD)	Kilograms	59	4.088 (0.56)	79	7.498 (1.002)	73	9.250 (1.164)
Length (mean, SD)	Centimetres	59	52.5 (1.9)	79	64.7 (2.4)	73	73.4 (2.1)
Stunted	Yes	6	10.2%	8	10.1%	8	11%
	No	53	89.8%	71	89.9%	65	89%
Underweight	Yes	2	3.4%	2	2.5%	2	2.7%
	No	57	96.6%	77	97.5%	71	97.3%
Wasted	Yes	2	3.4%	2	2.5%	2	2.7%
	No	57	96.6%	77	97.5%	71	97.3%
Exclusive Breastfeeding	Yes	3	5.2%	0	-	-	-
	No	55	94.8%	78	100%	-	-
Maternal Characteristics							
Age (mean, SD)	Years	57	27.5 (5.9)	74	27.9 (5.9)	70	28.7 (6.4)
Weight (mean, SD)	Kilograms	57	71.2 (13.4)	74	74.3 (16.4)	70	73.9 (17.7)
BMI (mean, SD)		45	27.5 (4.9)	74	29.9 (6.1)	66	29.9 (6.6)
Education	No formal Education, Primary, & Secondary	68	71.6%	61	77.2%	59	80.2%
	Tertiary	27	28,4%	18	22.8%%	14	19.8%
Employment	Yes	54	66.7%	55	70.5%	25	34.7%
	No	27	33.3%	23	29.5%	47	65.3%
Household Characteristics							
Crowding (mean, SD)		97	4.4 (2.6)	79	5.9 (2.9)	73	5.8 (2.7)
Wealth Index	Poorest	42	47.7%	37	50.7%	35	50.7%
	Richest	46	52.3%	36	49.3%	34	49.3%
WASH Characteristics							
Water Source	Safely Managed	69	74.2%	62	77.5%	51	69.9%
	Not Safely Managed	24	25.8%	18	22.5%	22	30.1%
Water Source on Premises	Yes	77	82.8%	62	77.5%	57	78.1%

	No	16	17.2%	18	22.5%	16	21.9%
Water Treatment	Treatment	18	19.4%	15	18.7%	11	15.1%
	No Treatment	75	80.6%	65	81.3%	62	84.9%
Interruptions to Supply	Rarely	70	75.3%	60	75%	57	78.1%
	> Once a Month	23	24.7%	20	25%	16	21.9%%
Water Storage	Bucket	20	90.9%	25	96.2%	19	95%
	Other (pot, bottle, tub, water can)	2	9.1%	1	3.8%	1	5%
Water Index	(mean, SD)	93	3.13 (0.91)	80	3.11 (0.84)	73	3.11 (0.68)
Type of Sanitation	Safely Managed	87	93.5%	77	96.3%	71	97.3%
	Not Safely Managed	6	6.5%%	3	3.7%	2	2.7%
Household Hygiene Characteristics							
Type of House	Formal	78	82.1%	63	80.7%	59	80.8%
	Informal	17	17.9%%	15	19.3%	3	19.2%
Type of Flooring	Improved	-	-	75	96.2%	65	89%
	Unimproved	-	-	3	3.8%	8	11%
Animals on Property	No	69	74.2%	59	73.4%	56	76.7%
	Yes	24	25.8%	21	26.3%	17	23.3%
Waste Storage	Outside House/Off Property	87	94.6%	72	90%	66	90.4%
	Inside House	5	5,4%	8	10%	7	9.6%
Frequency of Household Cleaning	Everyday	88	94.6%	76	95%	66	90.4%
	< 7 Times a Week	5	5.4%	4	5%	7	9.6%
Personal Hygiene Characteristics							
Hand Washing	Before/After Handling Food	29	31.2%	32	40	41	56.2%
	Before/After Using Sanitation	48	51.6%%	38	47.5	26	35.6%
	Other (when hands dirty, rarely, after touching money, after cleaning)	16	17.2%%	10	12.5%	6	8.2%
Hand Washing Detergent	Water & Soap/Ash	66	71.7%	60	76.9%	52	72.2%
	Only Water	26	28.3%	18	23.1%	20	27.8%
Food Hygiene Characteristics							
Food Hygiene Practices	Recommended Behaviour*	46	86.8%	54	68.4%	33	44.6%
	Not Recommended Behaviour	7	13.2%	25	31.6%	41	55.4%
Main Type of Water Used **	Tap Water Boiled	25	100%	36	100%	33	100%
Hygiene Index	(mean, SD)	46	3.35 (0.87)	65	3.38 (0.89)	65	3.14 (0.97)
Morbidity and Illness							
Diarrhoea	Yes	1	1.8%	6	8.3%	9	12.3%
	No	55	98.2%	66	91.7%	64	87.7%

* This variable was constructed by combining two variables pertaining to the cleaning of the breast and cleaning of utensils prior to feeding. Recommended behaviour was defined as an activity that is protective towards, or acts as a barrier to, the transmission of pathogens.

** All respondents reported using boiled tap water. There were no observations of the other categories (mineral water boiled, tap water not boiled, mineral water not boiled).

Table 10: Hierarchical regression analyses of WASH components on HAZ at 1, 6, and 12 months postpartum, the Soweto Baby WASH study

		HAZ											
		1 Month Postpartum				6 Month Postpartum				12 Months Postpartum			
		M1	M2	M3	M4	M1	M2	M3	M4	M1	M2	M3	M4
		n= 45	n= 44	n= 31	n=30	n=65	n=64	n=60	n=59	n=65	n=64	n=57	n=56
Model 1: WASH Characteristics													
Water Index		-0.10 (-0.44 - 0.24)	-0.02 (-0.31 - 0.27)	0.20 (-0.21 - 0.61)	0.20 (-0.27 - 0.66)	-0.20 (-0.46 - 0.05)	-0.17 (-0.41 - 0.08)	-0.16 (-0.41 - 0.08)	-0.12 (-0.37 - 0.13)	-0.20 (-0.52 - 0.12)	-0.25 (-0.56 - 0.06)	-0.24 (-0.57 - 0.09)	-0.21 (-0.53 - 0.12)
Sanitation	Safely Managed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Not Safely Managed	-0.14 (-1.19 - 0.90)	-0.45 (-1.36 - 0.46)	-2.22* (-3.98 - -0.47)	-2.24* (-4.28 - -0.20)	-0.88 (-1.90 - 0.14)	-1.02* (-1.99 - -0.05)	-0.96* (-1.92 - -0.01)	-0.98* (-1.93 - -0.03)	-0.93 (-2.15 - 0.28)	-0.95 (-2.12 - 0.22)	-0.64 (-1.91 - 0.63)	-1.03 (-2.29 - 0.24)
Hygiene Index		-0.13 (-0.51 - 0.24)	-0.22 (-0.54 - 0.10)	-0.52* (-0.96 - -0.08)	-0.53* (-1.02 - -0.03)	-0.18 (-0.43 - 0.06)	-0.17 (-0.40 - 0.06)	-0.20 (-0.43 - 0.03)	-0.12 (-0.36 - 0.13)	0.00 (-0.22 - 0.23)	0.05 (-0.16 - 0.26)	0.11 (-0.12 - 0.35)	0.12 (-0.11 - 0.35)
R^2		0.02	-	-	-	0.10	-	-	-	0.06	-	-	-
F		0.83	-	-	-	0.08	-	-	-	0.28	-	-	-
Model 2: Addition of Infant Characteristics													
Birthweight		-	1.47** (0.65 - 2.29)	1.09* (0.05 - 2.13)	1.09 (-0.13 - 2.30)	-	0.83** (0.24 - 1.42)	0.81** (0.21 - 1.42)	0.86** (0.25 - 1.47)	-	0.73* (0.09 - 1.37)	0.65 (-0.06 - 1.36)	0.62 (-0.07 - 1.30)
Gestational Age		-	0.09 (-0.12 - 0.30)	0.05 (-0.22 - 0.32)	0.04 (-0.31 - 0.39)	-	-0.04 (-0.22 - 0.14)	-0.03 (-0.22 - 0.16)	0.03 (-0.17 - 0.23)	-	0.02 (-0.16 - 0.19)	0.03 (-0.18 - 0.23)	0.00 (-0.19 - 0.20)
R^2		-	0.34	-	-	-	0.22	-	-	-	0.16	-	-
ΔR^2		-	0.32**	-	-	-	0.11*	-	-	-	0.10*	-	-
F		-	0.005**	-	-	-	0.01**	-	-	-	0.07	-	-
Model 3: Addition Maternal Characteristics													
Age		-	-	0.07 (-0.01 - 0.15)	0.08 (-0.04 - 0.19)	-	-	0.01 (-0.03 - 0.04)	0.01 (-0.03 - 0.05)	-	-	-0.03 (-0.07 - 0.01)	-0.03 (-0.07 - 0.01)
Height		-	-	0.01 (-0.05 - 0.08)	0.01 (-0.06 - 0.09)	-	-	0.04* (0.01 - 0.07)	0.04* (0.01 - 0.07)	-	-	0.03 (-0.00 - 0.07)	0.02 (-0.01 - 0.06)
BMI		-	-	-0.10* (-0.19 - -0.01)	-0.10 (-0.22 - 0.01)	-	-	0.01 (-0.02 - 0.05)	0.02 (-0.02 - 0.06)	-	-	0.01 (-0.02 - 0.05)	0.00 (-0.03 - 0.04)
Education	No formal Education, Primary & Secondary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Tertiary	-	-	-0.17 (-0.94 - 0.59)	-0.17 (-1.02 - 0.68)	-	-	-0.14 (-0.63 - 0.35)	-0.03 (-0.53 - 0.47)	-	-	0.06 (-0.51 - 0.64)	0.04 (-0.52 - 0.60)
Employment	Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	No	-	-	-0.35 (-1.16 - 0.45)	-0.36 (-1.27 - 0.55)	-	-	0.24 (-0.23 - 0.71)	0.38 (-0.12 - 0.89)	-	-	-0.12 (-0.60 - 0.36)	-0.05 (-0.53 - 0.44)
R^2		-	-	0.58	-	-	-	0.36	-	-	-	0.25	-
ΔR^2		-	-	0.23	-	-	-	0.14	-	-	-	0.09	-
F		-	-	0.03*	-	-	-	0.009**	-	-	-	0.17	-
Model 4: Addition of Household Characteristics													
Family Size		-	-	-	0.00 (-0.13 - 0.14)	-	-	-	-0.02 (-0.09 - 0.05)	-	-	-	0.00 (-0.08 - 0.08)
Wealth Index	Poorest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Richest	-	-	-	0.03 (-0.83 - 0.88)	-	-	-	-0.31 (-0.79 - 0.18)	-	-	-	-0.54* (-1.00 - -0.07)
R^2		-	-	-	0.58	-	-	-	0.39	-	-	-	0.34
ΔR^2		-	-	-	0.00	-	-	-	0.03	-	-	-	0.09
F		-	-	-	0.11	-	-	-	0.01**	-	-	-	0.07

95% Confidence Interval in parentheses
Significance levels: * p≤0.05 and ** p≤0.01

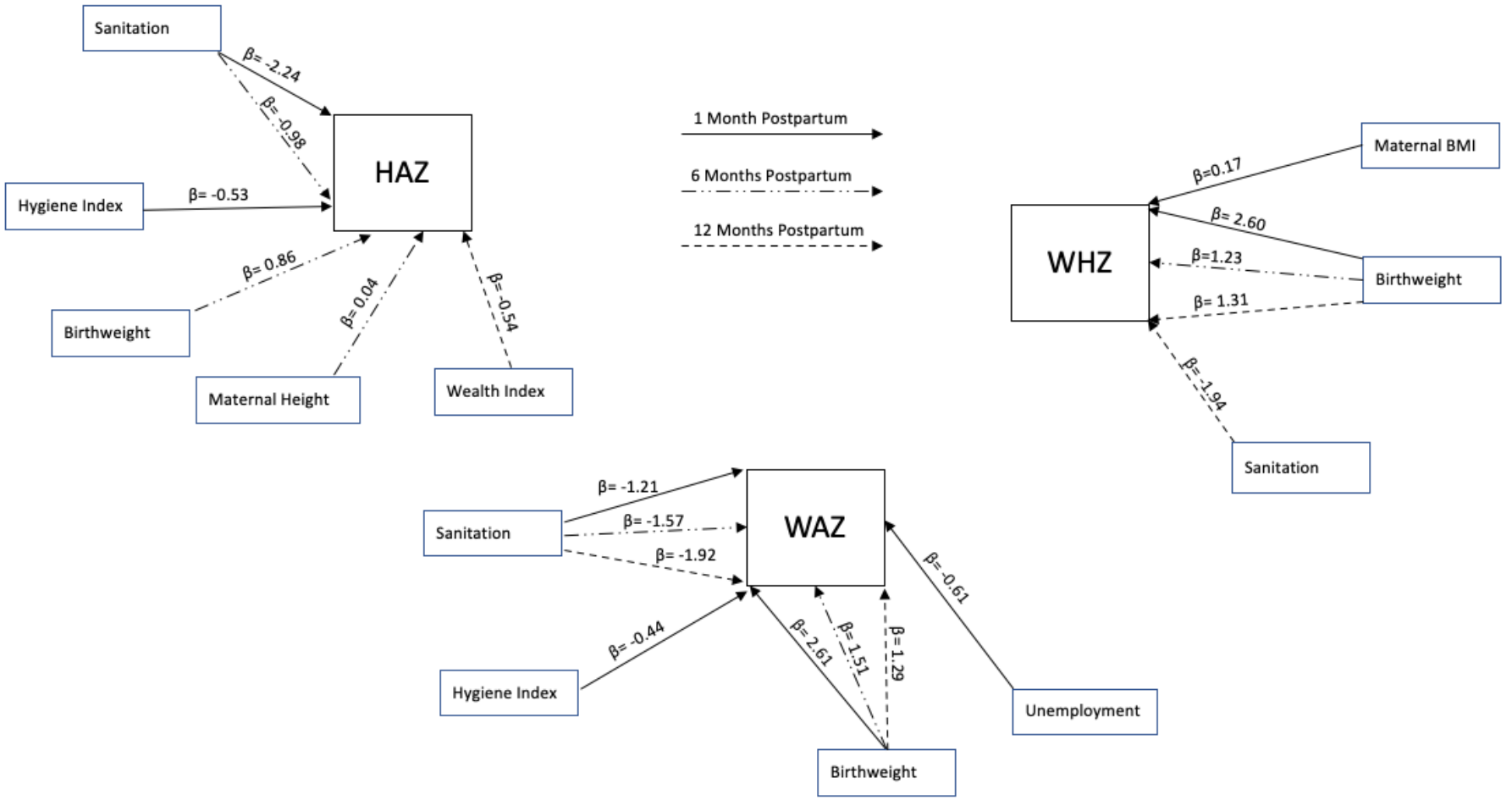
Table 11: Hierarchical regression analyses of WASH components on WAZ at 1, 6, and 12 months postpartum, the Soweto Baby WASH study

		WAZ											
		1 Month Postpartum				6 Month Postpartum				12 Months Postpartum			
		M1	M2	M3	M4	M1	M2	M3	M4	M1	M2	M3	M4
		n= 45	n= 44	n= 31	n=30	n=65	n=64	n=60	n=59	n=65	n=64	n=57	n=56
Model 1: WASH Characteristics													
Water Index		-0.05 (-0.36 - 0.25)	0.02 (-0.15 - 0.20)	0.17 (-0.03 - 0.38)	0.17 (-0.04 - 0.37)	-0.10 (-0.42 - 0.23)	-0.03 (-0.32 - 0.27)	0.01 (-0.31 - 0.33)	0.07 (-0.25 - 0.39)	-0.36 (-0.73 - 0.01)	-0.41* (-0.74 - -0.07)	-0.33 (-0.69 - 0.03)	-0.35 (-0.73 - 0.03)
Sanitation	Safely Managed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Not Safely Managed	0.17 (-0.78 - 1.11)	-0.35 (-0.91 - 0.20)	-1.32** (-2.19 - -0.44)	-1.21* (-2.12 - -0.30)	-1.28 (-2.57 - 0.00)	-1.50* (-2.69 - -0.31)	-1.51* (-2.75 - -0.26)	-1.57* (-2.78 - -0.36)	-2.21** (-3.63 - -0.79)	-2.12** (-3.39 - -0.84)	-1.84* (-3.24 - -0.45)	-1.92* (-3.39 - -0.46)
Hygiene Index		-0.06 (-0.40 - 0.28)	-0.21* (-0.40 - -0.01)	-0.39** (-0.61 - -0.17)	-0.44** (-0.66 - -0.22)	-0.04 (-0.34 - 0.26)	-0.03 (-0.31 - 0.25)	-0.06 (-0.36 - 0.25)	0.04 (-0.28 - 0.35)	-0.07 (-0.33 - 0.19)	0.01 (-0.22 - 0.25)	0.03 (-0.23 - 0.29)	0.00 (-0.26 - 0.27)
R^2		0.01	-	-	-	0.06	-	-	-	0.19	-	-	-
F		0.92	-	-	-	0.26	-	-	-	0.005**	-	-	-
Model 2: Addition of Infant Characteristics													
Birthweight		-	2.18** (1.68 - 2.68)	2.52** (2.00 - 3.04)	2.61** (2.06 - 3.15)	-	1.35** (0.63 - 2.07)	1.52** (0.73 - 2.31)	1.51** (0.72 - 2.29)	-	1.41** (0.71 - 2.11)	1.30** (0.52 - 2.09)	1.29** (0.50 - 2.09)
Gestational Age		-	0.01 (-0.12 - 0.13)	-0.01 (-0.14 - 0.13)	-0.05 (-0.21 - 0.11)	-	-0.06 (-0.28 - 0.16)	-0.10 (-0.34 - 0.14)	-0.07 (-0.33 - 0.19)	-	-0.11 (-0.30 - 0.08)	-0.12 (-0.35 - 0.10)	-0.14 (-0.37 - 0.09)
R^2		-	0.71	-	-	-	0.25	-	-	-	0.37	-	-
ΔR^2		-	0.70**	-	-	-	0.19**	-	-	-	0.18**	-	-
F		-	0.000**	-	-	-	0.004**	-	-	-	0.000**	-	-
Model 3: Addition Maternal Characteristics													
Age		-	-	0.02 (-0.02 - 0.06)	0.02 (-0.03 - 0.07)	-	-	0.00 (-0.05 - 0.05)	0.01 (-0.04 - 0.05)	-	-	0.00 (-0.04 - 0.05)	0.00 (-0.05 - 0.05)
Height		-	-	0.03 (-0.01 - 0.06)	0.02 (-0.01 - 0.06)	-	-	0.02 (-0.02 - 0.06)	0.02 (-0.02 - 0.06)	-	-	0.03 (-0.01 - 0.07)	0.03 (-0.02 - 0.07)
BMI		-	-	0.03 (-0.02 - 0.07)	0.02 (-0.03 - 0.08)	-	-	0.02 (-0.03 - 0.07)	0.03 (-0.02 - 0.07)	-	-	0.00 (-0.04 - 0.04)	0.00 (-0.04 - 0.04)
Education	No formal Education, Primary & Secondary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Tertiary	-	-	0.37 (-0.02 - 0.75)	0.36 (-0.02 - 0.74)	-	-	-0.06 (-0.70 - 0.58)	0.07 (-0.56 - 0.71)	-	-	0.17 (-0.46 - 0.80)	0.15 (-0.50 - 0.80)
Employment	Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	No	-	-	-0.53* (-0.93 - -0.13)	-0.61** (-1.02 - -0.21)	-	-	0.17 (-0.45 - 0.78)	0.39 (-0.25 - 1.03)	-	-	-0.27 (-0.80 - 0.25)	-0.30 (-0.87 - 0.26)
R^2		-	-	0.89	-	-	-	0.33	-	-	-	0.42	-
ΔR^2		-	-	0.18	-	-	-	0.08	-	-	-	0.05	-
F		-	-	0.000**	-	-	-	0.02*	-	-	-	0.002**	-
Model 4: Addition of Household Characteristics													
Family Size		-	-	-	-0.01 (-0.07 - 0.05)	-	-	-	-0.09 (-0.18 - 0.00)	-	-	-	0.06 (-0.04 - 0.15)
Wealth Index	Poorest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Richest	-	-	-	0.36 (-0.03 - 0.74)	-	-	-	-0.37 (-0.99 - 0.24)	-	-	-	-0.12 (-0.65 - 0.42)
R^2		-	-	-	0.91	-	-	-	0.40	-	-	-	0.45
ΔR^2		-	-	-	0.02	-	-	-	0.07	-	-	-	0.03
F		-	-	-	0.000**	-	-	-	0.01**	-	-	-	0.005**
95% Confidence Interval in parentheses Significance levels: * p≤0.05 and ** p≤0.01													

Table 12: Hierarchical regression analyses of WASH components on WHZ at 1, 6, and 12 months postpartum, the Soweto Baby WASH study

		WHZ											
		1 Month Postpartum				6 Month Postpartum				12 Months Postpartum			
		M1	M2	M3	M4	M1	M2	M3	M4	M1	M2	M3	M4
		n= 45	n= 44	n= 31	n=30	n=65	n=64	n=60	n=59	n=65	n=64	n=57	n=56
Model 1: WASH Characteristics													
Water Index		0.06 (-0.33 - 0.45)	0.07 (-0.30 - 0.44)	0.02 (-0.48 - 0.52)	0.01 (-0.54 - 0.56)	0.04 (-0.32 - 0.40)	0.10 (-0.26 - 0.45)	0.15 (-0.25 - 0.55)	0.19 (-0.22 - 0.59)	-0.35 (-0.75 - 0.06)	-0.38 (-0.76 - 0.01)	-0.29 (-0.70 - 0.11)	-0.33 (-0.76 - 0.09)
Sanitation	Safely Managed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Not Safely Managed	0.45 (-0.74 - 1.64)	0.05 (-1.10 - 1.21)	0.79 (-1.34 - 2.92)	0.93 (-1.49 - 3.35)	-0.90 (-2.35 - 0.54)	-1.06 (-2.48 - 0.35)	-1.12 (-2.66 - 0.43)	-1.18 (-2.71 - 0.35)	-2.38** (-3.94 - -0.83)	-2.25** (-3.72 - -0.79)	-2.08* (-3.65 - -0.50)	-1.94* (-3.59 - -0.30)
Hygiene Index		0.09 (-0.34 - 0.52)	-0.01 (-0.42 - 0.40)	0.11 (-0.42 - 0.64)	0.05 (-0.54 - 0.64)	0.11 (-0.23 - 0.45)	0.11 (-0.23 - 0.44)	0.10 (-0.28 - 0.47)	0.15 (-0.24 - 0.55)	-0.08 (-0.36 - 0.20)	-0.01 (-0.28 - 0.26)	-0.02 (-0.31 - 0.27)	-0.06 (-0.36 - 0.24)
R^2		0.02	-	-	-	0.04	-	-	-	0.18	-	-	-
F		0.87	-	-	-	0.48	-	-	-	0.008**	-	-	-
Model 2: Addition of Infant Characteristics													
Birthweight		-	1.41** (0.37 - 2.45)	2.46** (1.20 - 3.73)	2.60** (1.16 - 4.05)	-	1.05* (0.19 - 1.91)	1.29* (0.31 - 2.26)	1.23* (0.24 - 2.21)	-	1.32** (0.52 - 2.13)	1.30** (0.42 - 2.19)	1.31** (0.42 - 2.20)
Gestational Age		-	-0.12 (-0.39 - 0.15)	-0.11 (-0.44 - 0.22)	-0.16 (-0.57 - 0.26)	-	-0.05 (-0.31 - 0.21)	-0.10 (-0.41 - 0.20)	-0.11 (-0.44 - 0.22)	-	-0.16 (-0.38 - 0.06)	-0.18 (-0.43 - 0.08)	-0.18 (-0.44 - 0.08)
R^2		-	0.18	-	-	-	0.13	-	-	-	0.31	-	-
ΔR^2		-	0.16*	-	-	-	0.09	-	-	-	0.13**	-	-
F		-	0.17	-	-	-	0.14	-	-	-	0.0005**	-	-
Model 3: Addition Maternal Characteristics													
Age		-	-	-0.06 (-0.16 - 0.04)	-0.07 (-0.20 - 0.07)	-	-	-0.00 (-0.06 - 0.06)	-0.00 (-0.06 - 0.06)	-	-	0.02 (-0.03 - 0.07)	0.02 (-0.03 - 0.07)
Height		-	-	0.03 (-0.05 - 0.11)	0.02 (-0.07 - 0.12)	-	-	-0.01 (-0.06 - 0.04)	-0.01 (-0.06 - 0.04)	-	-	0.02 (-0.03 - 0.07)	0.02 (-0.03 - 0.07)
BMI		-	-	0.17** (0.06 - 0.28)	0.17* (0.03 - 0.31)	-	-	0.02 (-0.04 - 0.08)	0.02 (-0.04 - 0.08)	-	-	-0.00 (-0.05 - 0.04)	-0.00 (-0.05 - 0.04)
Education	No formal Education, Primary & Secondary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Tertiary	-	-	0.82 (-0.12 - 1.75)	0.81 (-0.19 - 1.82)	-	-	0.04 (-0.75 - 0.83)	0.13 (-0.68 - 0.93)	-	-	0.20 (-0.51 - 0.91)	0.19 (-0.53 - 0.92)
Employment	Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	No	-	-	-0.32 (-1.30 - 0.66)	-0.42 (-1.50 - 0.66)	-	-	0.02 (-0.74 - 0.78)	0.19 (-0.62 - 1.00)	-	-	-0.26 (-0.86 - 0.33)	-0.35 (-0.98 - 0.28)
R^2		-	-	0.57	-	-	-	0.18	-	-	-	0.38	-
ΔR^2		-	-	0.39*	-	-	-	0.05	-	-	-	0.07	-
F		-	-	0.03*	-	-	-	0.41	-	-	-	0.007**	-
Model 4: Addition of Household Characteristics													
Family Size		-	-	-	-0.02 (-0.18 - 0.14)	-	-	-	-0.10 (-0.21 - 0.02)	-	-	-	0.07 (-0.03 - 0.18)
Wealth Index	Poorest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Richest	-	-	-	0.44 (-0.58 - 1.46)	-	-	-	-0.24 (-1.02 - 0.53)	-	-	-	0.18 (-0.42 - 0.78)
R^2		-	-	-	0.57	-	-	-	0.22	-	-	-	0.42
ΔR^2		-	-	-	0.00	-	-	-	0.04	-	-	-	0.04
F		-	-	-	0.12	-	-	-	0.41	-	-	-	0.01*
95% Confidence Interval in parentheses Significance levels: * p≤0.05 and ** p≤0.01													

Figure 13: Significant associations between HAZ, WAZ, WHZ and WASH components, infant, maternal and household factors in model 4



5.4 Discussion

This study aimed to identify specific postnatal environmental factors related to WASH, and subsequent associations with HAZ, WAZ and WHZ scores in infants born healthy in Soweto, Johannesburg. This study identified statistically significant associations with each of the specific WASH components and growth outcomes, dependent on infant age. In summary, household access to sanitation facilities that were not safely managed was associated with a decrease in HAZ scores at 1 and 6 months (but not at 12 months) with WAZ at all timepoints; and finally, with WHZ scores at 12 months (but not at 1 or 6 months). The hygiene index was negatively associated with HAZ and WAZ scores at 1 month, but not at 6 or 12 months, or with WHZ scores at any of the timepoints. The evidence therefore suggests that the biggest impact relating to water is likely to affect WAZ around 12 months while the greatest impact of hygiene is around 1 month postpartum and is likely to affect HAZ and WAZ. Access to safely managed sanitation facilities is critical throughout the first year, and impacts HAZ, WAZ, and WHZ.

Improvements in water, as it relates to WASH, is expected to have positive effects on diarrhoea which has been implicated as a major cause of undernutrition (144). However, interventions delivered in the WASH Benefits trials, in Bangladesh and Kenya, and the SHINE trials in Zimbabwe found no effect of basic water interventions on linear growth, or on childhood diarrhoea (89,93,353). We found that in the current South African context there was no association between water conditions and growth outcomes in the various models. Noteworthy, however, is the negative association between the water index and WAZ at 12 months after adjusting for infant characteristics at birth, but not after adjusting for maternal or household characteristics, which may mean that the effect might be relative to nutritional status at birth.

This finding was also consistent with a recent study in South Africa (Eastern Cape) which found that an increase in the prevalence of use of an improved water source was associated with an increase in systemic inflammation among children under five years of age (354). Therefore, in the South African context, factors such as informal pipe connections, water quality, water removal devices, and household water storage practices may be associated with water source quality and to a certain extent affect infant growth.

In addition, early introduction of formula feeding and complementary foods, as is seen in our study population through the extremely low rates of EBF may also result in infants being exposed to pathogens, resulting in impaired intestinal function, or environmental enteric dysfunction (EED) (19,145). EED is thought to explain a significant portion of unresolved and

unexplained undernutrition in the developing world, through nutrient malabsorption and systemic inflammatory responses (19). In Zimbabwe for instance, it was found that non-exclusive breastfeeding may lead to faeco-oral transmission of bacteria among infants living in conditions of poor sanitation and hygiene; and that frequent exposure to potentially pathogenic organisms likely drives enteric inflammation (149).

In this study, we showed that household access to sanitation facilities that were not safely managed, were associated with a decrease in HAZ, WAZ, and WHZ. Similar associations between sanitation and undernutrition have been seen in a number of African settings. In Ethiopia for instance, unavailability of a latrine was associated with significant higher odds of stunting in children between 6 and 24 months (147) and poor household sanitary facilities were associated with undernutrition between 6 and 12 months (160) and in Zimbabwe, poor sanitation was associated with stunting and chronic inflammation between birth and 24 months (149).

A peculiarity in this respect is the fact that the infants are not, at this early stage, using sanitation facilities, which may allude to the importance of sanitation and hygiene at household, as well as community levels, transmitted through the mother or caregiver. Results from a study conducted in an urban setting in Maputo, Mozambique, reported associations with risk factors for faecal contamination of water, soil, and surfaces in households sharing poor-quality sanitation, and described a setting impacted by pervasive domestic faecal contamination, including from human sources, that was largely disconnected from the observed variation in socioeconomic and sanitary conditions (355).

It is noticeable that the effect size of sanitation decreased for HAZ between 1 month up until 12 months while the opposite effect was seen for WAZ and WHZ where the effect of sanitation increased from 1 month up to 12 months, with the greatest size effect seen in WHZ.

This may be indicative of WASH factors, such as sanitation, having a greater impact on weight, rather than height, during this initial period of early childhood growth, with height generally being a marker of chronic undernutrition persisting over a number of years. This is consistent with literature that suggests that adiposity is more sensitive to fluctuations driven by external environmental factors, including food security, and recurrent infections, and therefore more likely to affect children over the course of months rather than years (54,310,356,357). As such, the extent of WASH factors on height may only become evident later on during childhood. In turn, WASH interventions targeted on linear growth, with limited effects on the burden of diarrhoea, may reduce the likelihood of catch-up growth in the first two years (356,357). This

is seen in the contribution of WASH-factors to the variation in z-scores being minimal for all indices at 1 month, increasing somewhat to around 6-10% for HAZ between 6 and 12 months; however significant increases in explanatory contribution up to about 20% are seen when it comes to WHZ and WAZ at 12 months.

Negative associations for the hygiene index for HAZ and WAZ were detected at 1 month postpartum, contrary to the initial hypothesis, that an increase in the hygiene index would yield positive associations with the nutritional status outcomes. Given the significance of sanitation, during a period when infants are not themselves using sanitation facilities, a point of reflection that emerges is again whether undernutrition is driven through maternal and caregiver practices and health, with maternal and caregiver health being driven through WASH.

This study has a number of strengths. Firstly, using data driven processes, this study produced water and hygiene indices which are the first step in exploring various methodologies for creating WASH indicators that relate to child growth in the South African setting. This contributes to broader issues surrounding the fact that current indices have not been sufficient to detect associations with growth (89,93,353).

Secondly, this study, as far as the authors can tell, is the first, in the South African setting, specifically aimed at providing detailed information about WASH exposures, and precisely when in early childhood they affect growth. Limited data exists looking specifically at the effect of timing in the role that WASH plays in determining nutritional status in the African context (317). Furthermore only a handful of studies in this context have considered the link between WASH factors and nutritional status during early childhood (317). As such, this study begins to build the body of evidence in the South African setting, and allows for the translation of existing evidence relating to WASH and nutritional status into the sub-Saharan context, particularly in South Africa (317,345).

This study, like all studies investigating complex interactions, has a number of limitations. Despite attempting to validate respondents' answers with multiple questions, social desirability bias, whereby the participant is inclined to deny undesirable traits, may influence some of the variables that pertain to behavioural characteristics, including the hygiene index. During the course of the study unanticipated cultural dynamics were discovered, in terms of in- and out-migration of the child, where the child moved relatively frequently between caregivers and extended family in the urban Soweto setting and rural context (17,358,359). As a result it was not always the mother responding to the various surveys but sometimes

another caregiver, usually another family member, which is likely indicative of mothers seeking social and possibly economic support, in terms of childcare (17,358,359). This is consistent with our finding that maternal unemployment was associated with a decrease in WAZ at 1 month. Furthermore, infants were likely exposed to a number of different care practices and infrastructure installations during the first year. WASH interventions in this setting would therefore benefit from including considerations surrounding social support while reinforcing best WASH practices at the individual, household, and community levels.

Due to relatively small sample size, not all of the variables that the authors would have hoped to include in the indices and covariates were possible due to the low number of observations for variables, such as water storage, exclusive breastfeeding, and incidence of diarrhoea. Notwithstanding the small sample size, the fact that associations were detected allows the authors to postulate that these associations would be potentiated given a larger sample. Despite sample sizes being limited in-lieu of collecting more routine and detailed data, home-visits allowed the study team to limit biases in participant answers by probing and having first-hand experience of the household.

In light of the evidence raised in this study, interventions focussed on sanitation during the first thousand days are likely to be most effective in improving infant length (and thus reducing stunting) between birth and 6 months, weight (and thus reducing wasting) around 12 months, and overall underweight between birth and one year postpartum. Given that these infants were *a priori* born healthy, yet started short, might allude to the need for WASH interventions to begin earlier than previously anticipated, perhaps as early as pre-conception, targeting women, as well as the household and surrounding community (30,32). These findings are particularly relevant for policy makers in so far as the importance of service provision of safely managed sanitation facilities is concerned. Thus, suggesting that Radical changes and improvements to both household and community level sanitation may be required before meaningful impacts on targets related to undernutrition are achieved. In addition, within the South African setting, it is critical that these interventions are accompanied by universal promotion of EBF, and additional provision of social support to the most vulnerable.

5.5 Conclusion

The evidence suggests that the biggest impact relating to water is likely to affect WAZ around 12 months while the greatest impact of hygiene is around 1 month postpartum and is likely to affect HAZ and WAZ. Access to safely managed sanitation facilities is critical throughout the

first year, and impacts HAZ, WAZ, and WHZ. Interventions intending to address issues surrounding WASH in early childhood and nutritional status would therefore benefit from taking this timing into account and recognising specific timepoints in early childhood, and associated WASH factors for intervention. WASH is an important factor influencing infant growth, and improvements to both household and community level sanitation may be required in order to achieve targets in terms of minimising undernutrition.

Table 13: Participant characteristics, supplementary

		1 month postpartum (n=151)					6 months postpartum (n=80)					12 months postpartum (n=73)				
		Male (n=76)		Female (n=75)		p-value	Male (n=42)		Female (n=38)		p-value	Male (n=42)		Female (n=31)		p-value
		n		n			n		n			n		n		
WASH Characteristics																
Water Quantity (Enough)	Yes	43	97.7%	48	98%	0.94	41	97.6%	38	100%	0.34	42	100%	31	100%	-
	No	1	2.3%	1	2%		1	2.4%	0	-		0	-	0	-	
Interruptions to supply	Daily	2	4.5%	0	-	0.58	1	2.4%	0	-	0.60	2	4.8%	1	3.2%	0.67
	Once a week	2	4.5%	2	4.1%		1	2.4%	0	-		0	-	0	-	
	Once a month	9	20.5%	8	16.3%		9	21.4%	9	23.7%		8	19%	5	16.1%	
	Rarely/never	30	68.2%	37	61.2%		31	73.8%	29	76.3%		32	76.2%	24	77.4%	
	Don't know	1	2.3%	2	4.1%		0	-	0	-		0	-	1	3.2%	
Household Hygiene Characteristics																
Method of Waste Disposal	Municipal removal	44	100%	47	96%	0.40	41	97.6%	36	97.7%	0.57	41	97.6%	30	96.8%	0.35
	Bush/open plot	0	-	1	2%		1	2.4%	1	2.6%		0	-	0	-	
	Burning	0	-	0	-		0	-	0	-		1	2.4%	0	-	
	Dumping	0	-	1	2%		0	-	1	2.6%		0	-	1	3.2%	
Frequency of Waste Disposal	Weekly	44	100%	48	98%	0.34	42	100%	38	100%	-	42	100%	31	100%	-
	Fortnightly	0	-	1	2%		0	-	0	-		0	-	0	-	
Disposal of Infant Faeces	Put/rinsed into toilet	3	6.8%	1	2%	0.34	0	-	0	-	0.34	0	-	0	-	0.39
	Buried	0	-	1	2%		0	-	0	-		0	-	0	-	
	Throw into garbage	41	93.2%	47	96%		41	97.6%	38	100%		41	97.6%	31	100%	
	Other*	0	-	0	-		1	2.4%	0	-		1	2.4%	0	-	
	Water & ash	1	2.2%	0	-		0	-	0	-		0	-	0	-	
Animals	Domestic	14	93.3%	7	87.5%	0.13	14	100%	7	100%	0.13	11	100%	6	100%	0.49
	Livestock	1	6.7%%	1	12.5%		0	-	0	-		0	-	0	-	
Presence of Pests	Damp/mould	0	-	0	-	0.62	0	-	1	2.6%	0.76	0	-	0	-	0.95
	Cockroaches	4	9.1%	9	18.4%		8	19%	7	18.4%		7	16.3%	5	16.1%	
	Flies	16	36.4%	13	26.5%		10	23.8%	8	21.1%		14	33.3%	13	41.9%	
	Rodents	11	25%	12	24.5%		12	28.6%	8	21.1%		9	21.4%	5	16.1%	
	Bed lice	0	-	1	2%		1	2.4%	0	-		0	-	0	-	
	Other (ants, mosquitoes)	2	4.5%	1	2%		1	2.4%	2	5.2%		5	11.9%	3	9.8%	
	None	11	25%	13	26.5%		10	23.8%	12	31.6%		7	28.3%	5	16.1%	
Personal Hygiene Characteristics																
Infant Bathing Frequency	Everyday	42	95.5%	49	100%	0.13	40	95.2%	35	92.1%	0.57	41	97.6%	31	100%	0.39
	3-4 times/week	0	-	0	-		0	-	1	2.6%		0	-	0	-	
	Other*	2	4.5%	0	-		2	4.8%	2	5.3%		1	2.4%	0	-	
Hand Washing	Before and after eating	0	-	0	-		0	-	0	-		1	2.4%	0	-	
	When hands are dirty	20	45.5%	22	44.9%		0	-	0	-		1	2.4%	0	-	
	After using the toilet	0	-	2	4.1%		1	2.4%	4	10.5%		2	4.8%	1	3.2%	
	Before preparing food	4	9.1%	2	4.1%		6	14.3%	1	2.6%		13	30.9%	9	29%	

	Before & after feeding	5	11.3%	6	12.2%	0.73	13	30.9%	12	31.6%	0.21	11	26.2%	7	22.6%	0.89
	After changing diaper	8	18.2%	10	20.4%		18	42.9%	15	39.5%		12	28.5%	11	34.5%	
	Other (after touching money, after cleaning)	7	15.9%	7	14.3%		4	9.5%	6	15.8%		2	4.8%	3	9.7%	
* The option 'other' was included on the surveys with the intent to specify if the response was different from the categories provided. For these instances, while the participants responded 'other', there was no specification as to what this entailed.																

Part 3: Integrated Discussion and Conclusion

We shall not defeat any of the infectious diseases that plague the developing world until we have also won the battle for safe drinking water, sanitation, and basic healthcare - Kofi Annan

6 Chapter 6: Integrated Discussion and Conclusion

This chapter consolidates the findings from the previous chapters with regards to the key objectives of this thesis. It goes on to identify and discuss the main themes that emerged from the analyses, followed by reflections on the empirical contributions of the thesis and revisiting of the conceptual framework used. Discussion about the implications of the findings are considered, and recommendations for future research made, prior to reflecting on the strengths and limitations of this thesis.

6.1 Key Findings

This thesis aimed to examine two separate yet interrelated foci. Firstly, the governance landscape of WASH and secondly, links between WASH and nutrition. The governance landscape was contextualised through examining the sub-Saharan African and South African settings, while a longitudinal prospective cohort study from birth to one year of age was designed to address knowledge gaps surrounding links between WASH and nutritional status in urban South Africa. Three objectives emerged in service of this, the consolidated findings of which are presented in Table 14.

6.2 Emerging Themes

This section reflects upon themes that have emerged from the research conducted and is divided into two main areas, the first deals with methodological themes that emerged through the series of studies conducted, and the second contemplates empirical themes that arose.

6.2.1 Methodological Themes

When designing the studies that comprised this PhD a number of methods were considered in order to best describe the link between WASH, nutritional status in children, and governance. The decision to use a mixed-methods approach with a number of methodologies was not an easy one.

Table 14: Consolidated study findings

Chapter	Objective, Research Question, and Hypothesis	Key Findings
3	**Objective 1:** To conduct a systematic review examining the literature linking governance, WASH, and associations with undernutrition in children under five years of age. **Research Question 1:** How is WASH managed in relation to child nutrition in SSA settings? **Hypothesis:** Literature pertaining to WASH and nutritional status in children in SSA do not explicitly integrate governance into their study design, and findings.	• Neither observational studies nor intervention studies included components exploring the role of governance of WASH in their design, nor did they describe if and how actors in the field of WASH were incorporated into the research process. Integrating the role of governance through the involvement of civil society, communities, IGOs, government, as well as development agencies would be a recommendation for future studies on the topic. • There were no scientific studies or evidence specifically focused on linking the governance of WASH and nutritional status in children. All included studies noted some policy implications based on their results; however, the precise manner in which this could or should be operationalised was rarely elaborated on. • The scientific and research community could further contribute by considering the manner in which study findings could or should be operationalised and gain real-world application. Incorporating WASH components in line with consistent and established terminology and definitions will make study design, as well as the results that emanate from such studies more pertinent and reproducible.

Chapter	Objective, Research Question, and Hypothesis	Key Findings
4	**Objective 2:** To map the institutional and regulatory frameworks for WASH in South Africa and the Gauteng Province. To conduct in-depth interviews and expert panel discussions with key informants at the confluence between WASH and nutrition to examine the governance of WASH in relation to nutritional status in South Africa. **Research Question 2:** What is the governance landscape of WASH in South Africa in relation to nutritional status of children under five years of age? **Hypothesis:** Actors and policies surrounding WASH in South Africa do not explicitly attempt to improve child growth and nutritional outcomes.	• The public sector would benefit from better integrating the concept of WASH into their policy, planning, and implementation frameworks. • Of the policies reviewed, three mentioned WASH, nutrition, and children, however none explicitly linked WASH to nutritional status in children. • The WASH sector should take stronger action to integrate nutrition; too few WASH plans consider the impact of water, sanitation, and hygiene on nutritional status of children. The various public sector departments involved in WASH service provision, and other WASH stakeholders, including CBOs, NGOs, and IGOs, should be involved in the decision-making, monitoring and evaluation, and implementation of policies and strategies within the nutrition sector.
5	**Objective 3:** To assess the association between WASH components and childhood nutritional status at contrasted time points, namely, delivery and 1, 6, and 12 months postpartum, and associated factors, while characterising children's nutritional status. **Research Question 3:** What are the associations between WASH components and nutritional status of children between birth and one year of age? **Hypothesis:** Water, Sanitation and Hygiene are risk factors for growth delay between birth and one year of age.	• Overall, the results confirm that water, sanitation and hygiene are risk factors for undernutrition between birth and one year of age. • The evidence suggests that the biggest impact relating to water is likely to affect WAZ around 12 months while the greatest impact of hygiene is around 1 month postpartum and is likely to affect HAZ and WAZ. Sanitation is critical throughout the first year and impacts HAZ, WAZ, and WHZ. • Improvements to both household and community level sanitation may be required in order to achieve local and international targets in terms of undernutrition.

The precise configuration of methods described in this series of studies from the systematic review, to the institutional mapping, policy review, key informant interviews, and consensus development conference, to the prospective cohort study and statistical analyses was carefully and thoughtfully planned, but most definitely not without their own unique challenges.

6.2.1.1 Mixed-Methods

Traditionally, efforts to combine qualitative and quantitative methods have often lacked a solid methodological basis in research practice and have frequently combined quantitative and qualitative methods without providing a clear rationale for the choice of methods. Furthermore, it is often difficult to integrate qualitative and quantitative findings in a coherent way. Using a mixed-methods approach is however especially useful in understanding contradictions between quantitative results and qualitative findings. This in turn, tends to provide a more complete understanding of the problem, and yields a deeper, more comprehensive body of evidence.

Use of both qualitative and quantitative methods for the studies in this thesis were therefore combined to overcome the specific limitations inherent in both methodological approaches, in order to compensate for their mutual and overlapping weaknesses. In light of this, the methods selected in this series of studies were largely informed by the substantive research questions that emerged, and not exclusively by methodological and epistemological considerations alone. In doing so, the selection of methods sought to triangulate various forms of evidence, providing greater explanatory capacity in this series of studies.

Table 15 displays a summary of the various strengths and challenges associated with the mixed-methods approaches employed in this thesis.

Table 15: Summary of strengths and challenges associated with methods utilised in this series of studies

	Systematic Review	Qualitative Components	Quantitative Components
Strengths	• The systematic review provided a succinct summary of the quantitative and qualitative literature on the link between governance, WASH, and nutritional status in children at the regional scale of sub-Saharan Africa. • Given the regional inclusion of sub-Saharan Africa into larger meta-analyses and review articles, the systematic review also provided insight into the global discourses that surround the intersection between governance, WASH, and nutritional status in children. • The systematic review therefore provided a strong understanding of the complex set of stakeholders and the governance landscape of WASH in the sub-Saharan African context, as it relates to nutritional status in children. • The information collated from the systematic review allowed for the tailoring of both the qualitative and quantitative components that were to follow to the local and international	• The qualitative components allowed for the exploration of the social, cultural, and political contexts within which the intersection between governance, WASH and nutritional status in children occurs, at national, South Africa, and sub-national, Gauteng and the City of Johannesburg, scales. • The institutional mapping and policy review allowed for the identification of stakeholders at various scales and provided insight as to the precise governance remits, mandates, and jurisdictions relating to WASH and nutritional status in children. • The key-informants that participated in both the in-depth interviews and consensus development conference, provided invaluable insights into the context that South Africa faces, not only at sub-national (provincial) and national levels, but also at regional (AU), and international levels.	• The prospective cohort study allowed for the testing of the hypotheses and findings from other international contexts in the South African setting. • The study provided the platform for tailoring specific research tools that speak to the local setting, while answering questions and knowledge gaps that exist within the South African, sub-Saharan African, and global settings. • The water and hygiene indices constructed in chapter 5 (paper 3) function as a foundation for further exploration of the data in terms of what are the most significant WASH variables in this setting and which methodologies, for constructing indices, are likely to provide the most insight into the various pathways that link WASH and nutritional status in children, and at what timepoints these specific pathways are implicated.

	contexts surrounding WASH, nutritional status, and governance.	• These components allowed for a stronger understanding of the complex set of stakeholders and the governance landscape of WASH in the South African context as it relates to local and international challenges.	• The study provided a range of actionable recommendations and highlights the need for a consolidated approach that advocates for capitalising on a multiplier effect through augmenting existing gains through services and programmes related to child health and service provision.
Challenges	• Systematic reviews are incredibly time consuming and often in the time taken to conduct the searches, screen, review and extract the relevant data, new studies and data become available. • The inclusion of policy documents in the sub-Saharan African setting was problematised due to the fact that many governments have not made their policy documents available electronically. • With the transdisciplinary nature of the topic a limited, yet diverse, set of databases were utilised to source publications, thus potentially limiting the number of publications that were sourced.	• Challenges in conducting qualitative research include issues of case selection and transferability, whereby small sample sizes, and context specificity lead to a lack of representativeness and generalisability. • Both the in-depth interviews and consensus development conference were dependent on the willingness and ability of respondents to dedicate time which was often difficult to schedule. • Engaging with experts emerged as one of the major challenges. While experts at the confluence of WASH and nutritional status, were aware and cognisant of the importance of the links between WASH and nutritional status, few were prepared to engage in a formal setting.	• In developing and formulating hypotheses, and in constructing research instruments including standardised questionnaires, there are often a number of implicit assumptions that are not always explicitly addressed. • Quantitative research also often requires the formulation of precise hypotheses and operational definitions of variables as a necessary precondition for empirical research that are based on implicit assumptions. • Among the methodological obstacles that emerged, was the fact that there are a number of indices available to measure WASH, incorporating various combinations of the precise WASH factors. Thus, determining the precise configuration that addresses the South African context was not clear.

6.2.2 Empirical Themes

From the literature reviewed in the studies conducted, broader questions emerged including reflections on how population density and proximity to sanitation facilities are potential drivers for improving environmental conditions around children, while delivering community wide interventions are important for showing an effect of sanitation on linear growth (88). Other pathways, such as nutrition, animal waste, and complementary foods as pathways for enteric infection were also highlighted, along with reflection on the importance of exploring specific timing of WASH factors and interventions tailored to best respond to childhood developmental stages and growth. Another major gap, and one that was especially pertinent to this thesis was the lack of literature including components of governance into the scientific studies looking at the links between WASH and nutritional status, linking governance to health-related outcomes.

Figure 14 displays the triangulation of the various methods and evidence that was collected and summarises the emerging empirical themes.

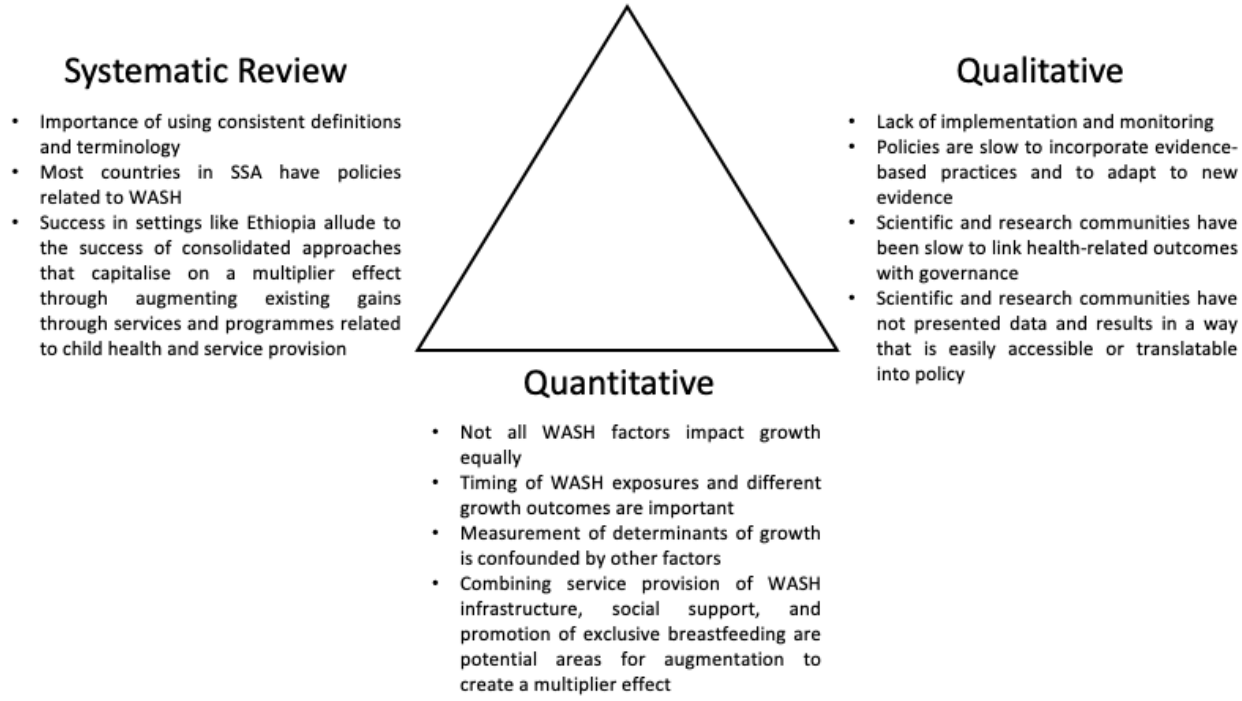


Figure 14: Triangulation and summary of empirical themes

Recognition of the need for research that more directly impacts public health has broadened the academic mindset somewhat and given rise to the discipline of implementation science; the scientific study of methods to promote the systematic and systemic uptake of research findings and evidence-based practices into routine practice to improve the quality and effectiveness of health services (360). The translation of research evidence into policies and in turn into practical operational programmes has been problematised by a lack of a cohesive reciprocal relationship between the funders of research, the scientific and research communities, the stakeholders and governance structures, and the emerging policy frameworks and implementation strategies. Research suggests that evidence-based practices take, on average, 17 years to become incorporated into routine healthcare practice (360). Thus, integration of how exactly evidence is to be translated into routine general practice in healthcare is imperative.

The learning from this series of studies is that, while little research has been done linking the role of governance of WASH in relation to health-related outcomes, in terms of childhood nutritional status, in practicality this is an extremely complex problem to address. While the various stakeholders understand the causal pathways, failure to address the complexity of the problem, by poorly implemented programmes and a lack of monitoring with accurate and crosscutting indicators, including health-related metrics, has resulted in a failure to multiply and augment gains made through existing services and programmes.

Failure of stakeholders to think in terms of the augmentation of existing services and programmes, such as social support grants, promotion of exclusive breastfeeding, and the provision of basic services has meant that these various complementary components exist in isolation. Failure to tackle the complexity of the problem and addressing these challenges in a piecemeal manner, fails to multiply and capitalise on the existing gains from these various complementary strategies. In addition, the timing of when these components come together to address challenges in the growth and development of children is integral to creating a multiplier effect.

6.3 Conceptual Frameworks

This section reflects upon the conceptual frameworks presented at the beginning of this study. The UNICEF Conceptual Framework (Figure 15), and the 5-F diagram (Figure 16) formed the foundation upon which this series of studies were built.

With respect to the UNICEF Conceptual Framework (Figure 15) (24), a scalar model is

presented that incorporates immediate causes such as disease and dietary intake, underlying causes including household environment, food security, and health services, as well as basic causes, referring to socio-economic and political context.

In applying this framework, we see that our results contribute to confirming the continued use of the conceptual framework as a guide for exploring the determinants of undernutrition. The various studies conducted have limited capacity to confirm the immediate causes of undernutrition, as delineated in the framework. However, significant associations emerged with the underlying causes in terms of household environment, seen especially in the role that sanitation plays, and inadequate feeding practices, seen in the role that early cessation of exclusive breastfeeding may play in exposing infants to poor quality water and poor food hygiene practices. Basic and systemic causes also emerged as important factors in so far as associations with undernutrition surfaced related to maternal unemployment. The role that the cultural context and social capital plays in the continuum of undernutrition also surfaced in the need for mothers to seek social support, through the in- and out-migration of the child. In addition to this, care for children is usually provided in families and households where women are the main caregivers, and decisions about childcare are rarely made by an individual but often involve negotiations within families, as well as between families (358). Finally, the political and policy contexts are particularly relevant in terms of the policy environment within which the provision of water, sanitation, and hygiene infrastructure is delivered. This too implies a number of stakeholders that are required to work together in a cohesive and collaborative manner, across ideological and political boundaries, in order to deliver basic services.

In terms of the 5-F Diagram (Figure 16), specific pathways are proposed, which describe the faecal-oral transmission route, which was adapted here to pertain to both individual and community levels (29). Of particular relevance for this study, rather than examining each of the suggested pathways, was to look at the specific barriers to transmission, namely the latrine, safe water, and hygiene barriers.

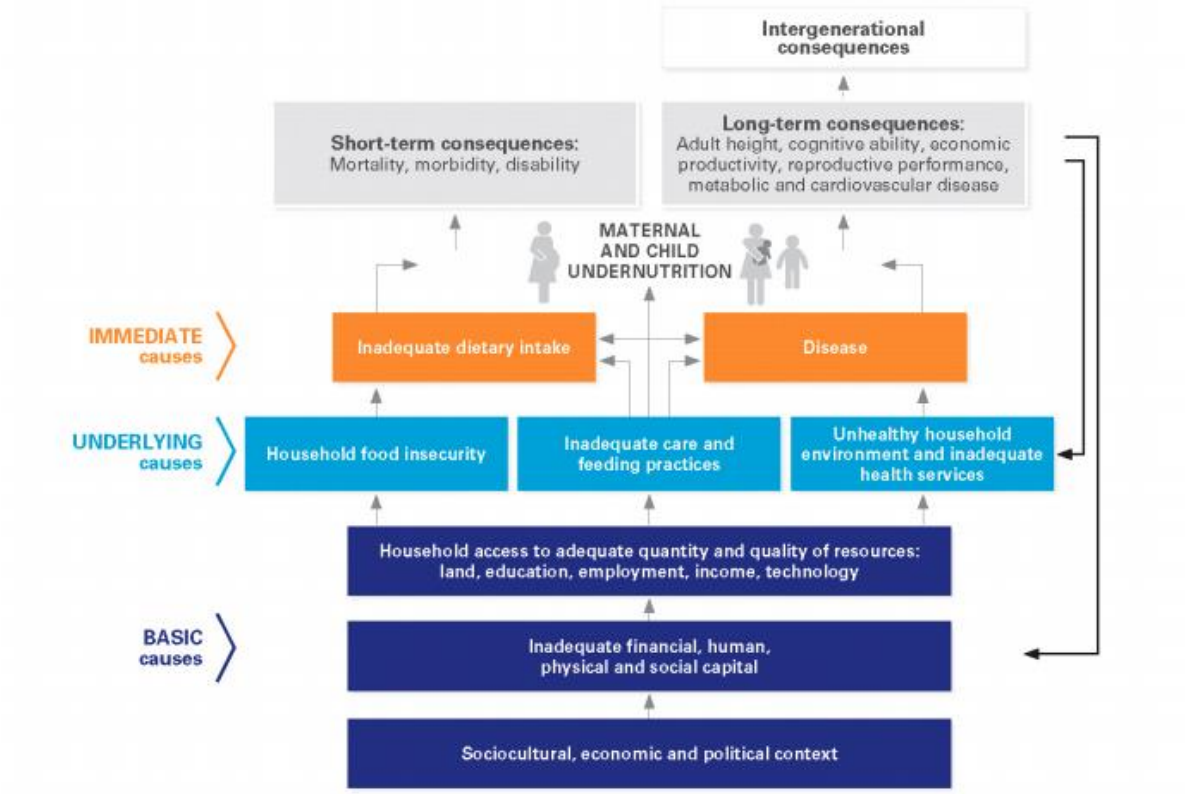


Figure 15: UNICEF Conceptual Framework for Maternal and Child Undernutrition (24)

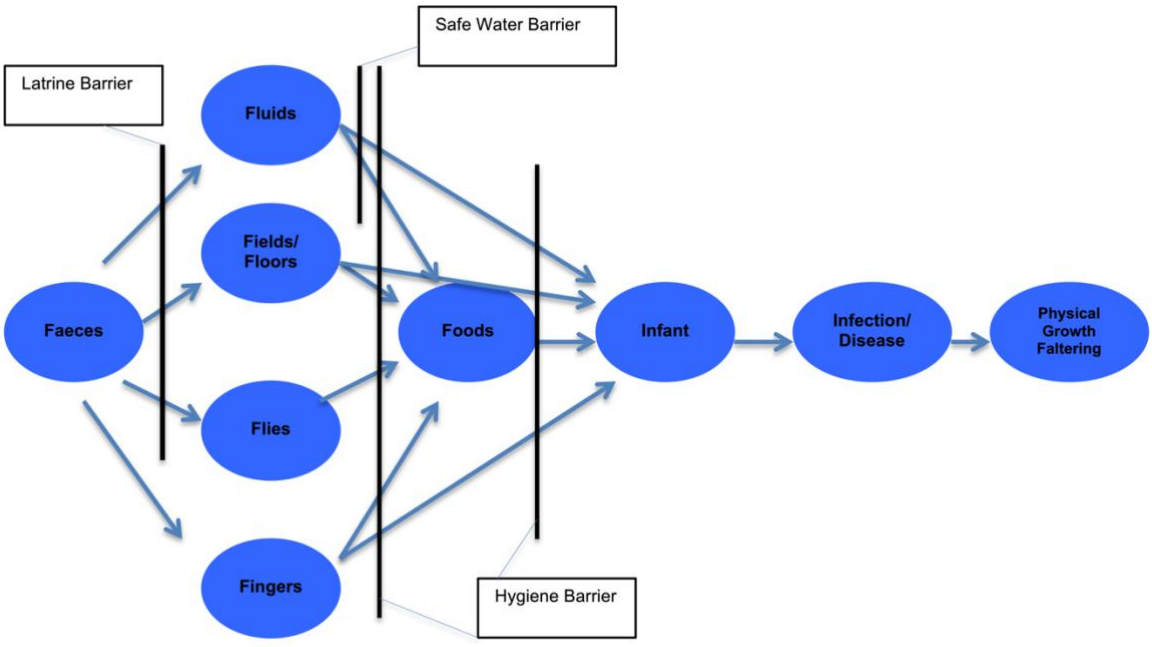


Figure 16: 5-F Diagram (29)

While the results suggest that further investigation into the specific water and hygiene barriers is required, the data implies that access to safely managed sanitation is critical at both household and community levels. While the literature on the sanitation and clean water barriers is well established, the importance of hygiene related practices has largely been neglected in the literature (317). Hygiene is by far the most difficult of the WASH components to study and relies heavily on individual behaviours and reporting thereof, with objective measurement and monitoring especially difficult. Hygiene does however remain one of the most important components, as seen in the diagram, due to its ability to act as a last line of defence, and by implication mitigate some of the shortcomings of the latrine and safe water barriers, either through handwashing, food hygiene, or water treatment, and the like.

What has become evident is that while these frameworks are largely confirmed through this particular series of studies, both the UNICEF Conceptual Framework, and the 5-F diagram have been a guiding structure for a number of decades, remaining largely unchanged, and would therefore benefit from a modest update. For instance, specific focus on the precise age ranges and timing of specific pathways during critical periods of early childhood development and incorporating transmission pathways from the mother or caregivers. Reference and integration of intersectoral action and associated actors would be advantageous as well as incorporation of existing WHO frameworks, such as those relating to the social determinants of health. Identifying how adverse exposures affect the body and lead to illness and disease is an area rich for exploration, central to which is examining how social mechanisms shape the pathways that lead to health disparities. Focus on education, household environment, risk behaviour and access to healthcare and their relation to health outcomes are alone not enough. Research to elucidate how social determinants such as governance and policy, as well as social and economic policies set in motion a series of steps that result in health disparities is imperative. In addition, including explicit reference to the various SDGs and associated indicators that are implicated in the framework, as well as the various scales at which these are evident would go a long way in making the framework accessible and operational for the current global health environment.

6.4 Implications

- The results of this series of studies are the first of its kind in the South African context that seeks to triangulate different forms of evidence to highlight the link between the governance of WASH with nutritional status of children.

- This thesis has laid the foundation for understanding the literature related to WASH and nutritional status in children in sub-Saharan Africa and has elucidated the various stakeholders and the policy landscape in the South African context, while addressing specific gaps in the early stages of childhood development and growth through a longitudinal prospective cohort study.
- This series of studies has highlighted a number of gaps in terms of our understanding of the links between the governance of WASH and nutritional status in children and made a series of recommendations to augment existing programmes and services in order to create a multiplier effect to close those gaps.
- This thesis has provided a methodological foundation for integrating quantitative results and qualitative findings and triangulating linkages between governance and health-related outcomes.
- Recommendations made, have advocated for an integrated approach to conducting research that identifies, maps, and incorporates various stakeholders, including government, from an early stage in order to ensure that the research being designed and conducted is relevant to the specific context within which it is being conducted while augmenting existing programmes and services.
- Expansion of the mapping exercise to better understand the multi-sectorial connections between various stakeholders and policies will help identify specific areas where consolidation and augmentation of existing programmes and services can multiply the gains already being made. Such an exercise would benefit greatly from considering literature associated with the intersectoral activity and further analysis of the dynamics of interaction that are the basis for social determinants of health, recognizing the dual political and technical nature of the changes required for better health equity governance.
- This thesis has also highlighted the importance of policy analysis and how research results need to speak to specific linkages between policy documents, as well as the stakeholders responsible for design and implementation thereof, in order to capitalise on augmenting and multiplying the effects of existing programmes and services. The integration of policy analysis into existing clinical and health related research emphasises not only the link between the policy document and the stakeholders and actors, but also underscores the influence of context which guides how actors engage with the process.
- Translation of study results into actionable recommendations that are accessible and scalable by the various stakeholders is imperative in ensuring that evidence-based

practices reach the relevant stakeholders and are integrated into the policy and implementation frameworks.

- Agility and capacity to integrate new findings into policies and implementation frameworks at various scales are vital to providing rapid and sustained responses to health issues related to growth and development in early childhood.
- Use of consistent terminology has been highlighted as a pervasive theme in the studies conducted. This allows for the transferability of findings and recommendations within sub-national, national, regional, and global scales, as well as allowing for the articulation of context specific requirements as it compares and relates to other settings at various scales. Use of consistent terminology also allows for more accurate measurement and comparability thereof between various scales and across globally acceptable indicators, such as the SDGs.
- The need for consistent and reproducible indices is also integral. While some foundational work has been done in creating water and hygiene indices, evaluation of specific indices that align with the SDG indicators and speak to the South African context is part of the ongoing body of work that emanates from this thesis.
- At local level, the promotion of exclusive breastfeeding and appropriate hygiene behaviours, at household and community levels, in conjunction with the provision of social and economic support have emerged as themes where augmentation and integration into existing policy and implementation frameworks, can capitalise on current services and create a multiplier effect in addressing deficits in nutritional status in children.
- Finally, provision of safely managed sanitation at both household and community levels is integral to address not only growth faltering but also the redress of impoverished communities that have been deprived of access to basic services.

6.5 Future Research

Given the literature that is currently emerging in the field linking WASH and nutritional status, one manifest shortcoming is our lack of understanding of which WASH interventions, at which period during early childhood, are likely to provide the greatest return on investments, both biologically and financially. Results on the ground from randomised controlled trials have thus far been disappointing, showing no effect on linear growth and only mixed results in the reduction of diarrhoea. Explicit and documented engagement with various stakeholders are necessary in the early stages of the research process in order to ensure scalability and

sustainability. Reporting the stakeholders and the means of engagement and collaboration is integral; from stakeholder and institutional mapping, to analysis of existing policies, to project design and implementation, through to incorporating study findings back into policy and programmatic frameworks.

The emergence of a substantial body of literature examining the subclinical manifestation of environmental enteric dysfunction and the chronic inflammatory response that it elicits suggests that this may be integral to understanding the links between a number of WASH pathways and growth faltering. Integration of objective measures, including for instance, the level of residual chlorine in water stored in the household and presence of coliforms. Fomite swabs of integral surfaces such as food preparation areas and those surrounding sanitation facilities. Measurement of inflammatory markers in children, and detailed assessment of breastfeeding practices through deuterium dilution, are areas that would benefit from additional research.

Specific pathways that also require further consideration are the various practices and behaviours associated with water handling such as access through informal connections, as well as storage within the household context. How community level access to sanitation influences community and household level hygiene and exposure to pathogens, and the association with individual outcomes.

In addition, focus on different aspects of the various sub-components within the specific WASH factors, such as infrastructure including for instance, water source and access, or behaviour, such as water treatment and storage, as opposed to objective measurement of water quality and quantity, further complicate the scalability and reproducibility even within different sub-national contexts, let alone other regional or international settings.

In terms of specific WASH factors, the importance of sanitation, having a greater impact on weight, rather than height, during this initial period of early childhood growth, with height generally being a marker of chronic undernutrition persisting over a number of years. This is consistent with literature that suggests that adiposity is more sensitive to fluctuations driven by external environmental factors, including food security, and recurrent infections, and therefore more likely to affect children over the course of months rather than years (54,310,356,357). Reflection on the applicability of particular growth-related outcomes at specific times is therefore imperative. For instance, at what particular stages in early childhood are HAZ, WAZ and WHZ appropriate markers for determining nutritional status.

The importance of nutritional status, and in particular stunting seems to revolve around using

linear growth as a proxy for other developmental constraints. Recent studies suggest that undernutrition in infancy and early childhood may trigger adaptive physiological mechanisms that prioritise brain development, at the cost of linear growth. In other words, proposing that there is an energy trade-off between linear growth and brain growth, which may manifest through a negative correlation between the energy costs of the two processes (344).

In comparison to other primates, the human brain is metabolically very costly to grow and maintain. With finite energy resources, especially in early infancy, this implies that there is a shifting allocation of energy between growth and maintenance.

In the post-natal period, the energy costs of growth accounts for 35% of individual total energy requirements at 1 month postpartum, declining to 3% at 1 year of age. In contrast, the brain accounts for 87% of resting metabolic rate energy utilisation at birth decreasing to about 44% during childhood (344). In essence, being short is not a biological deficit per se, what it does however allude to is a host of other biological mechanisms/developments that have been forfeited or compromised along the way.

In light of this, the fact that specific WASH factors are integral at different stages during early childhood development, one future research endeavour will be the further exploration of the data that has been collected in the Soweto Baby WASH study. Specific emphasis is being placed on examining the impact of WASH factors on early childhood developmental outcomes, exploring the roles that the aforementioned trade-offs might precipitate in terms of cognitive- and neurodevelopment and growth in early childhood. Assessing the efficacy of various outcome measures, HAZ, WAZ, and WHZ, in comparison to early childhood developmental outcomes including cognitive- and neurodevelopment.

In addition, existing data collected will be used to explore the construction of indices that are specific enough to address the local context, yet aligned with international norms including the JMP and SDGs, in order to provide a methodological foundation for the measurement of progress being made in the achievement of local and international nutrition related targets.

An ongoing research initiative that has emanated from the body of work presented in this thesis, surrounds issues pertaining to household access to shared WASH facilities in informal settlements. Novel approaches are being developed in the use of digital interfaces as a means for delivering interventions, as well as a tool for data collection. A digital platform is currently in development, through funding from the Bill and Melinda Gates Foundation and the African Academy of Sciences, in order to address issues surrounding gender-based violence, and morbidity and illness, associated with accessing communal sanitation facilities in informal

settlements in Soweto. Utilising a user-centred design approach, the platform intends to promote the sharing of information among female headed households with children under five years of age. This information sharing is intended to cover the cleanliness, functionality, and safety of communal water and sanitation facilities. The objective is to improve biological and physical safety at communal WASH facilities, while leveraging crowdsourced data from the platform to aid service providers to prioritise unsanitary facilities for maintenance, thereby increasing accountability for latrine and water source maintenance.

A controlled before-and-after intervention study design is being employed to assess the immediate impacts our platform will have on the safety of women, latrine maintenance, and household morbidity. Participants in the study include one woman per household, with children under five years of age, in both the enumerated areas, for intervention (n=100) and control (n=100). The intervention arm includes training on how to access and use the platform and messages regarding general good WASH practices. The control arm includes messages on general information related to critical administrative procedures for citizens, at the same frequency as the intervention arm.

Surveys are being conducted to collect data on; socio-economic and demographic characteristics; access to WASH facilities and associated behaviours; perceived safety; anthropometry; social support, stress and depression; and morbidity levels. In addition, we are collecting environmental samples, including a water sample (1 Litre) from one of the water sources, and a swab of the floor of one of the toilet facilities (100cm^2), identified by the participants as facilities of primary use.

Integral to this is of course the early integration and continued involvement of a number of stakeholders, including community policing forums, ward councillors, and the various WASH service providers, that will help ensure the sustainability and scalability of the intervention being delivered.

6.6 Limitations

This section attempts to address the major limitations of this thesis as a whole. The literature examined throughout this series of studies has identified the period between conception to two years as an integral period. The first two objectives examined aspects of the continuum between governance, WASH, and nutritional status from birth to five years of age, however the prospective cohort study was only able to collect detailed data from birth to one year of age. Critical changes occur as children become more mobile and independent and begin to

engage and explore their environment and are therefore exposed to various pathogens. Changes that have not been completely covered through the various studies conducted.

The study was further limited due to the nature of the interview guide and policy review document. This, in conjunction with the low number of respondents in the in-depth interviews, is definitely a limitation that is being addressed in the ongoing work being conducted. A richer set of qualitative data surrounding WASH and service providers is currently being collected in other projects for which the candidate is a co-investigator, in an attempt to better elucidate the governance terrain of WASH in South Africa.

This thesis had, from the outset, ambitious objectives to reconcile not only various methodologies ranging from qualitative to quantitative, but also transcended a number of disciplines, from paediatrics and child health, to epidemiology, while also incorporating aspects of political science, sociology, and anthropology. Thus, a number of the phenomena examined, as well as the concepts associated therewith have been informed by simplified models that attempt to reduce the complexity of the problem under review in lieu of incorporating complementary perspectives.

6.7 Conclusion

In conclusion, childhood nutritional status and early life exposures remain pertinent fields of study if we are to continue our efforts to protect our future generations.

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8 Appendices

Appendix A: In-Depth Interview Info and Consent

MRC/WITS DEVELOPMENTAL PATHWAYS FOR HEALTH RESEARCH UNIT

Department of Paediatrics, School of Clinical Medicine
University of the Witwatersrand
Johannesburg

Corner of College and Clinic Roads
Chris Hani Baragwanath Academic Hospital

Telephone: +27-11-933-2120
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SOWETO BABY WASH STUDY: IN-DEPTH INTERVIEWS

INFORMATION SHEET

Hello, my name is Doug Momberg. I am a student at the School of Clinical Medicine at the University of Witwatersrand. Together with colleagues from the Department of Paediatrics, we are conducting a study to explore the intersection of water, sanitation and hygiene (WASH), nutrition, and infant growth over the first year of babies' lives. Before you decide whether to participate, we would like you to understand why the research is being done and what it involves.

What is involved in the study?

The study will be conducted either at your offices, or our research facilities at Chris Hani Baragwanath Academic Hospital (MRC/Wits Developmental Pathways for Health Research Unit), depending on your preference. We will only need to meet with you one time. If you agree to take part in the study, we will ask you a series of questions related to yourself and your work in the WASH/Nutrition sector. The content of these questions are described in the next section.

Study Procedures

Interviewer-completed questionnaire and in-depth interview

During the visit, we will fill in a questionnaire with your help about your knowledge of the governance of the WASH sector. You will also be asked to participate in an in-depth-interview after the questionnaire. During this interview we will explore a little bit more about the policy and governance landscape of the WASH in South Africa and how it relates to nutrition.

If you come to Chris Hani Baragwanath Academic Hospital, we can guarantee that the interview will take place in a private room with an interviewer and research assistant. The interview will be in English,

but a research assistant will be available to assist with any language questions. With your permission, this will be audio-recorded to ensure that we do not missing anything that you say. The interview is expected to take approximately one hour.

Possible benefits:

You will not benefit directly from participation in this study. However, the information you provide will assist us in mapping the WASH landscape in South Africa and identifying strategies that link WASH and nutrition in children.

Costs to you:

Participating in the research will involve no cost to you.

Voluntary participation in research:

You have the right to agree or refuse to participate in this research. If you decide to participate and later change your mind, you are free to stop at any time. Your refusal to participate will not result in any penalty or loss of benefits to which you are otherwise entitled.

Records of your participation in this research:

You have the right to privacy. The principal investigator will keep information about your participation in locked files. The questionnaire and interview will be labelled with a code to ensure your privacy. If you participate in an interview, the recordings will also be kept securely and any information that may identify you from the interview will be anonymised before we analyse it.

Ethical approval: This study protocol has been submitted to the University of the Witwatersrand's, Human Research Ethics Committee (HREC), and that committee has granted written approval. Ethics Clearance number: M170872

Publication of the results of the research: The results of this research may appear in scientific publications without identifying you in any way.

Your questions:

The investigator listed on the first page of this form is available to answer your questions about this research. You may contact the investigator at any time on the following number (011) 933-2120. If you require any further information or have any questions/complaints about the study, please contact the Human Research Ethics Committee of the University of the Witwatersrand on (011) 717-1234 or rhulani.mkansi@wits.ac.za

YOU WILL HAVE A COPY OF THIS INFORMATION SHEET TO KEEP

If you are happy to take part in the study, please read and sign the attached consent form and contact us to confirm your participation.

Your signature on the consent form certifies the following:

· You have read the information provided in this consent form

· You have received answers to all of your questions.

· You have freely decided to participate in this research.

· You understand that you are not giving up any of your legal rights.

MRC/WITS DEVELOPMENTAL PATHWAYS FOR HEALTH RESEARCH UNIT

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SOWETO BABY WASH STUDY: CONSENT SHEET (IDI)

I agree to being a participant in the study. The goals and methods of the study are clear to me.

I understand that the study will involve a questionnaire and possibly an interview. All the details and purposes of this study have been explained to me. I understand that I have the right to refuse to participate in the study.

I agree to participation in the study on the condition that:

1. I can withdraw voluntarily from the study at any time and that no adverse consequences will follow on withdrawal from the study.
2. I have the right not to answer any or all questions posed in the questionnaire and interview.
3. The University of the Witwatersrand's Human Research Ethics committee has approved the study protocol and procedures.
4. All results will be treated with the strictest confidentiality.
5. Only group results, and not my individual results, will be published in scientific journals and in the media.
6. The study scientific team are committed to treating participants with respect and privacy through interviews conducted in private and follow-up counselling available on request.
7. I will receive a referral note to psychological services if I experience any psychological distress during the study.

IDI Participant

_____

Printed Name Signature / Mark or Thumbprint Date and Time

RESEARCH ASSISTANT

_____

Printed Name Signature Date and Time

Appendix B: In-Depth Interview Guide

Interview Guide
1. Awareness on WASH and Nutritional Status/Health in the department
• Is the department aware of the challenges consequences of WASH (and Nutritional Status/Health) on development and service delivery? • Has the department assessed the impact of WASH (and Nutritional Status/Health) on the department's functioning?
2. Strategy to address WASH (and Nutritional Status/Health)

• Does the department have a strategy for WASH (and Nutritional Status/Health)?
 	
• What are the main components of the strategy?
 	
• Does the strategy link WASH and Health Outcomes/Nutritional Status?
 	
• Who is responsible to oversee implementation of the department's strategy?
 	
• Does the department have an implementation plan to execute the WASH (and Nutritional Status/Health) strategy?
 	
• What are the main components of the WASH (and Nutritional Status/Health) implementation plan?
 	
• Are roles and responsibilities clearly defined?
  • What activities and programmes?
  • Are there special key populations that the plan is targeting?
  • Is there a budget for WASH (and Nutritional Status/Health) activities?
  • What are the targets and indicators?
  • What mechanism for monitoring and evaluation?
  • What reporting mechanism, how to who, when?

3. Multi-level cooperation WASH (and Nutritional Status/Health) within the department

• Is there alignment on the response within the department (from national, province and local levels)?
• Please explain the collaboration process, how its established and coordinated?
• Who facilitates the collaboration?
• What evidence on cross sector programmes on WASH (and Nutritional Status/Health)?
• Are there any specific key populations that the strategy targets, if yes, please give examples stating which programmes, and who are the target groups?
• Is the alignment also executed in WASH (and Nutritional Status/Health) related programmes?
• How is the alignment coordinated, by whom, and what are the roles of different levels (national, provincial and local)?
• How is the alignment coordinated, by whom, and what are the roles of different levels (national, provincial and local) on the urban area's WASH (and Nutritional Status/Health) response?
  • What are the roles and responsibilities of different actors, and who defines them?
  • What has been the impact of the programmes?
  • Does the department collaborate with other government sectors on HIV and AIDS programmes?

4. Horizontal collaborations on WASH (and Nutritional Status/Health) between government departments
• Does the department collaborate with other government sectors on WASH (and Nutritional Status/Health) programmes? • Evidence of collaboration across government departments? • Who facilitates the collaboration? • What is the nature of the collaboration? • Are there any specific key populations that the programme targets, if yes, please give examples stating which programmes, and who are the target groups? • Are roles and responsibilities clearly defined? If yes, give evidence (examples)? • Who defines roles and responsibilities of different government departments? • What drives collaboration with other departments? • Indicate the level of coordination and integration (information, budget, and in other areas)?
5. Challenges of vertical and horizontal collaborations
• What are some of the challenges experienced working with other levels within the department? • What are some of the challenges experienced working with other government departments? • What are the benefits and challenges of collaborations within government departments? • How are challenges addressed? • What are the benefits and challenges of collaborations between government and non-government actors?

• How are the challenges addressed? • What recommendations could be suggested for both vertical and horizontal collaborations on the WASH (and Nutrition) response?
Themes
Mapping
What are the perceived links between WASH, Nutrition, and Governance
What are the challenges/barriers/gaps to implementation
Solutions/recommendations



SQ

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Screening Questionnaire (SQ)

Screening ID:	**SSBW**				

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y	

For Office Use:						
Eligible:	**Yes**		**No**		**Comment:**	
Enrolled:	**Yes**		**No**			
SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

1. Do you verbally consent to us asking you some questions for possible enrolment in a research study?

(0) No		**If No, thank her for her time and move on to the next person.**
(1) Yes		**If Yes, continue to next question.**

2. Are you older than 18 years of age?

(0) No		**If No, thank her for her time and move on to the next person.**
(1) Yes		**If Yes, continue to next question.**

3. What is your HIV status? (extract from Maternal Case Records)

(0) HIV+		**If +, thank her for her time and move on to the next person.**
(1) HIV-		**If -, continue to next question.**

4. Was this a singleton pregnancy?

(0) No		**If No, thank her for her time and move on to the next person.**
(1) Yes		**If Yes, continue to next question.**

5. What was your baby's gestational age?__ __ weeks (extract from Maternal Case Records)

(0) If <37 weeks (below)		**Thank her for her time and move on to the next person.**
(1) If ≥37 weeks (above or equal)		**Continue to next question.**
(2) If ≥42 weeks (above or equal)		**Thank her for her time and move on to the next person.**

6. What was your baby's birthweight? _ _ _ _ g (extract from Maternal Case Records)

(0) If <2500g (below)		**Thank her for her time and move on.**
(1) If ≥2500g (above or equal)		**continue to next question.**
(2) If ≥4000g (above or equal)		**Thank her for her time and move on.**

7. Has your baby been hospitalised or diagnosed for any disorder at birth? (extract from Maternal Case Records) (Yes=1, No=0)

0. Hospitalised	YES	NO	**10. Gastro-intestinal**		
1. Head	YES	NO	**11. Bladder/Kidneys**	YES	NO
2. Brain	YES	NO	**12. Limbs**	YES	NO
3. Face	YES	NO	**13. Lungs**	YES	NO
4. Ear	YES	NO	**14. Genitalia**	YES	NO
5. Nose	YES	NO	**15. Skin**	YES	NO
6. Throat	YES	NO	**16. Down's Syndrome**	YES	NO
7. Neck	YES	NO	**17. Foetal Distress**	YES	NO
8. Spine	YES	NO	**18. Jaundice**	YES	NO
9. Heart	YES	NO	**19. Other**	YES	NO
If Other, Specify:					

If Yes to ANY, thank her for her time and move on.
If No to ALL, continue to next question.

8. Formal / Informal Dwelling:

8.1 Do you live in Soweto?

(0) No		**If No, thank her for her time and move on to the next person.**
(1) Yes		**If Yes, continue to next question.**

8.2 In which neighbourhood in Soweto do you live?

_____

8.3 Are you planning on leaving Soweto in the next 12 months?

(0) No		**If NO, continue to next question.**
(1) Yes		**If YES, thank her for her time and move on to the next person.**

8.4 Which of these best describes your living conditions: (use flipchart to help identify type of housing)

Criteria for informal versus formal dwellings	**YES**	**NO**
(0) Informal: **Make-shift dwelling not erected according to architectural plans with land tenure that is illegal, not officially sanctioned or documented**		
(1) Formal: **Dwelling erected according to architectural plans with land tenure that is legal, officially sanctioned or documented.**		

If the participant has gone through all the questions so far, it means that she and her baby are eligible for the study. You can now proceed with the Information and Consent.

9. Did the participant consent to be part of the study?

(0) No		**If No, thank her for her time and move on to the next person.**
(1) Yes		**If Yes, continue to next section.**

10. Complete the contact sheet

Complete		**When complete, continue to next section.**

11. Book her for her first home visit in 1 Week.

Booking Date:	

When booked, thank her for her time and move on to the next person.

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THE SOWETO BABY WASH STUDY:

INFORMATION SHEET AND CONSENT

Hello, my name is Dr Rihlat Said Mohamed, and I am a Researcher for the Department of Paediatrics at the University of the Witwatersrand. Together with other colleagues from the University, we will be conducting a research study to investigate the well-being of mothers and growth and development of babies over the first year of the babies' lives. Before you decide to participate, we would like you to understand why the research is being done, and what it would involve for you and your baby.

What is involved in the study?

The study will be conducted at your home and at our offices at Chris Hani Baragwanath Academic Hospital (MRC/Wits Developmental Pathways for Health Research Unit). For this study there are certain investigations that we will be performing, but your baby will still need to go for his/her regular clinic and doctor check-ups.

We would like to collect data from you and your baby at weekly intervals over the next 6 months and every two weeks for the following 6 months (from 6 to 12 months) and then at 18 and 24 months. We would also like to give you a call between each visit to schedule our next appointment.

If you agree to take part in the study, we will collect the following research data:
Your baby's weight, length, mid-upper arm circumference, temperature and head circumference
Your height and weight
Body composition measures on you and your baby (DXA, Hydrometry or Deuterium Oxide Dilution and skinfold measurements) Body composition is the quantity of fat, muscle, bones that form part of your body

Ask you a series of questions related to yourself and your baby

Procedures involving the Mother:

Measurements

Your height will be measured once.

Your weight will be measured every month until 12 months, at 18 month and 24 months.

Skinfold measurements on your biceps, triceps and subscapular will be done at 1, 3, 6, 9, 12, 18, 24 Months.

Your quantity of fat, muscle, bones will be measured by DXA at 6, 12 and 24 months

Interviewer-completed questionnaires

At each visit at home and at our offices, we will fill in some questionnaires with your help about your education, household circumstances and employment, dietary habits and events that have recently happened in your life. We will also ask you some questions about your feeding practices for your baby, as well as some questions about your interaction with and feelings around your baby. We will ask you some questions about your baby's health and if he/she has been sick. If you are uncomfortable answering any of the questions you need not answer them. Each questionnaire will take approximately 15-20 minutes to complete and each visit at your household will take 30 to 45 minutes.

Procedures involving the Infant:

Measurements

At every visit we would like to measure your baby's weight, length, mid-upper arm circumference, temperature and head circumference

Skinfold measurements on your baby's biceps, triceps and subscapular will be done monthly.

Dual-energy X-ray Absorptiometry (DXA)

DXA is a full body scan which determines your muscle, fat and bone mass. Your baby will lie on a bed and then a machine will move over him/her (it does not touch the baby) and sends an image to the computer of the baby's bone, fat and muscle composition. The levels of radiation in DXA are extremely low. DXA scans will be performed at your baby's 12 and 24 months visit.

Body composition assessment using Deuterium Dilution Technique

This technique will be performed when your baby is 6, 12 & 24 months of age. You will need to have NOT fed the baby for 30 minutes beforehand. The technique is safe. It involves giving your baby 1ml (at 6 and 12 months) and 2ml (at 24 months) of a water-like solution. This solution is called Deuterium and it tastes like water. Before the solution is given the nurse or research assistant will swab your baby's mouth with a cotton swab to collect about 1ml of saliva. After that the Deuterium will be given

to your baby through a 3ml syringe in his/her mouth. The solution tastes like water and cannot harm your baby. Once your baby has drunk the solution, we will wait 2.5 hours and then swab his/her mouth again to collect some saliva. After an additional 30 minutes we will swab his/her mouth again. This solution that we give your baby will help us determine his/her body composition e.g. how much fat the baby has. Once the 3 hours is over you can then feed your baby and take him/her home.

DXA and Deuterium measurement will be done at our offices at Chris Hani Baragwanath Academic Hospital (MRC/Wits Developmental Pathways for Health Research Unit).

Possible risks:

What to do if you or your child has problems: If it is discovered that you or your child have a health problem you will be notified and the right health care practitioner to help you with the problem and treatment will be recommended.

There are chances that some of the questions we ask might trigger some emotional setbacks. If this occurs one of our staff, trained in counselling, will be available to talk with you and refer you to the Psychology Unit at Chris Hani Baragwanath Academic Hospital where you will be given an appointment with a psychologist.

Heavy water, formally called deuterium oxide or 2H2O or D2O, is a form of water that contains a larger than normal amount of the hydrogen isotope deuterium, (also known as heavy hydrogen, which can be symbolized as 2H or D) rather than the common hydrogen-1 isotope (called protium, symbolized as 1H) that makes up most of the hydrogen in normal water. Some or most of the hydrogen atoms in heavy water contain a neutron, making each hydrogen atom about twice as heavy as a normal hydrogen atom (though the weight of the water molecules is not as substantially affected, since about 89% of the molecular weight resides in the unaffected oxygen atom). The increased weight of the hydrogen in the water thus makes it slightly denser. Heavy water is not radioactive at all. In its pure form, it has a density about 11% greater than water, but otherwise, is physically and chemically similar. The human body naturally contains deuterium equivalent to about five grams of heavy water, which is harmless, thus the technique to be used in this study is noted as “enrichment” (final deuterium levels –baseline deuterium levels of infants)

Possible benefits:

If we find any problems during the visits, we will refer you to the appropriate medical professionals further management and referral.

Costs to you:

Participating in the research will involve no cost you. When visiting our offices, you will be given refreshments once your measurements and assessments have been completed. You will also be given R100 for transport costs.

Voluntary participation in research:

You have the right to agree or refuse to participate in this research. If you decide to participate and later change your mind, you are free to stop at any time, or to opt out of any part of the study. Your refusal to participate will not result in any penalty or loss of benefits to which you are otherwise entitled.

Records of your participation in this research:

You have the right to privacy. The principal investigator will keep information about your participation in locked files. Your samples will be labelled with a code to ensure your privacy.

Ethical approval: This study protocol has been submitted to the University of the Witwatersrand's, Human Research Ethics Committee (HREC), and that committee has granted written approval. Ethics Clearance number: M170753

Publication of the results of the research: The results of this research may appear in scientific publications without identifying you in any way.

Your questions:

The investigator listed on the first page of this form is available to answer your questions about this research. You may contact the investigator at any time on the following number (011) 933-2120. If you require any further information or have any questions/complaints about the study, please contact the Human Research Ethics Committee of the University of the Witwatersrand on (011) 717-1234 or rhulani.mkansi@wits.ac.za

YOU WILL HAVE A COPY OF THIS INFORMATION SHEET TO KEEP

If you are happy to take part in the study, please read and sign the attached consent form and contact us to confirm your participation.

Your signature on the consent form certifies the following:

· You have read the information provided in this consent form

· You have received answers to all of your questions.

· You have freely decided to participate in this research.

· You understand that you are not giving up any of your legal rights.

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THE SOWETO BABY WASH STUDY: CONSENT SHEET

I agree to myself and my child being participants in the study. The goals and methods of the study are clear to me.

I understand that the study will involve interviews, measurements, and body composition assessments. All the details and purposes of this study have been explained to me. I understand that I have the right to refuse to participate in the study.

I agree to participation in the study on the condition that:

1. I can withdraw voluntarily from the study at any time and that no adverse consequences will follow withdrawal from the study.

2. I have the right not to answer any or all questions posed in the interviews and not to participate in any or all of the procedures / assessments.

3. The University of the Witwatersrand's Human Research Ethics committee has approved the study protocol and procedures.

4. All results will be treated with the strictest confidentiality.

5. Only group results, and not my individual results, will be published in scientific journals and in the media.

6. The study scientific team are committed to treating participants with respect and privacy through interviews conducted in private and follow-up counselling available on request.

7. I will receive a referral note to a health service if any result is out of the normal range or a problem is detected during the course of the study.

MOTHER OF CHILD

_____

Printed Name Signature / Mark or Thumbprint Date and Time

RESEARCH ASSISTANT

_____

Printed Name Signature Date and Time

Appendix E: Sample Collection Table

	Measures	Timepoints																																		
		D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	28	30	32	34	36	38	40	42	44	46	48
SQ	Screening	X																																				
Info and Consent Sheet	Consent	X																																				
Contact Sheet	Contact	X																																				
WASH (LF)	WASH (LF)					X										X										X						X					X
SES	SES & Demographics				X										X											X						X					X
MIA	Maternal and Infant Illness & Morbidity		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BWP	Breast & Complementary Infant Feeding Practices		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
IA	Infant Length	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Infant Weight	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Mid-Upper Arm Circumference	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Infant Head Circumference	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Infant Temperature		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Infant Skinfolds					X				X				X				X				X				X		X		X		X		X		X		
	Infant DXA																																					X
MA	Maternal Height																									X												
	Maternal Weight					X				X				X				X				X				X		X		X		X		X		X		X
	Maternal Skinfolds					X								X												X						X						X
	Maternal DXA																									X												X
DSCF	Deuterium Saliva Collection																									X												X
FFQ	Maternal Diet																									X												X



IA

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Infant Anthropometry (IA)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y	

Infant Weight 1: (Every Visit)			•				**Kg**
Infant Weight 2: (Every Visit)			•				**Kg**

Infant Temperature 1: (Every Visit)			•		**° C**
Infant Temperature 2: (Every Visit)			•		**° C**

Infant Length 1: (Every Visit)				•		**Cm**
Infant Length 2: (Every Visit)				•		**Cm**
Infant Length 3: (Every Visit)				•		**Cm**

Mid-Upper Arm Circumference 1: (Every Visit)			•		**Cm**
Mid-Upper Arm Circumference 2: (Every Visit)			•		**Cm**
Mid-Upper Arm Circumference 3: (Every Visit)			•		**Cm**

Head Circumference 1: (Every Visit)			•		**Cm**
Head Circumference 2: (Every Visit)			•		**Cm**
Head Circumference 3: (Every Visit)			•		**Cm**

Infant Road to Health Card: (Every Visit)	**YES**		**NO**	

Infection Diary: (Every Visit)	**YES**		**NO**	

Infant Bicep Skinfolds 1: (Monthly)			•		**mm**
Infant Bicep Skinfolds 2: (Monthly)			•		**mm**
Infant Bicep Skinfolds 3: (Monthly)			•		**mm**

Infant Tricep Skinfolds 1: (Monthly)			•		**mm**
Infant Tricep Skinfolds 2: (Monthly)			•		**mm**
Infant Tricep Skinfolds 3: (Monthly)			•		**mm**

Infant Subscapular Skinfolds 1: (Monthly)			•		**mm**
Infant Subscapular Skinfolds 2: (Monthly)			•		**mm**
Infant Subscapular Skinfolds 3: (Monthly)			•		**mm**

Infant DXA: (12 Months)	**YES**		**NO**	



MA

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Maternal Anthropometry (MA)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y	

Comments:

Maternal Height 1: (Once)				.		**cm**
Maternal Height 2: (Once)				.		**cm**

Maternal Weight 1: (Monthly)				.		**kg**
Maternal Weight 2: (Monthly)				.		**kg**

Maternal Bicep Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**
Maternal Bicep Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**
Maternal Bicep Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**

Maternal Tricep Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**
Maternal Tricep Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**
Maternal Tricep Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**

Maternal Subscapular Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**
Maternal Subscapular Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**
Maternal Subscapular Skinfolds 1: **(1, 3, 6, 9 & 12 Months)**			•		**mm**

Maternal DXA: (6 & 12 Months)	**YES**		**NO**	



WASH (LF)

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
WASH (LF)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y	

Comments:

SECTION A: Water Supply (Quantity and Quality)							
1. What are the most common (within past 2 weeks) sources of water you have access to and what do you use the water for? Multiple responses possible, please report all appropriate answer(s) Coding: 1 = Yes 0 = No							
	Drinking	Domestic	Cooking		Drinking	Domestic	Cooking
Bottled Water				Public Tap			
Piped into dwelling				Tanker/Cart with small tank			
Piped into yard/plot				Unprotected dug well			
Protected dug well				Surface water			
Rainwater				Unprotected spring			
Protected spring				Borehole			
Other Specify:							

2. How long does it take to collect water, get there and come back? **If water is on the premises, skip to Question 7. If water is collected outside the house complete Questions 3, 4, 5, and 6.**			
Water on Premises		Number of Minutes	

3. If water is collected outside the house, who usually goes to collect water for the household?			
(0) Adult Man		(1) Adult Woman	
(2) Male Child (under 15 years)		(3) Female Child (under 15 years)	

4. If water is collected outside the house, what do you use to transport water?							
(0) Bucket		(1) Pot		(2) Bottle		(3) Tub/Basin	
(4) Water Can		(5) Other, Specify					

5. If water is collected outside the house, what do you use to store water?							
(0) Bucket		(1) Pot		(2) Bottle		(3) Tub/Basin	
(4) Water Can		(5) Other, Specify					

6. If water is collected outside the house, how do you take water out of where it stored?							
(0) Cup		(1) Ladle/Jug		(2) Bowl			
(3) Tap		(4) Pour		(5) Other, specify			

7. What type of infrastructure do you have access to? incl. Number of points and location of infrastructure Multiple responses possible, please tick appropriate answer(s) Coding: (0) No and (1) Yes				
	Wash Room	Kitchen	Communal	Other, specify:
Taps				
Sink				
Bath				
Shower				
Tub/Bucket				
Toilet				

8. How often do you have interruptions to your water supply? Please tick only one response			
(0) Daily		(3) Rarely/Never	
(1) Once a Week		(99) Don't know	
(2) Once a Month			

9. Do you have enough water for all your needs? Please tick only one response			
(1) Yes		(0) No	

10. Who is your water service provider? Please tick only one response			
(0) Johannesburg Water		(2) Other, specify:	
(1) Private		(99) Don't know	

11. Do you pay for water? Please tick only one response **If YES, ask Question 12 and 13, If NO skip to Question 14**					
(1) Yes		(0) No		(99) Don't know	

12. If yes, who pays? Please tick only one response			
(0) Participant		(2) Home Owner	
(1) Partner		(3) Other, specify:	

13. How much do you spend on average a month for water Please tick only one response					
(0) R0 - R100		(1) R100 - R200		(2) R200 - R300	
(3) R300 - R400		(4) > R400		(99) Don't know	
14. What methods do you use to treat your water? Multiple responses possible, please tick appropriate answer(s)					
(0) None		(1) Add Bleach/Chlorine		(2) Boiling	
(3) Strain it through a cloth		(4) Use a water filter		(5) Solar Disinfection	
(6) Let it Stand/Settle		(7) Other, specify:			

SECTION B: Sanitation					
15. Type of Toilet facilities available Multiple responses possible, please tick appropriate answer(s) Coding: (0) No and (1) Yes					
	Household	Communal		Household	Communal
Flush/Pour to piped Sewer System			Ventilated Improved pit latrine		
Flush/Pour to Septic Tank			Pit Latrine with Slab		
Flush/Pour to Pit Latrine			Pit Latrine without Slab (Open Pit)		
Flush/Pour to Elsewhere			Composting Toilet		
Bucket			No facilities (bush or Field)		
Portable Toilet			Other Specify:		
If Portable Toilet, how often are the facilities serviced per week?					
16. If applicable, how many households share the communal toilet facilities?					
17. How often do you have interruptions to your sanitation supply? Please tick only one response					
(0) Daily		(1) Never		(2) Once a Week		(3) Once a Month	

SECTION C: Hygiene					
Waste Disposal					
18. How is waste stored prior to disposal? Please tick only one response					
(0) Plastic Bags		(1) 'Black' bins		(2) Bucket	
(3) Other, specify:					
19. Where is waste stored prior to disposal? Please tick only one response					
(0) Inside the house		(1) Outside the house		(2) Off the property	
(3) Other, specify:					
20. How is waste disposed of? Please tick only one response					
(0) Around or outside the house		(1) Bush/Open plot		(2) Waste pit	
(3) Municipal removal		(4) Burning		(5) Dumping	
(6) Other, specify:					
21. How often is waste disposed of? Multiple responses possible, please tick appropriate answer(s)					
(0) Weekly		(1) Fortnightly		(2) Monthly	
22. How are infant faeces disposed of? Please tick only one response					
(0) Put/Rinsed into Toilet/Latrine		(1) Put/Rinsed into Drain/Ditch		(2) Buried	
(3) Throw into Garbage		(4) Left in the Open		(5) Child used Latrine/Toilet	
(6) Other, specify:					
Personal Hygiene: Household					
23. How often do you clean the house? Please tick only one response					
(0) Everyday		(1) 3-4 times per week		(2) 1-2 times per week	
(3) Other, specify:					

24. What do you use to clean your house? (detergent) Multiple responses possible, please tick appropriate answer(s)					
(0) Only Water		(1) Multi-purpose Cleaner (e.g. Handy Andy)		(2) Bleach (e.g. Jik)	
(3) Other, specify:					
25. Do you have problems with any of the following in your house? Multiple responses possible, please tick appropriate answer(s)					
(0) Damp/mould		(1) Cockroaches		(2) Flies	
(3) Rodents		(4) Bed lice		(5) Other, specify:	
26. Do you have any animals on the property? Multiple responses possible, please tick appropriate answer(s) **If NO Skip to Question 27**					
(1) Yes		(0) No			
A: Domestic:					
(0) Cats		(1) Dogs		(2) Other, specify:	
B: Livestock:					
(0) Chickens		(1) Goats		(4) Other, specify:	
(2) Sheep		(3) Cattle			
Personal Hygiene: Handwashing and Ablutions					
27. When do you wash your hands? Multiple responses possible, please tick appropriate answer(s)					
(0) Before and after eating		(1) When hands are dirty		(2) After using toilet	
(3) Before preparing food		(4) Before and after feeding		(5) After changing diaper	
(6) Never/Rarely		(7) Other, specify			
28. Since our last visit, has your baby ingested any stones or soil?					
(1) Yes		(0) No		(99) Don't Know	
29. What do you wash your hands with?					
(0) Only water		(1) Soap and Water		(2) Water and ash	
(3) Other, specify:					

30. How do you wash yourself and your baby? Please tick only one response for you and one response for your baby							
	Mother	Baby			Mother		Baby
Sink				Shower			
Bath				Basin			
Other Specify:							

31. How often do you wash yourself and your baby? Please tick only one response for you and one response for your baby					
	Mother	Baby		Mother	Baby
Everyday			3-4 Times per Week		
1-2 Times per week			Other, specify:		

32. How do you heat the water to wash yourself and your baby? Please tick only one response					
(0) Electric Geyser		(1) Boil on Stove, gas or Fire		(2) Use cold water	
(3) Other, specify:					

33. What do you use to wash yourself and your baby? Please tick only one response for you and one response for your baby					
	Mother	Baby		Mother	Baby
Only water			Water and Soap		
Water and Ash			Other, specify:		

SECTION D: Researcher Observations and General
34. Where does the baby sleep?
35. Where does baby spend the majority of its time?
36. Who looks after the baby most of the time?
37a. Are there animals in the house?
37b. Are there kennels/kraal (separate area) for domestic animals and livestock?

38. General Cleanliness of House	Good (0)		Average (1)		Poor (2)	
Comments:						
39. General Cleanliness of Toilet	Good (0)		Average (1)		Poor (2)	
Comments:						
40. General Cleanliness of Kitchen	Good (0)		Average (1)		Poor (2)	
Comments:						
41. General Cleanliness of Baby Area	Good (0)		Average (1)		Poor (2)	
Comments:						
Adapted from UNICEF/Palestinian Hydrology Group (Gaza) & USAID/Mercy Corps (North Kivu -DRC) & DPHRU SES and IA Questionnaires. Core Questions on Drinking-Water and Sanitation for Household Surveys. WHO and UNICEF. 2006.						

Criteria for Researcher Observations	
No dirt/grease/stains	1 - 2 Criteria met (Poor) 3 - 4 Criteria met (Average) 5 - 6 Criteria met (Good)
Furniture, fixtures and surfaces are without dust or grease	
No foul Smell	
Floors are clean and dry	
Waste is separated and stored separately	
Absence of pests (flies, cockroaches, etc)	



BWP2

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study

BREASTFEEDING AND WEANING PRACTICES QUESTIONNAIRE VISIT 2 TO 12 MONTHS OLD

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**					
Researcher Code:			**Date:**	D	D	M	M	Y	Y

Comments:

_____

_

_____

_____

__

MODULE I. GENERAL

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	**Do you receive support or advice on how to feed (*NAME*)?** *Food includes anything that the infant eat.*	Yes _____ 1 No _____ 0	If YES, Ask 2 If NO, Ask 3
2	**Who mainly give you support or advice on how to feed *(NAME)*?** *One possible response.* *Food includes anything that the infant eat.*	My spouse/boyfriend _____ 0 My mother, mother-in-law, grandmother _____ 1 My sister or my husband's sister _____ 2 My friend/neighbour _____ 3 Doctor _____ 4 Health workers (other than a doctor) at the Health Centre_____ 5 Community Health Workers _____ 6 Other _____ 7 Other, specify_____ Do not know _____99	Ask 3
3	**Since our last visit, did you ever give *(NAME)* breastmilk, whether it is your own or from another women?**	Yes _____ 1 No _____ 0	If YES, Ask 4 If NO, Ask 8
4	**Are you still giving breastmilk to *(NAME)*?**	Yes _____ 1 No _____ 0	If YES, Ask 7 If NO, Ask 5
5	**How old was *(NAME)* when you stopped giving breast milk?**	|___|___| day(s) |___|___| week(s) |___|___| month(s)	Ask 6
6	**What was the main reason for stopping to give (NAME) your own breast milk?** *Only one response*	Mother ill/Weak _____ 0 Child ill/Weak _____ _ 1 Nipple/Breast Problem _____ 2 Insufficient Milk_____ 3 Milk not good _____ _ 4 Mother Working/at School (Or Planning to) _____ 5 Child Refused _____ __ 6 Worried About HIV and AIDS _____7 Chose to formula feed _____ 8 Doctor/health provider's Advice _____ 9 Advice of Family Member/Friend _____ 10 Other _____ 11 Other, specify_____ Do not know/Do not remember _____ 99	Ask 8
7	**In the last 7 days, how did you give breastmilk to (NAME)?** *Multiple responses possible.*	Breast (your own) _____ 0 Breast (from another women) _____ 1 Spoon _____ 2 Cup _____ 3 Bottle _____ 4 Other _____ 5 Other, specify _____ Don't know _____ 99	Ask 8
8	**Do you clean your breast or nipples before feeding *(NAME)*?**	Yes, always _____ _____ 1 Yes, sometimes _____ __ 2	Ask 9 if the response is Yes

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
		No _____ _____ 0	Ask 10 if the response in No
9	**How do you clean the breast or nipples?**		Ask 10
10	**Is *(NAME)* fed by** *Food includes breast milk, formula milk, solid food…*	Demand? _____ 0 Schedule? _____ 1	Ask 11
11	**Is *(NAME)* following any special diet?** *Do not read the list* *Multiple responses possible*	Vegetarian _____ 0 Gluten-free _____ 1 Low-lactose _____ 2 Low-phenylalanine _____ 3 Other _____ 4 Other, specify _____ None _____ 5 Don't know _____ 99	Ask 12
12	**Where is most of *(NAME)*'s food prepared?**	No preparation – breastfeeding _____ 0 At home _____ 1 Family/friend _____ 2 Restaurant _____ 3 Shop _____ 4 Crèche_____ 5 Don't know _____ 99	Ask 13
13	**In the last 7 days, were you with *(NAME)*?**	Yes _____ 1 No _____ 0	Ask 14
14	**Yesterday, were you with *(NAME)*?**	Yes _____ 1 No _____ 0	Go to Module 2

MODULE 2. INFANT FEEDING: 24 HOURS AND 7 DAYS DIETARY RECALL

I would like to ask you about some liquids that ***(NAME)*** may have had in the last 7 days during the day or at night.

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		15 Yesterday, did ***(NAME)*** have any (***ITEM FROM LIST***)?			16 Yesterday, how many times during the day or at night did ***(NAME)*** consume any (***ITEM FROM LIST)***? *Record '99' for Don't Know.*	17 During the past 7 days, did ***(NAME)*** consume any *Read **only** item that were not eaten yesterday*?
		YES	NO	DK		
A	Breast milk (own, when applicable)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
B	Breast milk (other women)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
C	Plain water (tap water, mineral/bottled water)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
D	Water with sugar	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
E	ORS (Oral Rehydration Solution)? Like the Sorol etc..	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
F	Infant formula or Soya milk such as Nan, Infacare, Isomil or any other formula milk…?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
G	Infant cereals such as Nestum, Purity, Cerelac…?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
H	Fruit or vegetable juice?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
I	Clear broth (clear salty soup)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
J	Cow's milk (including powdered milk for adults, liquid milk from shops, fresh milk from cows, long life milk)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
K	Yogurt (Danone…)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
L	Thin porridge (Mabele, Ace, Iwisa, Impala…)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
M	Cold drinks or squash (coke, crème-soda, OROS…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
N	Any other water-based liquids such as tea/coffee without milk, traditional herbal drinks, rooibos tea…? Specify _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
O	Any other liquids Specify _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

I would like to ask you about some solid or semi-solid foods that ***(NAME)*** may have had in the last 7 days during the day or at night.

NO.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		18 I would like to ask you about some solid or semi-solid foods that *(NAME)* may had yesterday during the day or at night.			19 How many times yesterday during the day or at night did *(NAME)* consume any (*ITEM FROM LIST*)? *Record '99' for Don't Know.*	20 During the past 7 days, did *(NAME)* consume any (*READ ONLY ITEMS THAT WERE NOT EATEN YESTERDAY*)?
		YES	NO	DK		
A	Porridge, bread, rice, noodles, or other foods made from grains	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
B	Pumpkin, carrots, Herbert squash, or sweet potatoes that are yellow or orange inside	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
C	Potatoes or sweet potatoes, white yams, cassava, or any other roots that is white	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
D	Any dark green leafy vegetables (spinach, cabbage, broccoli, maroggo…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
E	Ripe mangoes, ripe papayas, pineapples, peach (or other local vitamin A-rich fruits)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
F	Any other fruits or vegetables (bananas, apples, avocado, grape fruit, grape, cucumbers, red tomato, garlic, lettuce light green, baby marrows…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
G	Liver, kidney, heart, or other organ meats	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
H	Any meat, such as beef, pork, lamb, goat,	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
I	Eggs	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
J	Poultry (chicken, duck etc..)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
K	Fresh or dried fish, shellfish, tin fish or seafood	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
L	Any foods made from beans, peas, lentils, nuts, or seeds	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
M	Cheese, yogurt, or other milk products	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
N	Any oil, fats, or butter, or foods made with any of these (margarine/Rama, peanut butter, fish oil, ghee, mayonnaise, sour cream, avocado, olive, coconut…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
O	High-sugar foods (Biscuits, cakes, candies, chocolates, honey, jam, marmalade, condensed milk added to tea…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		18 I would like to ask you about some solid or semi-solid foods that *(NAME)* may had yesterday during the day or at night.			19 How many times yesterday during the day or at night did *(NAME)* consume any (*ITEM FROM LIST*)? *Record '99' for Don't Know.*	20 During the past 7 days, did *(NAME)* consume any (*READ ONLY ITEMS THAT WERE NOT EATEN YESTERDAY*)?
		YES	NO	DK		
P	Crisps, savoury snacks	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
Q	Condiments for flavour, such as chilies, spices, herbs, salt, pepper or fish powder	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
R	Insects (Mopani worms, termites, locust, grasshopper…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
S	Other items cited: _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
T	_____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

If the mother reported that she gave infant formula, go to Module 3: INFANT FORMULA
If the mother did not give infant formula, go Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT

MODULE 3: INFANT FORMULA

21. We are going to talk about the preparation of ***(NAME)*** formula. **Please show me the container of the formula you currently use to feed *(NAME)*.**

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
A	***Report the brand of the formula you are currently using*** *Brand is the name on package, report that name.*	_____	**Go to B**
B	***Circle in which form is the formula***	Liquid – ready to use? _____ 0 Powder form? _____ 1 Concentrated form? _____ 2 Other _____ 3 Other specify _____	**IF *Liquid*, *Powder form, Concentrated form* , Go to C** **IF *Other*, Ask M**
C	***Report the size of the container*** *Report the number written in the container.* *Circle whether it is grams (g), kilograms (kg), litre (l), millilitres (ml).*	|___|___|___|___| **gram(s)/ kilogram(s)/ litre(s)/ millilitre(s)**	**Ask D**
D	**For how long does the formula container last?** *Write the number.* *Circle whether it is day(s), week(s) or month(s).*	|___|___| **Day(s) /Week(s) /Month(s)**	**Ask E**
E	**Do you <u>mainly</u> feed *(NAME)* with:** *Only one possible response* *Circle the response given*	Bottle ……..... 0 Cup ……..... 1 Spoon ……..... 2	**IF *Bottle* Ask F** **IF ELSE and the infant has formula in liquid form, Ask M** **IF ELSE and the infant has formula in powder or concentrated form, Ask H**
F	**How many bottles do you own?** *Ask to see the bottles*	|___|___| bottles	**Ask G**
G	**What is the size of the bottle that you <u>MAINLY</u> use CURRENTLY?** *Ask to see the bottle mainly used* *Report the maximum volume of the bottle used in ml.*	|___|___|___| ml	**Please look at response B** **IF the infant has *Liquid formula,* Ask M** **IF the infant has *Powder or Concentrated formula* Ask H**
H	**In which order do you usually incorporate the formula and the water?**	Water then formula _____ 0 Formula then water _____ 1	**Ask I**

I	**What type of water do you <u>mainly</u> use?** *Only one possible response.* *Circle the response given.*	Tap water <u>not</u> boiled _____ 0 Tap water boiled _____ 1 Mineral water (bottled water) <u>not</u> boiled _____ 2 Mineral water (bottled water) boiled _____ 3 Other _____ 4 Other, specify _____	**Ask J**
J	**How much water do you put in the mix?** *Ask her to show you in the bottle.* *Report the volume.* *Circle whether the unit is litre (l) millilitres (ml), cups etc…*	|___|___|___|___| **litre(s)/ millilitre(s)/ cups**	**Ask K**
K	**How much powder/concentrated formula do you put in the mix?** *If liquid or concentrated formula ask her to show you with the bottle* *Circle whether the unit is scoops, litre (l) millilitres (ml), cups etc…*	|___|___|___|___| **scoops/ cups/ litre(s)/** **millilitre(s)/**	**Please look at response B** **IF the respondent use powder, Ask L** **IF the respondent use concentrated formula, Ask M**
L	**Are the scoops usually:** *Only one possible response* *Circle the response given*	Rounded (heaped) _____ 0 Flat (levelled) _____ 1 Other _____ 2 Other, specify _____	**Ask M**
M	**Do you add anything else in the formula milk?**	Yes _____ 1 No _____ 0	**IF YES, Ask N** **IF NO, Ask P**
N	**Please describe what is (are) the ingredient(s) you add to the formula.** *Multiple responses possible*	_____ _____ _____	**Ask O**
O	**How many times <u>a day</u> do you add this (these) ingredient(s) to the formula?**	Every time _____ 000 *OR* Number of times _____ |___|___| *OR* Every number of feeds _____ |___|___|	**Ask P**
P	**Before preparing food for *<u>(NAME)</u>*, do you wash your hands?**	Yes _____ 1 No _____ 0	**IF YES, Ask Q** **IF NO, Go to Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT**
Q	**How do you usually clean the utensils used for feeding *<u>(NAME)</u>*?** *Including bottles, cups, spoons etc…*	With cold water _____ 0 With cold water and soap _____1 With boiled water _____ 2 With boiled water and soap _____ 3 With sterilization solution _____ 4 Other _____ 5 Other, specify _____	**Go to Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT**

MODULE 4: INFANT SLEEPING, FEEDING AT NIGHT AND MATERNITY LEAVE

We are going to talk about how ***(NAME)*** sleeps at night.

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
22	Does the ***(NAME)*** sleep with you?	Yes _____ 1 No _____ 0	**Ask 23**
23	Are you aware how many times ***(NAME)*** wakes up?	Yes _____ 1 No _____ 0	**Ask 24**
24	Are you being woken-up by ***(NAME)***?	Yes _____ 1 No _____ 0	**Ask 25**
25	Is ***(NAME)*** breastfeeding when he/she wakes?	Yes _____ 1 No _____ 0	**Ask 26**
26	Do you have a job? (by job we mean any activity that you may do on a regular basis and for which you earn money)	Yes _____ 1 No _____ 0	**If response is No, end here the Breastfeeding and weaning practices questionnaire** **Ask 27 if response is Yes**
27	Are you currently working?	Yes _____ 1 No _____ 0	**Ask 28**
28	Are or were you on maternity leave?	Yes _____ 1 No _____ 0	**Ask 29**
29	When are you planning to go back to work?	_ _ / _ _ / _ _ _ _ DD MM YYYY	**End here the Breastfeeding and weaning practices questionnaire**



SES

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Socioeconomic Status in Growth (SES GROWTH)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:			**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y

Comments:

SECTION I: MATERNAL GENERAL INFORMATION	
How many people have been living in your home over the past 3 months?	NUMBER

Can you please list the other people who have stayed in your household and say for each adults if they currently have a job or not?
(*On average at least four nights a week over the last 3 months. Do not forget to include babies, the bedridden and elderly people, also include your partner but not yourself*)

Children (≤to 18 years of age)				Adults (>18 years of age)				
Age	Sex	Highest level of education	Relationship to yourself	Age	Sex	Highest education level	Relationship to yourself	Job
	M/F	CODE EDUCATION	CODE RELATIONSHIP		M/F	CODE EDUCATION	CODE RELATIONSHIP	CODE
	M/F	CODE EDUCATION	CODE RELATIONSHIP		M/F	CODE EDUCATION	CODE RELATIONSHIP	CODE
	M/F	CODE EDUCATION	CODE RELATIONSHIP		M/F	CODE EDUCATION	CODE RELATIONSHIP	CODE
	M/F	CODE EDUCATION	CODE RELATIONSHIP		M/F	CODE EDUCATION	CODE RELATIONSHIP	CODE
	M/F	CODE EDUCATION	CODE RELATIONSHIP		M/F	CODE EDUCATION	CODE RELATIONSHIP	CODE

CODES EDUCATION	0= No formal schooling 1= Grade R to Grade 3 2= Grade 4 to Grade 7	3= Grade 8 to Grade 12 4= Tertiary/College 5= Undergraduate 6= Postgraduate
CODES RELATIONSHIP	0= Parent 1= Grandparent 2= Your own child 3= Sibling 4= Other relative (including other children, in laws, etc)	5= Spouse 6=Partner 7= Friend 8= Housemate/flatmate/roommate 9= Other: Specify
CODES JOB (for only adults)	0= Not job 1=Job 99= Don't know	

Who was the main person looking after the child in the past three months?	CODE

CODES	0= Mother 1= Father 2=Grandparent 3=Sibling	4= Uncle/Ant 5= Neighbour 6=Creche 7=Other (Specify)

SECTION II : MARITAL STATUS		
What is your current marital status? (Legal Status)		CODE
CODES	0= Married with certificate (by home affairs) 1= Married traditionally 2= Widowed	3= Divorced or Separated 4= Single 5= Cohabitation
If the response is Widowed, Divorced or Separated or Single, go to question 8 *Otherwise, go to question 5*		
What has you and your partner living situation been the past 3 months?		CODE
CODES	0= Living together 1= Not living together	90= Refused to respond
What is your marital situation regarding the number of spouses?		CODE
CODES	0= Polygamous 1= Monogamous	
If the response is Polygamous, go to question 7 *Otherwise, go to question 8*		
How many spouses does your partner have?		NUMBER
CODES	99= Don't know Number of co spouses, if known.	
SECTION III: MATERNAL OCCUPATION		
Have you ever had a job? *By job we mean any work done to earn money or to gain skills. This includes casual/informal & volunteer work*		YES/NO
If the response is No, go to question 9 *Otherwise, go to question 10*		
What is the MAIN reason you have never had a job? *Only one possible response*		CODE
CODES	0= Family responsibilities 1= Lacking information about job 2=Lack of job opportunities	3= Not looking or not interested in job 4= Other (Specify)
Go to question 17		
Do you currently have a job?		YES/NO
If the response is Yes, go to 11 *If the response is No, go to 17*		

What is your current job?		
How would you classify your current job?		CODE
CODES	0= Occasional Part time 1= Occasional Full time 2= Permanent Full time 3= Permanent Part time 99= Don't know	
Is your current job on contract or casual (informal)?		CODE
CODES	0= Contract 1= Casual 99= Don't know	
When did you start your current job? (Month & Year)		MM/YY
Who is your employer		CODE
CODES	0= Self 1= Family 2= Government 3= Non-governmental/community-based organisation 4= Private company 5= Other: Specify	
If you resumed work during in the last 3 months, when did you go back to work?		YY/MM/DD or Not applicable
CODES	0= Not applicable	
If you have stopped working in the past 3 months, why did you stop?		CODE
CODES	0= Resigned 1= Fired 2= Retrenched 3= Health reasons 4= Maternity leave 5=No transport 6=Others	
If you currently don't have a job, what is your source(s) of income?		CODE
CODES	0= Inheritance 1= Pension 2= Support from family or friend (grandparents, parent, sibling, friend, etc.) 3= Community support (other than family: anonymous donation, church...) 4= Partner 5= Grant (child support, disability) 6= Profit 7= Own loan 8= Other: Specify	
SECTION IV : MATERNAL EDUCATION		

What is your highest level of education?			CODE
CODES	0= No formal schooling 1= Grade R to Grade 3 2= Grade 4 to Grade 7 3= Grade 8 to Grade 12 4= Tertiary/College 5= Undergraduate 6= Postgraduate		
Are you still studying?			YES/NO
If the response is No, go to question 21 *Otherwise, go to question 22*			
Why did you stop studying?	CODE		
CODES	0= Schooling sufficient 1= Lack of books 2= Poor quality of teaching 3= Lack of teachers 4= Facilities in bad condition 5= Fees too high 6= No space available 7= Crime at school 8= Poor discipline 9= Too many learners in class 10= Other: Specify		
Did you do the following in the past 3 months?	Listening to radio	CODE	
CODES 0= less than once a week 1= At least once a week 99= Don't know	Watching TV	CODE	
	Reading newspapers	CODE	
	Using cell phone for internet	CODE	
	Using cell phone for transaction	CODE	

SECTION V: INCOME, ASSETS, HOUSING AND HOUSEHOLD CHARACTERISTICS

A household is considered as one or more people habitually living in the same dwelling, sharing a meal and having a joint budget.

On average, how much money have you earned in your household per month during the past 3 months?				CODE
CODES	0= less than 900 1= 900-1800 2= 1800-2700 3= 2700-3600	4= 3600-4500 5= 4500-5400 6= 5400-6300 7= 6300-7200	8= 7200-8100 9= 8100-9000 10= 9000-9900 11= 10800-20700	12= 20700-30600 13= > 30600 90= Refused 99= Don't know
How many sources of funding have you had in the 3 past months in your household? (*Sources of money could be social grant, salary/income, maintenance, family allowance…)*				NUMBER
What is your home ownership situation?				CODE
CODES	0= Owner 1= Renting 2= Squatting 3= Not renting, not owner, but family property 90= Refused to respond			
If the response is Owner, go to question 26 *Otherwise, go to question 27*				
Where did you find funding for your house?				CODE
CODES	0= Inheritance 1= Mortgage from bank 2= Own funding 3= Government 4= Other (Specify)			
What is the total number of rooms for currently used for sleeping in your home? *Include outside bedrooms if they are used by household members, and exclude if rented out, kitchen and bathroom.*				NUMBER

Which of the following do you have in your current home? *Place where you spent most nights in the past 3 months* *It does not matter who owns/pays for these things. (answer all questions)*	Electricity	YES/NO
	Bicycle	YES/NO
	Motorcycle/Bike	YES/NO
	Motor vehicle/Car	YES/NO
	Fridge	YES/NO
	Microwave oven	YES/NO
	Washing machine	YES/NO
	Landline telephone	YES/NO
	Camera	YES/NO
	Cell phone	YES/NO
	Television	YES/NO
	Video machine/DVD player	YES/NO
	MNet/DSTV/Satellite	YES/NO
	Agricultural land	YES/NO
	Farm animals	YES/NO
	Computer/laptop	YES/NO
	Internet access	YES/NO
Do you have any debts?	Money owed to banks or financial institutions (legal and documented loans)	YES/NO
	Money owed to money lenders (loan sharks, community money-lenders)	YES/NO
	Money owed to family or friends	YES/NO
	Money owed to shops/private companies/ municipality/unpaid bills/accounts/store accounts (e.g. Jet or Edgars)	YES/NO
Who has usually paid for the following expenses for you during the past 3 months *(Please answer all questions)*	Food	CODE
	Transport	CODE
	Housing & utilities	CODE
	Education	CODE
	Clothing	CODE
	Cell phone airtime or contract	CODE
CODES	0= I pay for this with my own funds (Myself) 1= Family members pay for this 2= Partner pays for this 3= Someone else pays for this: Specify	
How would you describe the home you are living in?		CODE
CODES	0= Shack/Zozo 1= Flat/Cottage 2= House 3= Room/Garage 4= Residence (attached to education or employment) 5= Hostel 6= RDP/Government Housing 7= Other: Specify	

What are the main walls in your current home made of?		CODE
CODES	0= No walls 1= Mud 2= Plaster finished 3= Corrugated Zinc 4= Prefab 5= Bare brick or cement block 6= Cement 7= Other: specify	

What is the main floor material in your current home?		CODE
CODES	0= Ceramic tiles 1= Cement 2= Carpet 3= Earth/sand/mud 4= Wood planks 5= Parquet or finished wood 6= Vinyl/linoleum 7= Other: Specify	

Which of the following types of energy do you use the most for cooking in your current home?		CODE
CODES	0= Electricity 1= Egoli gas 2= Grass/ Shrubs 3= Kerosene 4= Charcoal 5= Liquid Propane 6= Wood 7= Animal Dung 8= Paraffin 9= Solar Panel 10= Generator 11= No Cooking facilitates 12= Other: Specify	

Which of the following types of material does the roof of your current house have the most?		CODE
CODES	0= Poured concrete 1=Metal 2=Wood 3=Thatch 4= Other: Specify	



MIA (LF)

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Morbidity and Illness Assessment (MIA - LF)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**					
Researcher Code:			**Date:**	D	D	M	M	Y	Y

Comments:

1. Since our last visit, has your child had any of the following?

	Yes (1)	No (0)	How many days did your baby have this condition?	Where did you get the treatment?
Fever				
Poor appetite				
Irritability				
Coughing/Wheezing/Hoarseness				
Difficulty breathing (rapid, noisy)				
Sneeze/runny/stuffy nose				
Diarrhoea: Three or more loose or liquid stools per day. If yes, was the diarrhoea;				
Acute watery diarrhoea (lasts several hours or days)				
Acute bloody diarrhoea (dysentery)				
Persistent diarrhoea (lasts 14 days or longer)				
Vomiting				
Gut/Stomach Sensitivity				
Rash				
Eye problems (red/ itching eyes)				
Other (specify)				

Coding:

0: No treatment	6: Well baby clinic
1: Self treatment	7: Private Hospital
2: Private Doctor (General Practitioner)	8: Chemist/ Pharmacist
3: Government Clinic	9: Faith Healer
4: Private Clinic	10: Sangoma/ Traditional Healer
5: Government Hospital	11: Other (specify)

2. Since our last visit, has your child being diagnosed with the following by a doctor: (Check the Road to Health Card)

	Yes (1)	No (0)	How many days did your baby have this condition?	Where did you get the treatment?
Pneumonia				
Bronchilitis				
Bronchitis				
Gastroenteritis				
Asthma				
Croup				
Measles				
Allergy				
Rhinitis				
Chicken Pox				
Other (specify)				

3. Has your child been vaccinated in the last month?

Yes (1)		No (0)	

If YES, which vaccine(s)? (Check the Road to Health Card and weight)

Timepoint	Vaccination	Date given	Weight (grams)
Birth	BCG	DD/ MM/ YY	
	OPV0		
6 Weeks	OPV1	DD/ MM/ YY	
	RV1		
	DTap-IVP-Hib1		
	Hep B1		
	PCV1		
10 Weeks	DTap-IVP-Hib2	DD/ MM / YY	
	Hep B2		
14 Weeks	DTap-IVP-Hib3	DD/ MM/ YY	
	Hep B3		
	PCV2		
	RV2		
9 Months	MEASLES1	DD/ MM/ YY	
	PCV3		

4. Since our last visit, was the baby admitted to a hospital or clinic, for injury or serious medical or developmental problems? (Check the Road to Health Card)

Yes (1)		No (0)	

If YES, please specify…

Date of admission	How many days did the baby stay?	What was the diagnosis when your baby was admitted?
DD / MM / YY		
DD / MM / YY		
DD / MM / YY		
DD / MM / YY		

5. Since our last visit, from whom did you receive medical care for your child? (several responses possible)

0: No treatment		6: Well baby clinic	
1: Self treatment		7: Private Hospital	
2: Private Doctor (General Practitioner)		8: Chemist/ Pharmacist	
3: Government Clinic		9: Faith Healer	
4: Private Clinic		10: Sangoma/ Traditional Healer	
5: Government Hospital		11: Other (specify)	

6. How long does it take you to get to where you receive medical care?

Hours		Minutes	

7. On average how long do you spend there?

Hours		Minutes	

8. On average how many times have you used this service in the past month?

Number of Visits	

9. Do you have a medical aid?

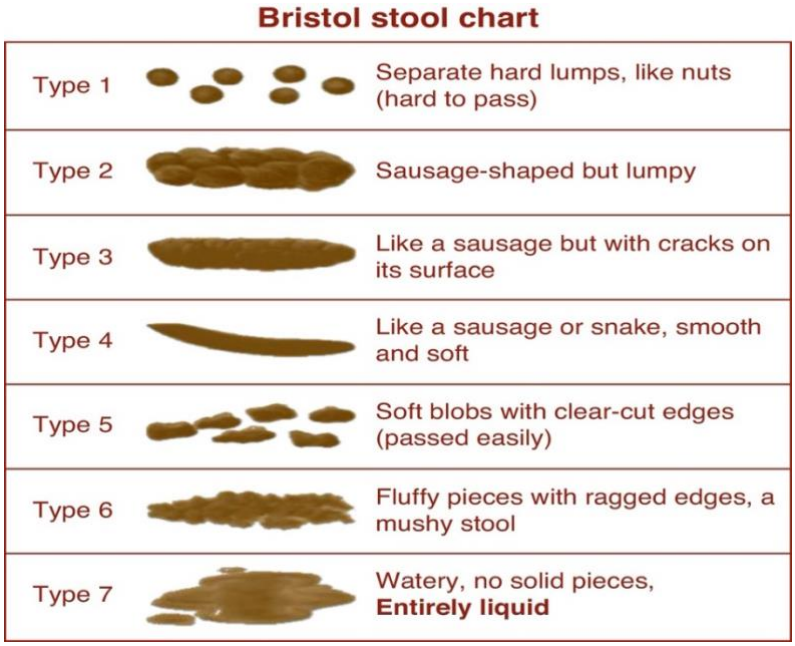
Yes (1)		No (0)	

10. Does your child have medical aid?

Yes (1)		No (0)	

11. How would you describe your child's last bowel movement?

0. Type 1	
1. Type 2	
2. Type 3	
3. Type 4	
4. Type 5	
5. Type 6	
6. Type 7	



12. In the past month, when you went to (location of sensitisation) for baby care, do they tell you about (topics of sensitisation)?

Location(s) of sensitisation in the past month		Topic of sensitisation	Yes (1)	No (0)
0. Clinic		Breastfeeding		
1. Hospital				
2. Community/Church Group				
3. Family/Friends				
4. Other, Specify:				
0. Clinic		Diseases prevention		
1. Hospital				
2. Community/Church Group				
3. Family/Friends				
4. Other, Specify:				

0. Clinic		Hygiene and Sanitation		
1. Hospital				
2. Community/Church Group				
3. Family/Friends				
4. Other, Specify:				
0. Clinic		Nutrition		
1. Hospital				
2. Community/Church Group				
3. Family/Friends				
4. Other, Specify:				
0. Clinic		Other, specify: _____		
1. Hospital				
2. Community/Church Group				
3. Family/Friends				
4. Other, Specify:				

13. Has a Community Health Worker been to see you and your baby since our last visit?

Yes (1)		No (0)	

If YES, please specify…

Days post-partum			Weeks Post-Partum			Months Post-Partum			Other, please specify
2 days	YES (1)	NO (0)	**2 weeks**	YES (1)	NO (0)	**2 months**	YES (1)	NO (0)	
7 days	YES (1)	NO (0)	**6 weeks**	YES (1)	NO (0)	**3 months**	YES (1)	NO (0)	
						4 months	YES (1)	NO (0)	
						5 months	YES (1)	NO (0)	
						6 months	YES (1)	NO (0)	
						9 months	YES (1)	NO (0)	
						12 months	YES (1)	NO (0)	

14. Do you, or others at home, suffer from any of the following conditions?

	Adult		Children			Adult		Children	
1. Hypertension	YES (1)	NO (0)	YES (1)	NO (0)	**6. Diarrhoea**	YES (1)	NO (0)	YES (1)	NO (0)
2. Diabetes	YES (1)	NO (0)	YES (1)	NO (0)	**7. LRTI**	YES (1)	NO (0)	YES (1)	NO (0)
3. Anaemia	YES (1)	NO (0)	YES (1)	NO (0)	**8. Other**	YES (1)	NO (0)	YES (1)	NO (0)
4. TB	YES (1)	NO (0)	YES (1)	NO (0)		YES (1)	NO (0)	YES (1)	NO (0)
5. HIV	YES (1)	NO (0)	YES (1)	NO (0)		YES (1)	NO (0)	YES (1)	NO (0)
If Other, Specify:									

Appendix L: HREC Clearance Certificate (M170753)

R14/49 Dr R Said Mohamed et al

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M170753

NAME: (Principal Investigator)	Dr R Said Mohamed et al
DEPARTMENT:	School of Clinical Medicine Developmental Pathways for Health Research Unit Medical School
PROJECT TITLE:	Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age
DATE CONSIDERED:	28/07/2017
DECISION:	Approved conditionally
CONDITIONS:	The socio-economic status and demographic questionnaire may NOT be used without further consultation with the HREC (Med)
SUPERVISOR:	Not applicable
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	06/11/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially reviewed in **July** and will therefore be due in the month of **July** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature _____ Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix M: HREC Clearance Certificate (M170872)

R14/49 Mr D Momberg

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M170872

NAME: (Principal Investigator)	Mr D Momberg
DEPARTMENT:	School of Clinical Medicine Developmental Pathways for Health Research Unit Medical School
PROJECT TITLE:	Governance of water, sanitation and hygiene (WASH) in South Africa and associations with nutritional status in children between birth and one year of age
DATE CONSIDERED:	25/08/2017
DECISION:	Approved conditionally
CONDITIONS:	The socio-economic status and demographic questionnaire may NOT be used without further consultation with the HREC (Med)
SUPERVISOR:	Dr R Said Mohamed
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	06/11/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially reviewed in **August** and will therefore be due in the month of **August** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature _____ Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix N: HREC Clearance Certificate (M170955)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr BC Ngandu

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M170955

NAME: (Principal Investigator)	Dr BC Ngandu
DEPARTMENT:	School of Clinical Medicine Developmental Pathways for Health Research Unit Medical School
PROJECT TITLE:	Association between socioeconomic status and birth outcomes and infant growth in the first year of life: case studies in South Africa and the DR Congo
DATE CONSIDERED:	29/09/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Drs RM Said & L Chola; Professor SA Norris
APPROVED BY:	Professor CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	16 /01/2018

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially reviewed in **September** and will therefore be due in the month of **September** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix O: Ethics Amendment M170753

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

15/03/2018

Dr R Said Mohamed et al
School of Clinical Medicine
Developmental Pathways for Health Research Unit
Medical School

Sent by e-mail to: rihlat.saidmohamed@wits.ac.za

Dear Dr Said-Mohamed

Re: **Protocol Ref No: M170753**
Protocol Title: *Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age*
Principal Investigator: Dr R Said Mohamed et al

Thank you for your letter of 14/02/2018.

I confirm that the amendments you propose to Protocol No. M170753 have been noted and approved.

Please remind me where we are up to with a review of the Socio-economic and Demographic Questionnaire.

Yours Sincerely

J. Burns

.....
Mr I Burns
For the Human Research Ethics Committee (Medical)

Appendix P: Co-Authors Declaration

Declaration: Student's contribution to article(s) and agreement of co-author(s)

I, Douglas James Momberg, student number 1156232 declare that this Thesis is my own work and that I contributed adequately towards research findings published in the article(s) stated below which are included in my Thesis.

Signature of Student:  Date: 16/03/2020

Name of Primary Supervisor: Dr Rihlat Said Mohamed

Signature of Primary Supervisor:  Date: 16/03/2020

Agreement by co-authors:

By signing this declaration, the co-authors listed below agree to the use of the article by the student as part of his Thesis. In cases where the student is not the 1st author of a published article, the primary supervisor must explain (under comments) why the student is entitled to use the paper for his degree purposes.

Article 1:

Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: A systematic review. *Journal of Developmental Origins of Health and Disease*: 1–27 (*Published Online 6 January 2020*). DOI: https://doi.org/10.1017/S2040174419000898 (Appendix Q)

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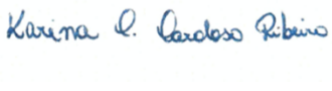
3rd Author	L. E. Voth-Gaeddert		16/03/2020

4th Author	K. Cardoso Ribeiro		16/03/2020
5th Author	J. May		16/03/2020
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Comments by Primary Supervisor:

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Article 2:

Intersectoral (in)activity: towards an understanding of water, sanitation, and hygiene (WASH), and childhood undernutrition in public sector departments in South Africa. *Journal of Health Policy and Planning*: 1-41 (*Published Online 14 June 2020).* DOI: 10.1093/heapol/czaa028 (Appendix R)

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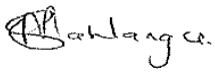
2nd Author	P. Mahlangu		17/03/2020
3rd Author	B. C. Ngandu		16/03/2020
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5th Author	S. Norris		16/03/2020
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Comments by Primary Supervisor:

Article 3:

Momberg D, Voth-Gaeddert L, Ngandu B, Richter L, May J, Norris S, Said-Mohamed R. Water, sanitation, and hygiene (WASH) factors associated with growth between birth and one year of age in children in Soweto, South Africa: Results from the Soweto Baby WASH study. *Journal of Water and Health* (*Published Online 21 September 2020).* DOI: https://doi.org/10.2166/wh.2020.085 (Appendix S)

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Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: a systematic review

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Review

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Abstract

Associations between different forms of malnutrition and environmental conditions, including water, sanitation and hygiene (WASH), may contribute towards persistently poor child health, growth and cognitive development. Experiencing poor nutrition in utero or during early childhood is furthermore associated with chronic diseases later in life. The primary responsibility for provision of water and sanitation, as a basic service and human right, lies with the State; however, a number of stakeholders are involved. The situation is most critical in sub-Saharan Africa (SSA), where, in 2015, 311 million people lacked a safe water source, and >70% of SSA populations were living without adequate sanitation. The aim of this paper was to conduct a systematic review to investigate the state of literature concerned with WASH and its association with nutritional status, and governance in children from birth to 5 years of age in SSA. Articles were sourced from PubMed Central, Science Direct and ProQuest Social Science databases published between 1990 and 2017. The PRISMA Statement was utilised and this systematic review is registered with PROSPERO (CRD42017071700). The search terms returned 15,351 articles for screening, with 46 articles included. This is indicative of a limited body of knowledge; however, the number of publications on this topic has been increasing, suggesting burgeoning field of interest. Targeted research on the governance of WASH through the identification of the various role players and stakeholders at various levels, while understanding the policy environment in relation to particular health-related outcomes is imperative to address the burden of child undernutrition.

Introduction

Undernutrition is a major public health concern because of associations with adult health and disease risk later in life, including among others, diabetes, hypertension and cardiovascular disease (CVD), and furthermore acts as a predictor of physical, mental and cognitive child development.[1–5] Experiencing poor nutrition in utero or during early childhood is furthermore associated with chronic diseases later in life. During the first 1000 days of growth and development, specific cells, organs and systems may be differentially affected by undernutrition.[6] Among the three primary forms of undernutrition – stunting, wasting and being underweight – stunting is the most prevalent in children under 5 years of age[7] and is defined as having a height-for-age z-score less than two standard deviations (SDs) of the median of the World Health Organization (WHO) Child Growth Standards.[8,9]

Undernutrition emanates from a variety of circumstances and determinants, including antenatal, intrauterine and postnatal malnutrition. The realisation that physical growth cannot completely be improved by optimised diet and reduced burden of infection has led to the hypothesis that linkages between different forms of undernutrition and environmental conditions, including water, sanitation and hygiene (WASH), may contribute towards persistently poor child growth and nutritional status.[10] Specific pathways are proposed by the so-called 5-F diagram, which describes the faeco-oral transmission route whereby faeces and associated pathogens are transmitted via fluids, fields/floors, flies and fingers to foods, and then to the infant which causes disease and infection which in turn leads to growth faltering.[11] Exposure to poor WASH during early childhood has been associated with higher risks of infections and poor nutritional status, including stunting.[12,13] Repeated infections in early life is associated with chronic low-grade inflammation[14,15] and associated CVD risks in adulthood.[16]

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Data from 140 Demographic and Health Surveys (DHS) in 65 countries reported that over half of the variation in child height between countries was explained by the frequency of open defecation. Another analysis of 171 surveys in 70 low- and middle-income countries (LMIC) found that increasing access to and use of improved water sources reduced the risk of stunting.[3,4,17] The situation is most critical in sub-Saharan Africa (SSA), where at the closing of the Millennium Development Goals cycle in 2015, the portion of people relying on untreated surface water for drinking was eight times higher than any other region. Furthermore, over 70% of the SSA populations were living without adequate sanitation and the absolute number of people practising open defecation actually increased.[18]

In response to these observations a number of trials, in various phases, have explored the effects of WASH interventions on nutritional status in children.[19–22] Initial results have indicated that there is only a marginal effect of WASH interventions on linear child growth.[21,23,24] In 2012, the WHO set ambitious global nutrition targets to reduce the number of children under the age of 5 that are stunted by 40% by 2025 with particular emphasis being placed on the role that WASH, financing and policy interventions will need to play in achieving these targets.[25]

The United Nations (UN) formally declared the right to water in November 2002 and noted that the right to water was indispensable to leading a life of human dignity and was furthermore a prerequisite for the realisation of other human rights. The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use. This also provided the first implicit reference to the responsibilities that governments and stakeholders have in delivering clean water and sanitation to everyone.[26] In the post-2015 agenda Sustainable Development Goals (SDGs) have been established, most notably in this regard SDG 6: Universal and equitable access to safe water and adequate sanitation (WASH); and SDG 2: End all forms of malnutrition, by 2030.[27,28] A key challenge to achieving the above SDGs is the unique combination of governance systems, stakeholder dynamics and institutional structures found in each country which manifest various problems and subsequent priorities.[29] Governance of WASH in this regard is the set of systems that are involved in decision-making about management and service delivery. Investigating the governance of WASH by disentangling the various actors, role players and stakeholders at various levels, while unravelling the policy environment is imperative to the understanding, design and implementation of WASH initiatives targeted at addressing the burden of childhood undernutrition.[25,27,30] The authors chose to conduct the review from 1990 onwards primarily due to the introduction of the United Nations Children's Fund (UNICEF) conceptual framework[31] which proposed a causal framework for maternal and child undernutrition which included WASH. In addition to this, the dramatic geopolitical shifts that occurred as a result of the ending of the Cold War, as signalled by the fall of the Berlin wall in 1989 had far-reaching consequences for the provision of basic services and healthcare, and transformed the dynamics of economic and health development at global, regional and national levels.[32,33] The rise of civil society and the movement on social justice, equity and rights significantly reshaped governance of health at all levels.[33,34] Furthermore, the Lancet Series on Maternal and Child Nutrition in 2013 provided an updated framework for maternal and child nutrition, as well as recommendations for inter-sectoral approaches to the challenges of malnutrition in LMIC settings, including WASH.[7,35] In order to explore this nexus, this systematic review aims to examine the literature linking WASH, childhood nutritional status and governance in sub-Saharan African settings.

Methods

Protocol and registration

A systematic review has been conducted to examine the governance of WASH in sub-Saharan settings and associations with nutritional status in children under 5 years of age. The PRISMA Statement[36] was utilised, while this systematic review has also been registered with PROSPERO (CRD42017071700).[37]

Eligibility criteria

Peer-reviewed articles published between January 1990 and October 2017 reporting governance or policy, WASH and associations with nutritional status in children in SSA were included. Studies pertaining to children with known chronic and acute diseases or abnormalities affecting growth were excluded along with publications not in English or French. In addition, a survey of government websites, the Global Database on the Implementation of Nutrition Action (GINA)[38] and, where possible, the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS)[39] was conducted to investigate whether countries in SSA had water and/or sanitation policies and if they included any links to health and/or nutrition.

Study identification and selection

Data were sourced from electronic databases. All combinations of the following keywords were used to select publications from PubMed Central, Science Direct and ProQuest Social Science databases published between January 1990 and October 2017: Governance, Policy, Management; Water, Sanitation, Hygiene, WASH; Undernutrition, Under-Nutrition, Under Nutrition, Malnutrition, Stunt-ed/ing, Underweight, Wast-ed/ing; Children, Infant, Under Five Years of Age, Preschool, Pre-school; Africa. The authors opted for selecting papers that reported governance, WASH and nutritional status irrespective of links between the various components. With regard to water and sanitation policies in SSA, government websites, the GINA,[38] and where possible, the GLAAS[39] were searched for relevant policies. The authors searched grey literature databases including the Grey Literature Report in Public Health,[40] African Index Medicus,[41] the WHO Virtual Health Sciences Library,[42] as well as conference proceedings and websites, and furthermore reviewed reference lists and where appropriate contacted experts and authors.

Data extraction

Using a standard data extraction sheet for all studies included in the systematic review, data pertaining to the governance or policy mechanism were extracted along with nutritional status as defined by the WHO Multicentre Growth Reference Study,[9] and WASH metrics as defined by the United Nations Joint Monitoring Programme (JMP).[43] Study design, date of data collection, country, participant age and sex, as well as sample size, aims and results or outcomes were also extracted. In terms of the policies that were sourced, excerpts pertaining to the country, policy and date, as well as links to health and/or nutrition were extracted using a standard data extraction form.

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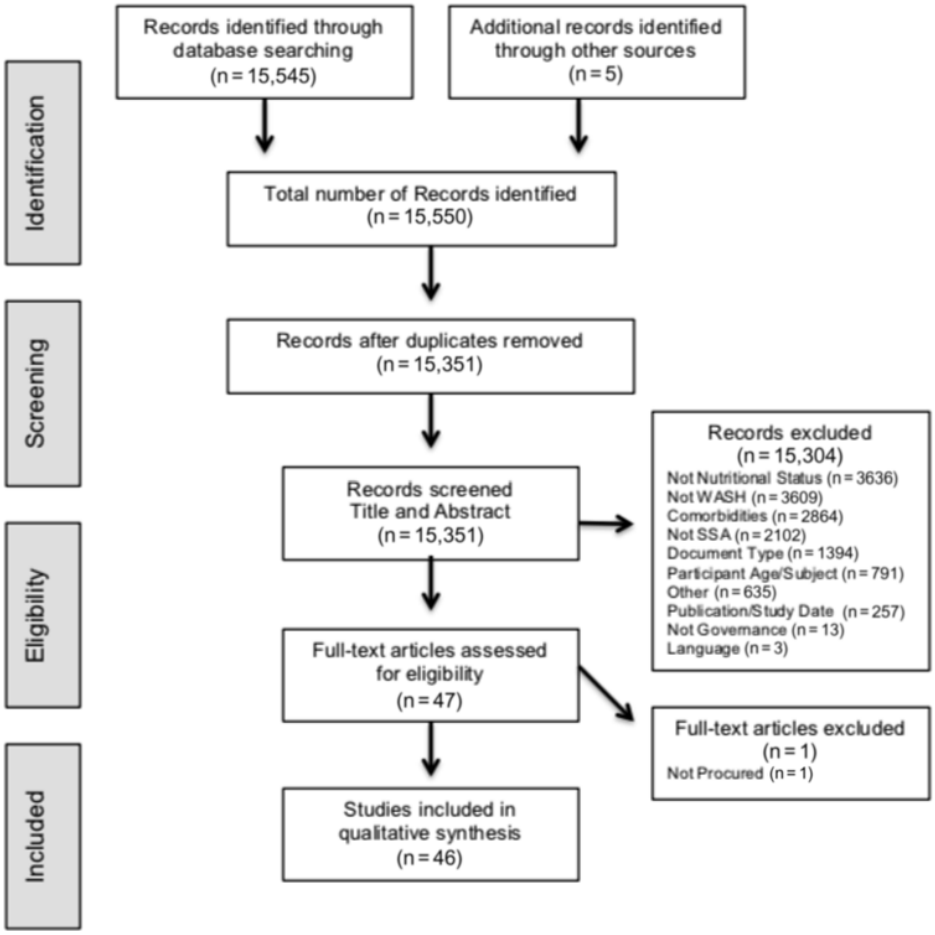

Fig. 1. Flow diagram.

Quality assessment and data analysis

For studies that were included, the strength of the individual articles and body evidence were assessed using the Grading of Recommendations, Assessment Development and Evaluation (GRADE) approach.[44,45] All studies were graded concerning their quality and summary data regarding data extraction fields, compiled. The studies included were assessed and classified to be of very low, low, moderate or high quality.

A synthesis of the eligible studies was compiled, and health policy and systems research – exploratory and descriptive frameworks utilised.[46,47] These sought to incorporate the context, content and processes surrounding knowledge production and act as a model for analysis.

Results

Description of publications

The search terms returned a total of 15,351 articles for screening as reflected in the flow diagram (Fig. 1), through which a total of 47 articles were identified for full-text review. Publications were excluded because: nutritional status was not reported ($n = 3636$), metric for WASH was not reported ($n = 3609$), comorbidities such as acute and chronic infections, congenital abnormalities or any condition that could affect growth was not reported ($n = 2864$), participant was >5 years of age ($n = 791$), publications did not geographically pertain to SSA ($n = 2102$), publication or date of study was not between 1990 and 2017 ($n = 257$), governance or policy mechanism was not reported ($n = 13$), publications were not in English or French ($n = 3$), the type of document was a newspaper, correspondence or book review ($n = 1394$), miscellaneous reasons ($n = 635$). One article could not be procured, thus 46 articles were included in the qualitative synthesis. For the purposes of this systematic review, the quality assessment yielded 3 publications of high quality,[7,35,48] 19 of moderate quality,[8,11,49–65] 24 of low quality[66–89] and none of very low quality.

Table 1 delineates the observational studies included in this systematic review while Table 2 indicates the reviews included. A total of 24 cross-sectional household surveys,[6,50–52,55–57,62,66,67,69–74,77–80,82–84,87] 14 reviews,[7,8,11,35,48,49,60,61,65,68,81,85,88,89] 4 cohorts,[58,59,63,75] 3 meta-analyses[53,76,86] and 1 case-control[64] studies were included (Fig. 2). The first publication documented dates from 1993[85] (Fig. 3). However, the period from 1993 to 2012 is characterised by a consistently low number of publications with a brief spike in 2008. There is a significant increase in the number of studies from 2013 to 2017.

Of the observational studies included, 30[50–59,62,64,66,67,69–72,74–80,82–84,86,87] aimed at assessing nutritional status and associated factors, while 2[63,73] were concerned with assessing the association between WASH and child growth. Water, either in terms of source, type of infrastructure or access, was reported as a significant risk factor in 21[50–52,57–59,63,66,69–71,74,76–80,82,84,86] of

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Table 1. Studies included in systematic review

Ref #	Country	Design	Age	Sample	Nutritional status	WASH	Governance	Aim	Results
[50]	Nigeria	DHS	0–59 months	24529	HAZ	Water (Source and Type); Sanitation (Type)	Policy; Intervention planning	To determine the factors associated with stunting and severe stunting in children 0–23 months and children 0–59 months	Significant risk factors for stunting and severe stunting, among children aged 0–23 months and 0–59 months, included children who were reported to have had diarrhoea in the 2 weeks prior to the survey ([AOR] for stunted children 0–23 months = 1.22 [95%CI: 0.99, 1.49]); (AOR for stunted children 0–59 months = 1.31 [95%CI: 1.16, 1.49]), (AOR for severely stunted children 0–23 months = 1.31 [95%CI: 1.03, 1.67]); (AOR for severely stunted children 0–59 months = 1.58 [95% CI: 1.38, 1.82])
[80]	Ethiopia	Cross-sectional survey	0–59 months	605	HAZ; WAZ; WHZ	Water (Source and Type); Sanitation (Type)	Policy	To assess the nutritional status and associated factors in children <5 years of age.	Stunting was predicted by households where water was taken from unprotected sources (AOR, 2.13; 95% CI, 1.09–4.14).
[71]	Ethiopia	Cross-sectional survey	6–59 months	3108	HAZ	Water (Treatment); Sanitation (Access)	Policy	To review socio-demographic characteristics, and child anthropometry on potential immediate, underlying and basic individual and community-level determinants of child undernutrition using the UNICEF conceptual framework.	Household-level water treatment practice was associated with higher child height-for-age z-score by 0.25 SD ($P < 0.05$) compared to households that did not treat water at household level.
[70]	Tanzania	Cross-sectional survey	6–59 months	3280	HAZ	Water (Source and Type); Sanitation (Access)	Intervention planning	To explore factors associated with stunting among pre-school children.	Stunting was associated with access to improved water source (AOR: 0.70; CI: 0.52–0.93) and to a functioning water station (AOR: 0.63; CI: 0.40–0.98).
[79]	Congo; Ivory Coast; Ethiopia; Gambia; Mali; Mozambique; Namibia; Niger; Nigeria; Sierra Leone; Uganda; Zambia	DHS	0–59 months	Not available	HAZ; WAZ; WHZ	Water (Source and Type); Sanitation (Type)	Intervention planning	To explore the major question about the association between different household environment conditions with child survival and health	Improved water sources were significantly associated with lower odds ratio of stunting (0.77) and wasting in Uganda (0.50), while it was found significantly associated with lower odds ratio of underweight in Mali (OR = 0.768) compared to the use of non-improved water sources. Use of improved sanitation significantly associated with lower risk of underweight in the Congo Republic (OR = 0.821), Ethiopia (OR = 0.811) and Mali (OR = 0.768). It was also associated with lower risk of stunting in Cote d'Ivoire (OR = 0.709) and Ethiopia (OR = 0.854)

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[83]	SSA	DHS	12–36 months	33000	HAZ; WAZ	Water (Source); Sanitation (Access)	Policy	To consider the relationship between child malnutrition and selected bio-physical and macro-demographic variables combined with anthropometric data via geographic location	In unadjusted regression models, increased usage of well water and decreased usage of surface water were associated with a high share of underweight children. A complete lack of toilet and lack of flush toilet facilities were associated with a high share of underweight children. However, neither the infrastructure of water nor of sanitation were significantly associated with underweight in adjusted models
[52]	Tanzania	Cross-sectional household survey	0–59 months	7324	HAZ	Water (Source)	Intervention planning	To assess the determinants of stunting and severe stunting in children aged 0–23 months and 0–59 months	Most consistent significant risk factors for stunted and severely stunted children aged 0–23 and 0–59 months were: unsafe sources of drinking water (AOR for stunted children aged 0–23 months = 1.37; 95% CI: [1.07, 1.75]); (AOR for severely stunted children aged 0–23 months = 1.50; 95% CI: [1.05, 2.14]), (AOR for stunted children aged 0–59 months = 1.42; 95% CI: [1.13, 1.79]) and (AOR for severely stunted children aged 0–59 months = 1.26; 95% CI: [1.09, 1.46])
[53]	SSA	Meta-analysis	0–59 months	Not available	HAZ	Water (Type and Source); Sanitation (Type)	Policy; Intervention planning	To determine the risk factors for childhood stunting	Unimproved water and sanitation had the second largest estimated impact on stunting in SSA. Unimproved sanitation; OR 1.37: 95% CI (1.33, 1.41). Unimproved water source; OR 1.09: 95% CI (1.06, 1.12)
[87]	Ghana	DHS	0–59 months	2379	HAZ	Water (Source); Sanitation (Type)	Policy; Intervention planning	To examine the correlates of stunting	Source of drinking water and kind of latrine were used as independent variables in intermediate (environmental) factor model; however, only descriptive statistics were reported
[63]	Ethiopia	Cohort	0–59 months	7715	HAZ	Water (Access and Type); Sanitation (Type); Hygiene (Non-specific)	Policy; Intervention planning	To understand associations between water, sanitation and child growth	In unadjusted models, household access to improved water and toilets was associated with reduced stunting risk. After adjusting for child, household, parent and community variables, access to improved water was associated with lower prevalence of stunting and thinness at 1 year and 5 years. However, access to improved sanitation is more frequently associated with reduced stunting risk than access to improved water

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Table 1. (*Continued*)

Ref #	Country	Design	Age	Sample	Nutritional status	WASH	Governance	Aim	Results
[62]	Ethiopia	Cross-sectional household survey	6–24 months	587	HAZ; WHZ	Sanitation (Access)	Intervention planning	To assess stunting, wasting and associated factors among children aged 6–24 months	Unavailability of latrine was significantly associated with higher odds of stunting (AOR = 1.76; 95% CI: 1.17, 2.66)
[76]	SSA	Meta-analysis	0–59 months	Not available	WHZ	Water (Access)	Policy	To understand how social context affects the nutritional status of populations, as reflected by the prevalence of wasting in children under 5 years of age. To present a systematic way of building models for wasting prevalence, using a conceptual framework for the determinants of malnutrition and to examine the feasibility of using readily available data collected over time to build models of wasting prevalence in populations	Low birth weight, measles incidence and access to a safe water supply explained 38% of wasting in Africa
[55]	Ghana; Malawi; Tanzania; Nigeria; Zambia; Zimbabwe	DHS	1–35 months	Not available	WAZ	Water (Type); Sanitation (Type)	Policy; Intervention planning	To compare individual and household predictors of underweight among young children	At the household level, type of toilet facilities was associated with lower weight for age z-scores
[56]	Uganda	Cross-sectional household survey	0–59 months	104	HAZ; WAZ; WHZ	Sanitation (Access)	Policy	To investigate factors associated with malnutrition among under-five children	Proximate variables mediate demographic and socio-economic factors like the duration of breast feeding, sanitation and mothers health seeking behaviours to influence under-five malnutrition
[77]	Ethiopia	Cross-sectional household survey	0–59 months	1723	HAZ	Water (Access); Sanitation (Access)	Intervention planning	Aims at exploring the spatial distribution of stunting at meso- (district) scale and evaluates the effect of spatial dependency on the identification of risk factors and their relative contribution to the occurrence of stunting and severe stunting	Underlying factors for child undernutrition also include household and family-related factors such as food security, childcare, access to water and sanitation and lack of basic health services
[84]	Zambia	DHS	0–59 months	12714	HAZ	Water (Source and Type); Sanitation (Type)	Policy; Intervention planning	To investigate changes in socio-economic inequality in stunting and fever	Improved water source and improved toilet were not associated with a higher likelihood of stunting

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[73]	SSA	DHS	0–59 months	Not available	HAZ	Water (Type); Sanitation (Access)	Policy	To assess whether the importance of dense settlement for infant mortality and child height is moderated by exposure to local sanitation behaviour. Is open defecation worse for infant mortality and child height where population density is greater? Is poor sanitation is an important mechanism by which population density influences child health outcomes?	Open defecation externalities are more important for child health outcomes where people live more closely together. A one log-unit increase in population density increases the corresponding decline in height-for-age by about 0.04 SD of a height-for-age z-score
[54]	Kenya; Zambia	DHS	0–48 months	2500	HAZ; WHZ	Sanitation (Access)	Intervention planning	To determine the prevalence and determinants of stunting.	There was a higher risk of stunting in both Kenya and Zambia, for those with no formal toilet (OR = 0.80; 95% CI: 0.55, 1.15)
[58]	Kenya	Cohort	0–59 months	3335	HAZ; WAZ; WHZ	Water (Access); Sanitation (Access)	Policy; Intervention Planning	To investigate associations between nutritional status and individual-level factors, maternal factors, and feeding practices	The double burden of malnutrition in the urban slums may be occasioned by prevailing adverse conditions in these settings including poor livelihoods and low socio-economic status, high levels of food insecurity, poor access to water and environmental sanitation and healthcare services, high prevalence of infections (especially from diarrhoea, respiratory diseases), and poor child feeding practices in these settings
[74]	Somalia	Cross-sectional household survey	6–59 months	73778	HAZ; WAZ; WHZ	Water (Source)	Policy	To assess the spatial co-distribution of wasting, stunting and underweight and investigate their shared correlates	Access to foods with high protein content and vegetation cover, a proxy of rainfall or drought, were associated with lower risk of wasting and stunting. A 1-unit increase in enhanced vegetation index (EVI) was associated with a 38 %, 49 % and 59 % reduction in wasting, stunting and low mid-upper arm circumference, respectively. Children who had diarrhoea and acute respiratory infection in the past 2 weeks had a higher risk of wasting, stunting and underweight
[69]	Somalia	Cross-sectional household survey	0–59 months	73778	HAZ	Water (Source)	Intervention planning	To test a Bayesian hierarchical space-time model to forecast stunting using the relationship between observed stunting and environmental covariates	Rainfall and vegetation cover were significant in forecasting stunting. Rainfall (OR = 0.994, 95% credible interval (CrI): 0.993, 0.995) and vegetation cover (OR = 0.719, 95% CrI: 0.603, 0.858) were significant in forecasting stunting

(*Continued*)

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Table 1. (*Continued*)

Ref #	Country	Design	Age	Sample	Nutritional status	WASH	Governance	Aim	Results
[66]	Somalia	Cross-sectional household survey	6–59 months	73778	HAZ; WHZ	Water (Source)	Policy; Intervention planning	To investigate the predictors of wasting, stunting and among children aged 6–59 months	Effects of distal environmental covariates associated with vector-borne diseases on child growth outcomes were examined. These were rainfall, EVI, mean temperature, distance to water features and urbanisation. Fever, diarrhoea, sex and age of the child, household size and access to foods were significant predictors of malnutrition
[82]	Sierra Leone	Cross-sectional household survey	0–59 months	604	HAZ; WHZ	Water (Access); Sanitation (Access and Type)	Intervention planning	To assess the changing patterns of stunting and wasting in children 0–59 months	Stunting is associated with a number of immediate factors including (e.g., environmental, economic and socio-political factors) restricting access to safe and sufficient food and water
[75]	Ethiopia	Cohort	0–12 months	1065	HAZ; WAZ; WHZ	Sanitation (Type)	Intervention planning	To determine the prevalence and predictors of undernutrition among infants aged 6 and 12 months	Significant and consistent predictors of infant underweight, stunting and wasting, in both logistic and linear multiple regression models were poor household sanitary facilities
[59]	Gambia	Cohort	0–24 months	3659	HAZ; WAZ; WHZ	Water (Source); Sanitation (Access); Hygiene (Non-specific)	Intervention planning	To assess trends in growth faltering in children younger than 2 years	Underweight, stunting and wasting were was markedly seasonal, with greater deficits occurring in the rainy season when infections are more common. Amplitude of seasonal z-score fluctuation between birth and 2 years. HAZ (–0.09 [95% CI: –0.10 to –0.08]). WAZ (–0.15 [95% CI: –0.16 to –0.14]. WHZ (–0·16 [95% CI: –0.18 to –0.14])
[51]	Cameroon	DHS	0–59 months	1923	HAZ; WAZ	Water (Type); Sanitation (Type)	Intervention planning	To assess the association between explanatory factors and nutritional status and to estimate the net effects of both household and community factors	Improved household water and sanitation were associated with better HAZ and WAZ
[64]	Zimbabwe	Case-Control	0–24 months	14110	HAZ	Water (Type); Sanitation (Type); Hygiene (Non-specific)	Intervention planning	To test the effects of a single high-dose vitamin A supplement given to mothers and/or infants during the immediate postpartum period on several infant health outcomes	Non-exclusive breastfeeding has been associated with faeco-oral transmission of bacteria among infants living in conditions of poor sanitation and hygiene; frequent exposure to potentially pathogenic organisms likely drives the T-cell-mediated enteric inflammation that characterises environmental enteropathy

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[78]	Tanzania	Cross-sectional household survey	0–59 months	678	HAZ	Water (Access and Source)	Intervention planning	To determine the prevalence and determinants of stunting	Time to water source was associated with stunting. (OR = 0.69; 95% CI: 0.48–1.01)
[86]	SSA	Meta-analysis	0–59 months	Not available	HAZ; WAZ	Water (Type); Sanitation (Type)	Policy;	To explore trends in mild, moderate, and severe stunting and underweight	Children's growth was associated with infection and suboptimal nutrition. Hence, food insufficiency, poor water and sanitation, and restricted access to high-quality primary care, all associated with household and community poverty and were associated with poor growth outcomes
[67]	SSA	DHS	0–59 months	Not available	HAZ; WAZ	Water (Source); Sanitation (Access)	Policy	To report on socio-economic inequality in childhood malnutrition and to provide evidence for an association between socio-economic inequality and the average level of malnutrition	An indicator of socio-economic status, including clean water and a toilet, was developed using principal component analysis. After correcting for the concentration index's dependence on mean malnutrition the median concentration index for SSA was −0.15, where negative values imply that malnutrition is more concentrated among poorer children. There was thus a marginal association between average stunting and socio-economic inequality
[72]	Ghana	DHS	0–59 months	3061	HAZ	Water (Access); Sanitation (Access)	Policy; Intervention planning	To summarise inequality in children's height-for-age z-scores across the entire socio-economic distribution and decompose this inequality into different contributing factors	Access to sanitation in terms of having a toilet and access to safe water was not associated with malnutrition
[57]	SSA	DHS	0–6 months	Not available	Stunting	Water (Access)	Policy	Examine the independent association of six different types of food (exclusive breastfeeding, non-exclusive breastfeeding, infant formula, milk liquids, non-milk liquids and solid foods) with five measures of infant health (length, weight, diarrhoea, fever and cough)	Study shows that for an infant younger than 6 months old following current guidelines and exclusively breastfeeding instead of giving the infant solid foods was associated with higher length by 0.75 cm and weight by 0.25 kg and lesser diarrhoea, fever and cough prevalence by 8, 12 and 11%, respectively. Authors were unable to control for access to sanitary water: a necessary ingredient in infant formula without which the results could be biased upwards

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Table 2. Review articles included in systematic review

Ref #	Country	Design	Age	Sample	Nutritional status	WASH	Governance		Results
[35]	SSA	Review	0–59 months	Not available	HAZ; WAZ; WHZ	Water (Source and Type); Sanitation (Type); Hygiene (Hand Washing)	Policy; Intervention planning	To assess nutrition-specific interventions across the life cycle for evidence of benefit	WASH interventions with significant effects: reduced risk of diarrhoea with hand washing with soap (RR 0.52, 95% CI 0.34–0.65), with improved water quality, and with excreta disposal Open defecation explained 54% of international variation in child height by contrast with GDP, which only explained 29%. A 20% point reduction in open defecation was associated with a 0.1 SD increase in child height
[7]	SSA	Review	0–59 months	Not available	HAZ; WAZ; WHZ	Water (Access); Sanitation (Access)	Policy; Intervention planning	To review maternal and child undernutrition and overweight in low-income and middle-income countries	Studies have consistently shown that diarrhoea is the most important infectious disease determinant of stunting. A framework for actions to achieve optimum child nutrition and development require nutrition-sensitive programmes and approaches including water and sanitation is proposed
[81]	South Africa	Review	0–59 months	Not available	Stunting	Water (Source); Sanitation (Access); Hygiene (Food and Domestic Hygiene)	Policy	To profile the current food hygiene and safety needs of children under the age of 5 in South Africa. To reflect the importance of domestic hygiene, access to water and sanitation in reducing the transmission of gastrointestinal pathogens while feeding infants and young children. To highlight the need for collaboration between healthcare professionals and the local authorities who provide basic services	Two studies reported that water source and sanitation were correlated with linear growth in children. In addition, latrine ownership was associated with lesser risk of stunting
[61]	SSA	Review	0–59 months	Not available	Stunting	Water (Source and Type); Sanitation (Access and Type); Hygiene (Hand Washing and Food Hygiene)	Policy; Intervention planning	To review the evidence linking WSH measures to faecal-oral diseases in children	While the relationship between diarrhoeal disease and malnutrition is complex, reviewing the evidence linking WASH measures to faecal-oral diseases in children suggests stunting in children aged 24 months was associated with five or more diarrhoeal episodes experienced in the first 2 years of life
[68]	SSA	Review	0–59 months	Not available	HAZ; WAZ; WHZ	Water (Source); Sanitation (Access and Type); Hygiene (Non-specific)	Intervention planning	To provide a narrative review of the current understanding of EED: epidemiology, pathogenesis, therapies and relevance to child health	EED is established during infancy and was associated with poor sanitation, certain gut infections and micronutrient deficiencies

[11]	SSA	Review	0–24 months	Not available	HAZ	Water (Source and Type); Sanitation (Type); Hygiene (Hand Washing)	Policy; Intervention planning	This review article considers two broad questions: (1) can WASH interventions make a significant contribution to reducing the global prevalence of childhood stunting, and (2) how can WASH interventions be delivered to optimise their effect on stunting and accelerate progress?	The evidence reviewed suggests that poor WASH conditions have a significant detrimental effect on child growth and development resulting from sustained exposure to enteric pathogens
[48]	SSA	Review	0–59 months	Not available	HAZ	Water (Source); Sanitation (Access); Hygiene (Non-specific)	Policy	To assess the global trends in stunting	Action to reduce stunting requires improvements in WASH
[49]	SSA	Review	0–59 months	Not available	HAZ; WAZ	Water (Type); Sanitation (Type)	Intervention planning	This review documents the evidence that intestinal infections lead to malnutrition and that malnutrition worsens intestinal infections. Also reviewed are the mechanisms by which enteric infections lead to undernutrition and by which malnutrition worsens enteric infections, with implications for potential novel interventions	Authors suggest that a substantial proportion of global malnutrition is due to impaired intestinal absorptive function resulting from multiple and repeated enteric infections. The economic, human and societal impact of repeated and prolonged enteric infections is far greater than ever calculated. Thus, any effective interventions, ranging from targeted antimicrobial therapy and key micro- and macronutrient approaches to improved water and sanitation, have far greater cost-benefit effects than ever adequately appreciated
[60]	SSA	Review	0–59 months	Not available	HAZ	Water (Source)	Policy; Intervention planning	To summarise what we do and do not know about these very early alterations in intestinal digestive function, discuss their potential impact on childhood growth and examine the policy implications for interventions to interrupt this pathway to stunting	A number of factors have been proposed to underlie altered function of small bowel mucosa, including a combination of microbial contamination of water and food. In young infants and children, EED may precede and dispose to malnutrition of varying degrees, which in turn contributes to an increased incidence of infectious disease, especially diarrhoea
[85]	SSA	Review	0–59 months	Not available	Stunting; Wasting	Water (Type); Sanitation (Type); Hygiene (Food Hygiene)	Policy; Intervention planning	Aims to demonstrate that weaning foods prepared under unhygienic conditions are frequently heavily contaminated with pathogens and thus are a major factor in the cause of diarrhoeal diseases and associated malnutrition	Weaning foods prepared under unhygienic conditions are frequently heavily contaminated with pathogens and thus are a major factor in the cause of diarrhoeal diseases and associated malnutrition. To prevent foodborne diseases, a multidisciplinary approach is needed. Environmental conditions need to be improved, including the provision of safe water supplies and sanitation

(*Continued*)

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Table 2. (*Continued*)

Ref #	Country	Design	Age	Sample	Nutritional status	WASH	Governance		Results
[65]	SSA	Review	0–36 months	Not available	HAZ	Water (Source, Type and Treatment); Sanitation (Access and Type); Hygiene (Hand Washing and Domestic Hygiene)	Policy; Intervention planning	To review evidence on the links between clean water, sanitation and hygiene (WASH), and stunting and anaemia, which are known risk factors for child developmental deficits, and highlight how current WASH interventions fail to adequately protect children in the first 3 years of life	In order to address stunting and anaemia as key risk factors for early childhood development, this review leads the authors to conclude that baby WASH interventions require baby hand washing at key times and creation of a hygienic and protective play environment, in addition to hygienic infant feeding and household hand washing and sanitation interventions in order to interrupt key faecal-oral vectors while paying attention to animal and human faeces
[8]	South Africa	Review	0–72 months	Not available	HAZ	Water (Access and Type); Sanitation (Access and Type)	Policy	To investigate the changes in the prevalence of stunting	Stunting is highly correlated with poorer socio-economic status and environmental conditions, especially in rural provinces with poor access to water and sanitation
[88]	SSA	Review	0–59 months	Not available	HAZ; Underweight; Wasting	Water (Type); Sanitation (Access); Hygiene (Hand Washing)	Policy	To discuss the burden and trends of global under 5 years, infections and nutrition conditions; aetiology and associated risk factors; biological plausibility and the interrelation between infections, nutrition and growth; and existing interventions and strategies to reduce major childhood infections and improve nutrition and growth and implications	Infection-specific risk factors include poor water quality, unhygienic excreta disposal, unwashed hands and consequent undernutrition WASH strategies (hand washing with soap, improved water quality and excreta disposal) can reduce diarrhoea morbidity in children by 42%, 37% and 31%, respectively; however, a recent meta-analysis suggests a small benefit of WASH interventions on length growth in children <5 years of age
[89]	SSA	Review	0–59 months	Not available	HAZ	Water (Access); Sanitation (Access and Type); Hygiene (Non-specific)	Policy; Intervention planning	To review the existing literature regarding the underlying causes of and potential interventions for EED and poor growth in children, highlighting the epidemiology, clinical and histologic classification of the entity, as well as discussing novel biomarkers and possible therapies	Improving WASH, as well as the child's macro- and micro-nutrient intake, may be the primary means of preventing or mitigating environmental enteropathy and undernutrition

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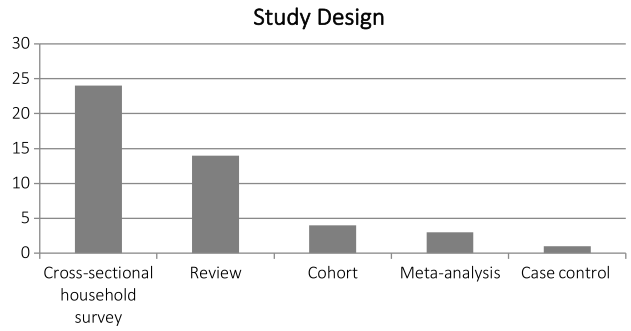

Fig 2. Study design.

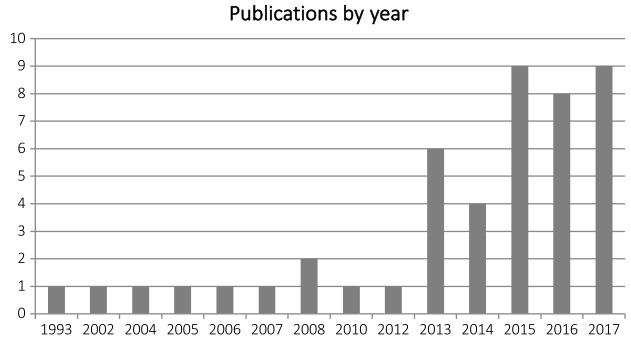

Fig. 3. Publications by year.

the observational studies, and access to sanitation, or type of sanitation infrastructure, as a significant risk factor in 15 of the studies.[51,53–56,58,62–64,73,75,77,79,84,86] Hygiene, considered here as multiple forms of hygiene, or hygiene as an integrated concept was reported as a significant risk factor in one study.[64] All significant risk factors are in the expected direction, that is, associations in the direction typically hypothesised, for example, improved wash conditions predict reduced stunting. No association between WASH and nutritional status was reported in four papers.[67,72,83,87] With regard to the observational studies assessing the association between WASH and child growth, in unadjusted models, that did not control for child, household, parent and community characteristics, household access to improved water and toilets was associated with reduced stunting risk. After adjusting for child, household, parent and community variables, access to improved water was associated with reduced stunting at 1 and 5 years of age (relative risk ratios from 0.55 to 0.57).[63] In adjusted models, those that controlled for child, household, parent and community characteristics, open defecation externalities were important for child height-for-age z-scores where people lived in close proximity to one another. One study found that a one log-unit increase in population density was associated with lesser height-for-age z-score by about 0.04 SD.[73]

In terms of the 14 review articles included, 3 papers[11,35,65] aimed at assessing WASH interventions, while 4[7,8,48,88] were concerned with assessing trends in nutritional status. A total of seven articles[49,60,61,68,81,85,89] aimed at reviewing evidence between environmental enteric dysfunction (EED) and nutritional status, with EED as a mediating factor between poor WASH conditions and nutritional status. Results of the reviews highlighted water either in terms of source, type of infrastructure or access was reported as a significant risk factor in 12[7,8,11,48,49,60,61,65,81,85,88,89] of the papers, while the importance of access to sanitation or type of sanitation infrastructure was emphasised in 13[7,8,11,35,48,49,61,65,68,81,85,88,89] articles and hygiene in 9[11,35,48,49,61,65,85,88,89] of the reviews.

Geographical coverage

Nineteen publications dealt with SSA as a region, while three articles dealt with more than one country in SSA.[54,55,79] Individually, Ethiopia had the most publications with six,[62,63,71,75,77,80] Tanzania[52,70,78] and Somalia[66,69,74] had three articles each, while Ghana[72,87] and South Africa[8,81] had two articles each, and Cameroon,[51] Gambia,[59] Nigeria,[50] Kenya,[58] Sierra Leone,[82] Uganda,[56] Zambia[84] and Zimbabwe[64] had one publication each (Fig. 4). An electronic survey of specific policies related to Water-only, Sanitation-only, and WASH and subsequent links to health and/or nutrition in individual SSA countries was also conducted (Table 3). Of the 49 countries surveyed, policies relating to water could not be found for 6 countries (Angola, Djibouti, Central African Republic, Equatorial Guinea, Gabon and Somalia). The authors could not access the specific water policy documents for 12 countries (Angola, Djibouti, Central African Republic, Comoros, Republic of Congo, Equatorial Guinea, Gabon, Gambia, Guinea-Bissau, Mauritius, Seychelles and Somalia). For nine countries (Central African Republic, Republic of Congo, Equatorial Guinea, Mauritius, Somalia, South Sudan, Swaziland, Tanzania and Zambia), no sanitation policy was found. The sanitation policy documents could not be accessed for 10 countries (Central African Republic, Republic of Congo, Equatorial Guinea, Seychelles, Somalia, South Sudan, Swaziland, Tanzania and Zambia). For four countries, there were no other policy documents reviewed that linked WASH and health/nutrition (Angola, Equatorial Guinea, Mauritius and Swaziland). No WASH policies were found.

In terms of the content of the policies, some 16 countries (Burkina Faso, Burundi, Eritrea, Ethiopia, Gambia, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Namibia, Nigeria, Sudan and Zimbabwe) made reference to hygiene in their respective policies. A total of four countries (Burundi, Mauritania, São Tomé and Príncipe, and Uganda) linked water and nutrition in general. A further two countries (Liberia and Zimbabwe) linked water and child health in general, while two countries (Rwanda and South Africa) linked water and nutritional status in children. Some 14 countries (Burundi, Cape Verde, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Gabon, Guinea-Bissau, Kenya, Niger, Rwanda, São Tomé and Príncipe, Senegal, and Togo) linked sanitation and nutrition in general. A total of six countries linked sanitation and child health in general, and three countries (Cameroon, Malawi and Uganda) made reference to the importance of the link between sanitation and nutritional status in children.

Nexus between WASH, undernutrition and governance

In terms of nutritional status, 44 articles considered stunting,[7,8,11,22,35,48–54,56–59,62–75,77–89] 17 articles underweight,[7,35,49,51,55,56,58,59,66–68,75,79,80,83,86,88] and 16 articles wasting.[7,35,54,56,58,59,62,68,69,74–76,79,80,82,88] A total of eight articles were concerned with water alone[52,57,60,66,69,74,76,78] while four articles dealt solely with sanitation.[54,56,62,75] A combination of water and sanitation was reported in 21 articles[7,8,49–51,53,55,58,67,70–73,77,79,80,82–84,86,87] and 13 articles reported

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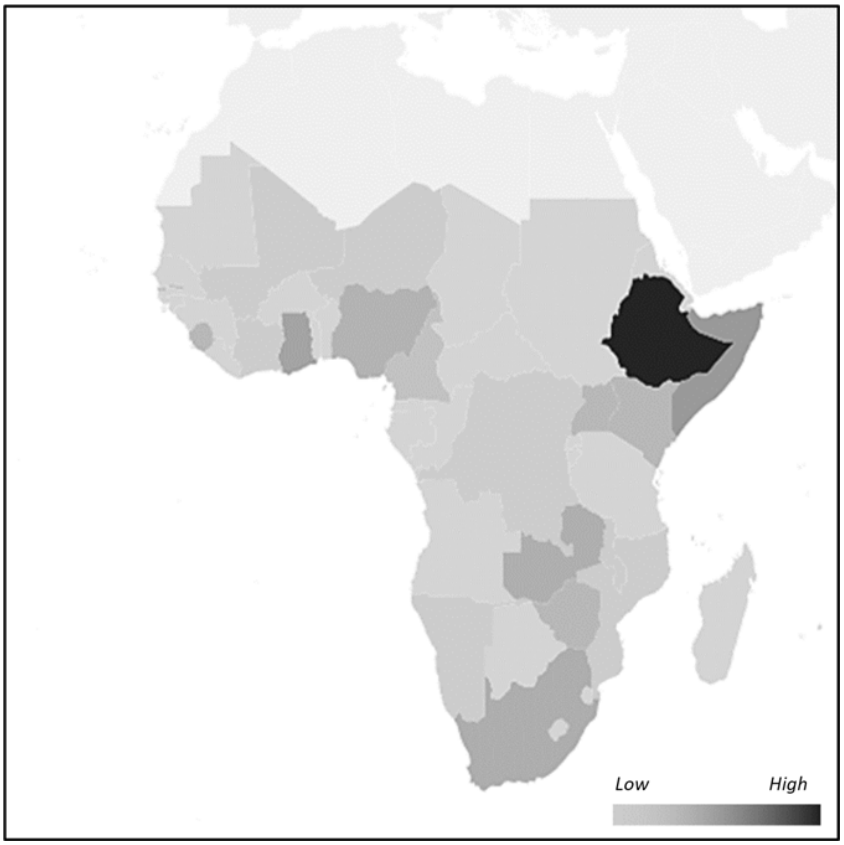

Fig. 4. Number of publications by country.

on WASH.[11,35,48,59,61,63–65,68,81,85,88,89] Twenty-one articles considered water source,[11,35,48,50,52,59–61,65–70,74,79–81,83,84,87] 11 were concerned with access to water,[7,8,57,58,63,72,76–78,82,89] 19 with type of infrastructure as defined by the JMP[11,35,50,51,53,55,61,63,64,70,73,79,80,84,86] and 2 with water treatment.[65,71] Twenty-one articles dealt with access to sanitation,[7,8,48,54,56,58,59,61,62,65,67,68,70,72,73,77,81–83,88,89] and 22 with type of sanitation.[8,11,35,49–51,53,55,61,63–65,68,75,79,80,82,84–87,89] A total of six articles were non-specific in so far as they considered multiple forms of hygiene or hygiene as an integrated concept,[48,59,63,64,68,89] while three considered food hygiene,[61,81,85] two domestic hygiene[65,81] and five hand washing.[11,35,61,65,88]

Fourteen articles made explicit reference to the sentiment that the results of the research conducted had policy implications,[8,48,56,57,66,67,71,73,76,80,81,83,86,88] while a total of 15 articles advocated for the importance of their results for the planning and development of interventions.[49,51,52,54,59,62,64,68–70,75,77–79,82] A total of 17 of the articles included noted the importance of their results for both policy and intervention planning.[7,11,35,50,53,55,58,60,61,63,65,72,74,84,85,87,89] None of the articles unfortunately elaborated on neither precise policies nor specific intervention mechanisms but rather remained non-descript in their reports.

Discussion

In the literature that was included in this review, only 46 articles were included and indicate a relatively limited body of knowledge on the nexus between governance, WASH and nutritional status in children in the sub-Saharan African context. Publications on this topic have however been increasing, suggesting that this is an emerging and growing field of interest. In conducting this systematic review, there were no scientific studies or evidence specifically focused on linking the governance of WASH and nutritional status in children. All included publications did note some policy implications based on study results; however, the precise manner in which this could or should be operationalised was rarely elaborated on.

In terms of the coverage of the literature for each of the individual WASH components, among the observational studies, more articles reported water as a significant risk factor than sanitation. Interestingly, among the reviews, more articles reported sanitation as a significant risk factor than water, with hygiene being the least represented component in both the observational studies as well as reviews. While some studies are concerned with water or sanitation separately, water and sanitation were reported most, followed by WASH. Water source was reported most often, followed by type of water infrastructure, access to water and finally water treatment. Access to sanitation was most reported followed by type of sanitation infrastructure. With regard to hygiene, being the least represented component, hand washing was reported most, followed by food and domestic hygiene, respectively.

In terms of geographic coverage, parts of the Horn, East Africa, along with Southern Africa and pockets of West Africa were represented. Governments are also making progress by having water and sanitation policies in place with reference to the importance of WASH have for the health and nutritional status of children. However, for many countries, much work needs to be done in the political sphere to bring new knowledge and evidence to the fore in order to keep policy mechanisms in tune with the requirements of the population. It is important to note that there are no

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Table 3. SSA policies

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Angola National Sanitary Development Plan (2012)	Angola	N/A	N/A	Angola National Sanitary Development Plan (2012)	The PNDS has ambitious objectives in all areas of the National Health System, including strengthening the fight against priority diseases, which currently frame communicable diseases and chronic non-communicable diseases, mother and childcare, improved proximity to services	N/A
National Water Policy (2008); National Action Plan for the Integrated Management of Water Resources (2011); National Heath Policy (2009); National Sanitary Development Plan (2009)	Benin	National Water Policy (2008); National Action Plan for the Integrated Management of Water Resources (2011)	Ensuring the public health protection with impacts on both public health and the socio-economic development of the country	National Sanitary Development Plan (2009)	Recognising the prominent role of health research in decision-making. The nutritional situation of women of childbearing age and their children is also worrying as 9% of them are underweight and 61% are anaemic	National Health Policy (2009) Policy initiatives for provision of water and sanitation through the Ministry of Mines, Energy and Water; Ministry of Health
Botswana National Water Policy (2012); Botswana National Health Policy (2011)	Botswana	Botswana National Water Policy (2012)	Safe, affordable and reliable water and sanitation must be provided to all the people of Botswana to promote a healthy population	Botswana National Water Policy (2012)	Safe, affordable and reliable water and sanitation must be provided to all the people of Botswana to promote a healthy population	Botswana National Health Policy (2011). Policy initiatives for provision of water and sanitation through the Ministry of Minerals, Energy and Water Resources
Policy and Strategies on Water in Burkina Faso (1997); Governance Programme for the Water and Sanitation Sector (2016); National Sanitary Development Plan (2011); National Health Policy (2011)	Burkina Faso	Policy and Strategies on Water in Burkina Faso (1997). Governance Programme for the Water and Sanitation Sector Burkina Faso (2016)	The impact of structures and facilities on public health, design of sanitation and irrigation systems to reduce diseases as well as then to education in hygiene and health. Decentralised technical services (water, health, education) improve the synergy of their actions towards local authorities	Governance Programme for the Water and Sanitation Sector Burkina Faso (2016). National Sanitary Development Plan (2011)	Decentralised technical services (water, health, education) improve the synergy of their actions towards local authorities. The major diseases of public health importance are malnutrition, diarrheal diseases women and child health. The Burkinabe Government is convinced that health is at the heart of development and has made it one of the priority sectors. Substantial progress has been made in the social sectors, including health and drinking water	National Health Policy (2011). Policy initiatives for provision of water and sanitation through the Ministry of Health

(*Continued*)

Table 3. (*Continued*)

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water Policy (2009); National Sanitation Policy and Operational Strategy Horizon 2025 (2013); National Sanitary Development Plan (2005)	Burundi	National Water Policy (2009)	The contribution of water in the health sector is the improvement of the health of populations through the consumption of quality water, environmental sanitation and hygiene. The agricultural deficit is due, among other reasons, to non-control of water for food production. It results in a high malnutrition, a precarious health situation	National Sanitation Policy and Operational Strategy Horizon 2025 (2013). National Sanitary Development Plan (2005)	The lack of adequate sanitation constitutes a disaster that is both sanitary, ecological and economic: the impact on the natural environment and on human health amounts to thousands of sick people and deaths. This policy aims to improve the health status of the population through nutrition and food security as well as the development of an inter-sectoral partnership that could contribute to improvement of health indicators – access to drinking water and basic nutritional services	Policy initiatives for provision of water and sanitation through the Ministry of Water, Environment, Development of the Territory and Urbanism and Public Health Ministry
National Action Plan for the Integrated Management of Water Resources (PANGIRE) (2009); National Health Technology Policy (2009); Sectoral Health Strategy (2016); Water Solidarity Programme (2013)	Cameroon	National Action Plan for the Integrated Management of Water Resources (PANGIRE) (2009)	It concerns the vital needs of men, economic activities, the protection of the environment, planning and public health. Water for agriculture, livestock and food	National Health Technology Policy (2009); Sectoral Health Strategy (2016)	The improvement of health services for the entire population of Cameroon through universal access to healthcare and services, the promotion of healthy behaviours and the development of healthy living environments. The acquisition of health-enhancing skills in the following areas: food and nutrition, nutritional status of children under five nutritional status of adults including women of childbearing age	Water Solidarity Programme (2013). Policy initiatives for provision of water and sanitation through the Ministry of Water and Energy (MINEE) and Ministry of Public Health
New Water and Sanitation Code (2015); National Health Policy (2007); National Sanitary Development Plan (2008); National Basic Sanitation Plan (2010)	Cape Verde	New Water and Sanitation Code (2015)	The human right to drinking water and sanitation is closely related to the right to the highest attainable standard of physical and mental health	National Sanitary Development Plan (2008) National Basic Sanitation Plan (2010); New Water and Sanitation Code (2015)	Among other objectives, health sector reform aims to promote equity in access to healthcare. Strengthening interventions targeting malnutrition. Environmental sanitation actions should be seen as a basic public health measure	Policy initiatives for provision of water and sanitation through the Ministry of health and National Water and Sanitation Agency National Health Policy (2007)

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Strategic plan to Strengthen Health Systems in CAR (2007); Health sector transition plan in Central African Republic (2015); National Health Development Plan (2017)	Central African Republic	N/A	N/A	N/A	N/A	Strategic plan to Strengthen Health Systems in CAR (2007); Health sector Transition Plan in Central African Republic (2015); National Health Development Plan (2017) The Central African Republic has developed and implemented several strategic documents related to the health sector with a view to improving the health of the people at the grassroots level. Improving the nutritional status of children. Schools and health centres lack sanitary facilities
The Master Plan for Water and Sanitation in Chad (2003); National health Policy (2006); National Sanitary Development Plan (2013); National Strategy for Universal Health Coverage of Chad (2015)	Chad	The Master Plan for Water and Sanitation in Chad (2003)	Water impacts on the sustainable improvement of population health	National Sanitary Development Plan (2013)	The national social protection strategy, in which the health component has been translated into a national strategy for universal sanitation coverage. In the field of malnutrition, there is still much to be done	Policy initiatives for provision of water and sanitation through the Ministry of Water and Sanitation and Ministry of Public Health National health Policy (2006). National Strategy for Universal Health Coverage of Chad (2015)
National Water Policy (N/D); Water Code (N/D); National Sanitary Development Plan (2010); National Health Policy (2005)	Comoros	National Water Policy (N/D). Water Code (N/D)	N/A	National Sanitary Development Plan (2010)	Protein-energy malnutrition is one of the national health concerns. Development of health services taking charge of health, nutrition	Policy initiatives for provision of water and sanitation through the Ministry of Production of the Environment, Energy, Industry and Crafts, Ministry of Health. National Health Policy (2005)
Law No. 15/026 concerning water (2015); Sanitary Development Plan (2016); Strategy for strengthening the health system (2006)	Democratic Republic of the Congo	Law No. 15/026 concerning water (2015)	Dealing with the health needs of the public health safety	Sanitary Development Plan (2016)	Contribute to the improvement of the state of health. Nutritional status: undernutrition is the most common type of malnutrition in the DRC	Policy initiatives for provision of water and sanitation through the Ministry of Public Health. Strategy for strengthening the health system (2006)
Water Code (2003)	Republic of the Congo	Water Code (2003)	N/A	N/A	N/A	Policy initiatives for provision of water and sanitation through the Ministry of Energy and Hydraulics; Ministry of Health and Population
Sectoral Policy for Drinking Water in Ivory Coast (2016); National Sanitary Development Plan (2016)	Ivory Coast	Sectoral Policy for Drinking Water in Ivory Coast (2016)	The overall objective of the programme is to contribute to the reduction of poverty and the improvement of population health	National Sanitary Development Plan (2016)	The overall objective of the programme is to contribute to the reduction of poverty and the improvement of population health. The Government of Côte d'Ivoire has made nutrition one of its priorities	Policy initiatives for provision of water and sanitation through the Ministry of Economic Infrastructure; Ministry of Health and Public Hygiene

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Table 3. (*Continued*)

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
Sanitary Waste Management Plan (2003); Sanitary Code (2007); National Sanitary Development Plan (2013)	Djibouti	N/A	N/A	Sanitary Waste Management Plan (2003); Sanitary Code (2007); National Sanitary Development Plan (2013)	Promotion of nutritional activities. The development of primary healthcare, health for all. A strong commitment to the fight against malnutrition	Policy initiatives for provision of water and sanitation through the Ministry of Health
	Equatorial Guinea	N/A	N/A	N/A	N/A	N/A
Ministry of Land, Water and Environment (Water Resources Department); Ministry of Health (Nutrition Unit); Eritrean Policy on Infant and Young Child Feeding (2013)	Eritrea	Action Plan for Integrated Water Resource Management (IWRM) in Eritrea (2008)	To improve the health and living condition of rural communities by achieving safe and sustainable sanitation and hygiene practices in relation to water supply and use	Action Plan for Integrated Water Resource Management (IWRM) in Eritrea (2008)	To improve the health and living condition of rural communities by achieving safe and sustainable sanitation and hygiene practices in relation to water supply and use	Eritrean Policy on Infant and Young Child Feeding (2013). Recommendations around food hygiene, hand washing and treatment of drinking water
Ethiopian Water Resource Management Policy (N/D); Ethiopian National Hygiene and Sanitation Strategy (2005)	Ethiopia	Ethiopian Water Resource Management Policy (N/D)	Provision of adequate reliable and clean water supply and sanitation services	Ethiopian National Hygiene and Sanitation Strategy (2005)	To complement the existing Health Policy and national water sector strategy while placing greater emphasis on 'on-site' hygiene and sanitation	Ethiopian National Hygiene and Sanitation Strategy (2005). Inter-sectoral collaboration delivered by health, water, education, rural development and agriculture offices
National Sanitary Development Plan (2011)	Gabon	N/A	N/A	National Sanitary Development Plan (2011)	Bring together the public health priorities accepted by all. Training/retraining health workers in the management of malnutrition cases. Developing cooperation between the Directorate General of Hydraulic Resources and the Ministry of Health	In 2018, Gabon plans to adopt a code of water and sanitation. Policy initiatives for provision of water and sanitation through the Ministry of Energy and Hydraulic Resources; Ministry of Health, Social Affairs, Solidarity and Family
Gambia National Water Policy (N/D); The Gambia National Strategy for Sanitation and Hygiene (2011)	Gambia	Gambia National Water Policy (N/D)	N/A	The Gambia National Strategy for Sanitation and Hygiene (2011)	Reduction in the frequency of environmental health and safety-related problems and diseases	Gambia National Nutrition Policy (2010). Support campaigns on environmental sanitation, including access to safe water supplies, personal hygiene, food hygiene and safety
National Water Policy (2007); Environmental Sanitation Policy (2010); National Nutrition Policy (2013)	Ghana	National Water Policy (2007)	Improving access to potable water and sanitation is critical to achieving favourable health outcomes, which in turn facilitates economic growth and sustained poverty reduction	Environmental Sanitation Policy (2010)	Improved environmental sanitation has direct effects on healthcare waste management, vector and waterborne diseases that affect millions of children and women	Through National Nutrition Policy (2013). The suboptimal water and sanitation situation in Ghana is a key underlying determinant of health and nutritional status

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Water Code (1994); National Declaration of Commitments of the Republic of Guinea: Water Sector and Sanitation Sector (N/D); National Health Policy (2014)	Guinea	Water Code (1994). National Declaration of Commitments of the Republic of Guinea: Water Sector and Sanitation Sector (N/D)	Health protection, pollution control and the preservation of the environment. Quantities of water needed for human nutrition, hygiene care. Improving the health status of populations. Impact on health and on the economy	National Declaration of Commitments of the Republic of Guinea: Water Sector and Sanitation Sector (N/D)	Impact on health and on the economy. Strengthening the national health system, scaling up of high-impact activities – vaccination, nutrition. Essential objectives that contribute to improving health. Protection of food and nutritional conditions	Policy initiatives for provision of water and sanitation through the Ministry of Water and Electricity; Health Ministry. National Health Policy (2014). Public Health Code (N/D)
Water Code (1992); Master Plan for Water Supply and Sanitation (1991); Sanitary Development Plan (2008)	Guinea-Bissau	Water Code (1992). Master Plan for Water Supply and Sanitation (1991)	N/A	National Sanitary Development Plan (2008)	Improving access to health services, equitable distribution of resources. Malnutrition is the first public health problem among non-communicable diseases	Policy initiatives for provision of water and sanitation through the Ministry of Public Health
The National Water Services Strategy (2007); Kenya Environmental Hygiene and Sanitation Policy (2016); National Food and Nutrition Security Policy (2011)	Kenya	The National Water Services Strategy (2007)	Assured water supply, sewerage services and basic sanitation for all Kenyans for improved health and wealth creation on an individual level and for the nation	Kenya Environmental Hygiene and Sanitation Policy (2016)	Ensure strong leadership and coordination at all levels to build and sustain governance for sanitation and hygiene across sectors especially water, health, nutrition, education, gender and the environment	National Food and Nutrition Security Policy (2011). Uptake of critical nutrition and health interventions focusing on child care practices, dietary choices, improved hygiene, water and sanitation are essential to address all forms of malnutrition
Lesotho Water and Sanitation Policy (2007); Health Sector Strategic Plan (2013)	Lesotho	Lesotho Water and Sanitation Policy (2007)	Develop and implement programmes aimed at creating public awareness on linkages between water supply, sanitation, health and hygiene	Lesotho Water and Sanitation Policy (2007)	Develop and implement programmes aimed at creating public awareness on linkages between water supply, sanitation, health and hygiene	Health Sector Strategic Plan (2013). Sanitation and hygiene are among the priorities of the health sector. Arrived at by examining contributions to the heaviest burden of disease
Water Supply and Sanitation Policy (2009); Nutrition Policy (2008)	Liberia	Water Supply and Sanitation Policy (2009)	Safe water, hygiene practices and sanitation are directly linked to improved public health, especially for vulnerable groups such as children	Water Supply and Sanitation Policy (2009)	Safe water, hygiene practices and sanitation are directly linked to improved public health, especially for vulnerable groups such as children	National Nutrition Policy (2008). To improve nutrition case management of childhood diseases and to improve access to quality health services, safe water, environmental sanitation and waste disposal systems
Water code (1999); Sectoral Policy Declaration for Water (2009); National Strategy for Water, Sanitation and Hygiene (2013); Policy and National Strategy for Sanitation (N/D). Health Sector Development Plan (2015)	Madagascar	Water code (1999). Sectoral Policy Declaration of water (2009). National Strategy for Water, Sanitation and Hygiene (2013)	The protection of water resources is integral to health and security. It is a necessary condition for poverty eradication, women's empowerment and health protection	National Strategy for Water, Sanitation and Hygiene (2013). Policy and National Strategy for Sanitation (N/D)	Integral to health and security. It is a necessary condition for poverty eradication, women's empowerment and health protection	Policy initiatives for provision of water and sanitation through the Water Ministry; Ministry of Energy and Mines; Ministry of Public Health. Health Sector Development Plan (2015)
National Water Policy (2007); National Sanitation Policy (2006); Infant and Young Child Nutrition Policy and Guidelines (2003); Food and Nutrition Security Policy (2005)	Malawi	National Water Policy (2007)	Improving public health through integration of rural water supply and Participatory Hygiene and Sanitation Transformation	National Sanitation Policy (2006)	Seeks to increase access to clean water and sanitation, improve the nutritional status of children and ensure food security	Infant and Young Child Nutrition Policy and Guidelines (2003). Caregivers should be advised to always follow the standard food hygiene rules when preparing food for the child to avoid food contamination. Food and Nutrition Security Policy (2005). Provision of safe water and adequate sanitation, and hygiene to prevent diseases

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Table 3. (*Continued*)

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water Policy (2006); National Water Policy and Code (2012); National Sanitation Policy (2009); Decennial Plan of Development and Health (2014)	Mali	National Water Policy (2006). National Water Policy and Code (2012)	Focus on sanitation, education for health and hygiene. Promote access to basic health, nutrition, clean water and sanitation	National Sanitation Policy (2009)	Broader vision of sanitation, which is then to make a healthier environment, not dangerous for human health and its environment	Policy initiatives for provision of water and sanitation through the Ministry of the Environment and Sanitation; Ministry of Health and Public Hygiene. Decennial Plan of Development and Health (2014)
Water Code (2005); Strategy for Development of the Water and Sanitation Sector (2012); National Health and Social Action Policy (2006); National Health Policy (2017)	Mauritania	Water Code (2005)	Ensure the supply of drinking water and ensure the protection of water intended for human nutrition decentralised health services for the promotion of autonomous sanitation and hygiene	Strategy for Development of the Water and Sanitation Sector (2012)	The taking into charge by the State, municipalities and investment associations of collective sanitation in public buildings (schools, health centres and others)	National Integrated Project of the Water Sector in Rural Areas (PNISER) – African Development Bank. Policy initiatives for provision of water and sanitation through the Ministry of Hydraulics; Ministry of Health. National Health and Social Action Policy (2006). National Health Policy (2017)
Water Management Policy (2013)	Mauritius	Water Management Policy (2013)	N/A	N/A	N/A	N/A
Water Law n.16/91 (1991); Water Policy (2007); National Strategy for Water and Urban Sanitation (2011); Health Sector Strategic Plan(2013)	Mozambique	Water Law n.16/91 (19991). Water Policy (2007). National Strategy for Water and Urban Sanitation (2011)	The purpose of sanitation of population centres is to ensure conditions compatible with the requirements of public health. To ensure maximum positive benefit for consumers and to avoid potential public health risks. Improving food security. It is urgent to introduce systematic measures to improve sanitation in order to safeguard the health and dignity of the population	National Strategy for Water and Urban Sanitation (2011)	It is urgent to introduce systematic measures to improve sanitation in order to safeguard the health and dignity of the population. Leading to a single result: improving the health status of the population	Policy initiatives for provision of water and sanitation through the Ministry of Construction and Water; Ministry of Public Works and Housing; Ministry of Health. Health Sector Strategic Plan (2013)
Water Supply and Sanitation Policy (2008); National Policy on Infant and Young Child Feeding (2003)	Namibia	Water Supply and Sanitation Policy (2008)	The development of adequate extension services for water supply and sanitation, covering the entire range from community management skills through technical training to health and hygiene education, is necessary for the revised WSS sector policy to succeed	Water Supply and Sanitation Policy (2008)	The development of adequate extension services for water supply and sanitation, covering the entire range from community management skills through technical training to health and hygiene education, is necessary for the revised WSS sector policy to succeed	National Policy on Infant and Young Child Feeding (2003). Wash hands before preparation. Use clean utensils washed in soap and water and boiled and kept covered. Boil water for 5 min and cool to room temperature before mixing
National Water and Sanitation Policy (N/D); National Sanitary Development Plan (2011); Strategic Plan of National System of Health Information (2012)	Niger	National Water and Sanitation Policy (N/D)	Following fundamental objectives: food security, protect the environment and health	National Water and Sanitation Policy (N/D) National Sanitary Development Plan (2011)	Following fundamental objectives: food security, protect the environment and health. Revitalisation of primary healthcare and halve malnutrition by 2015	Policy initiatives for provision of water and sanitation through the Ministry of Hydraulics and Sanitation of Niger; Ministry on Public Health. National System of Health Information (2012)

National Water Policy (2004); National Water Sanitation Policy (2004); National Policy on Food and Nutrition in Nigeria (2001); National Policy on Infant and Young Child Feeding in Nigeria (2010)	Nigeria	National Water Policy (2004)	The importance of eradicating poverty and therefore to enhance an improvement in public health through an optimal use of water resources for development remains the main driving force for the Government of Nigeria	National Water Sanitation Policy (2004)	Sanitation development is essentially multi-sectoral. An integrated approach combining safe sanitation, hygiene education and promotion and safe water supply ensures improved health and livelihood	National Policy on Food and Nutrition in Nigeria (2001). Malnutrition results from a combination of inadequate food intake, lack of access to clean water, and health and sanitation problems. National Policy on Infant and Young Child Feeding in Nigeria (2010). Combat disease and malnutrition, including within the framework of primary healthcare, through, the provision of adequate nutritious foods and clean drinking water
National Water Supply Policy (2016); National Sanitation Policy (2016); National Food and Nutrition Policy (2013); National Nutrition Policy (2007)	Rwanda	National Water Supply Policy (2016)	Poor water supply and sanitary conditions due to the lack of adequate water supply promote diarrhoea, intestinal parasites and environmental enteropathy, and have complex and reciprocal links to malnutrition in children	National Sanitation Policy (2016)	The health cross-sector collaboration has to be strengthened to tackle multi-factorial determinants affecting the health of the population (poverty reduction, nutrition and food security, water and sanitation	National Food and Nutrition Policy (2013). Problems of water, hygiene and sanitation affect the synergy between malnutrition and infection. High priority for hygiene is justified because improved personal and domestic hygiene practices can reduce diarrhoea. National Nutrition Policy (2007). Scaling up of community-based nutrition programmes requires social mobilisation activities for the promotion of safe water, personal and environmental hygiene
Participatory Strategy for Water and Sanitation of São Tomé and Príncipe (2012)	São Tomé and Príncipe	Participatory Strategy for Water and Sanitation of São Tomé and Príncipe (2012)	Recognising that the water and sanitation sector are two important axes for the development of the country, since they contribute positively to the improvement of health and contribute to poverty reduction, in particular in reducing malnutrition	Participatory Strategy for Water and Sanitation of São Tomé and Príncipe (2012)	Recognising that the water and sanitation sector are two important axes for the development of the country, since they contribute positively to the improvement of health and contribute to poverty reduction, in particular in reducing malnutrition	Policy initiatives for provision of water and sanitation through the Ministry of Public Works and Natural Resources
Integrated Management Action Plan for Water Resources in Senegal (2007); Sanitation Code (2009); National Plan of Health Development (2009); National Policy of Community Health (2014)	Senegal	Integrated Management Action Plan for Water Resources in Senegal (2007)	The issue of water is a national issue given its impact on different sectors of development of the country: health, industry	Sanitation Code (2009). National Plan of Health Development (2009)	Prevent damage to health. Health policy remains based on primary healthcare. Developing nutrition policy	Policy initiatives for provision of water and sanitation through the Ministry of Urbanism, Habitat, Urban Hydraulics, Public Health e Sanitation; National Plan of Health Development (2009). National Policy of Community Health (2014)
National Water Policy (2017); Comprehensive and Integrated Sanitation Master Plan (2014); National Health Policy (2016)	Seychelles	National Water Policy (2017)	N/A	Comprehensive and Integrated Sanitation Master Plan (2014)	N/A	National Health Policy (2016). The Constitution of Seychelles ensures free primary healthcare and universal access to safe drinking water, good sanitation and housing provision

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Table 3. (*Continued*)

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water and Sanitation Policy (2010); Sierra Leone National Food and Nutrition Security Policy (2012)	Sierra Leone	National Water and Sanitation Policy (2010)	The Ministry of Health and Sanitation is responsible for public health and sanitation in the country. By its mandate, it is responsible for conducting health studies and reporting incidences of waterborne communicable diseases; water quality testing; and investigating sources of water pollution	National Water and Sanitation Policy (2010)	The main objective is to improve the health of communities and ensure that the majority of the population has access to sanitation services	Sierra Leone National Food and Nutrition Security Policy (2012). Factors including access to reliable health services and living in sanitary environments with access to potable water are necessary for proper food utilisation
IYCF Strategy and Action Plan Somalia (2017)	Somalia	N/A	N/A	N/A	N/A	IYCF Strategy and Action Plan Somalia (2017). Poor water, hygiene and sanitation practices are common in Somalia and are a key contributor to malnutrition. There is low access to safe water or to sanitation facilities. Hygiene practices such as hand washing at key times with soap or ash are uncommon
National Water Policy for South Africa (1997); National Sanitation Policy (2016); Infant and Young Child Feeding Policy (2008); National Policy on Food and Nutrition Security (2014)	South Africa	National Water Policy for South Africa (1997)	The Right of access to sufficient water promises every child the right to, among other things, basic nutrition and healthcare services	National Sanitation Policy (2016)	The public health benefits of improved sanitation are maximised when sanitation is planned and provided in an integrated manner with other basic services	Infant and Young Child Feeding Policy (2008). Ingestion of contaminated water, fluids and food may lead to gut mucosal damage and disruption of immune barriers. National Policy on Food and Nutrition Security (2014). Tackling the problems of poverty, inequality and unemployment. It is a roadmap to a South Africa where all will have water, electricity, sanitation, jobs, housing, public transport and adequate nutrition
Water Policy (2007); Health Sector Development Plan (2012)	South Sudan	Water Policy (2007)	The provision of safe drinking water, basic sanitation and clean environment at household level can have a major impact on health	N/A	N/A	Health Sector Development Plan (2012). The widespread water contamination due to poor sanitation as a result of inappropriate solid and liquid waste disposal systems12 is a major risk factor for diseases
Water Supply and Environmental Sanitation Policy (2010); National Nutrition Policy (2009)	Sudan	Water Supply and Environmental Sanitation Policy (2010)	The overall goal of the water supply and environmental sanitation policy is to contribute in improving the health status and living conditions of the population and the economic growth of the nation by providing all of the population with adequate and sustainable access to WASH basic services and hygienic practices	Water Supply and Environmental Sanitation Policy (2010)	The overall goal of the water supply and environmental sanitation policy is to contribute in improving the health status and living conditions of the population and the economic growth of the nation by providing all of the population with adequate and sustainable access to WASH basic services and hygienic practices	National Nutrition Policy (2009). Nutrition is not adequately mainstreamed into either pre-service or in-service training for wider public health staff, nor for staff in related sectors such as education, water and sanitation and agriculture. As a result, the ability to work together across sectors is limited

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National Water Policy (2009)	Swaziland (Eswatini)	National Water Policy (2009)	Swaziland has a social, moral and economic responsibility to ensure that all its citizens have adequate access to safe water and adequate sanitation to guarantee human dignity and health	N/A	N/A	N/A
National Water Policy (2002); National Nutrition and Social Behaviour Change Communication Strategy (2013)	Tanzania	National Water Policy (2002)	Safe drinking water and good sanitation practices are basic considerations for human health. Use of contaminated sources pose health risks to the population as evidenced by the incidences of waterborne diseases	N/A	N/A	National Nutrition and Social Behaviour Change Communication Strategy (2013). Higher priorities for behaviour change in relation to provision of food, and attention to critical actions in the area of water and sanitation and hand washing
National Policy for the Supply of Drinking Water and Sanitation in Rural and Semi-Urban Areas (2006); National Action Plan for the Water and Sanitation Sector (N/D); National Action Plan for Integrated Water Resources Management (N/D); National Health Policy (N/D); National Plan of Sanitary Development (N/D)	Togo	National Policy for the Supply of Drinking Water and Sanitation in Rural and Semi-Urban Areas (2006). National Action Plan for the Water and Sanitation Sector (N/D)	Improving the health of users is one of the objectives of this policy. Very significant potential impact in terms of improving public health	National Action Plan for the Water and Sanitation Sector (N/D); National Plan of Sanitary Development (N/D)	Strengthening the fight against malnutrition and micronutrient deficiencies. Very significant potential impact in terms of improving public health. Based on the vision of a Togo where the highest level of health is ensured to the population	Policy initiatives for provision of water and sanitation through the Ministry of Mines, Energy and Water; Ministry of Water, Sanitation and Rural Hydraulics; Ministry of Health and Social Protection
National Water Policy (1999); National Sanitation Policy (1997); Uganda Food and Nutrition Policy (2003); Policy Guidelines on IYCF (2009)	Uganda	National Water Policy (1999)	Promotion of public health and nutrition through reducing public health risks in irrigation and livestock water supply systems and increasing nutritional levels	National Sanitation Policy (1997)	The high incidence of diarrhoea has remained a leading cause of nutritional stunting. The goal of this policy is to promote and preserve the health of the community through improved sanitation. Attaining and maintaining a good standard of sanitation will greatly contribute to reducing mortality and morbidity from sanitation-related diseases as well as improving the socio-economic status of the community	Uganda Food and Nutrition Policy (2003). Promote the use of safe drinking water and sanitary means of waste disposal. Policy Guidelines on IYCF (2009). Encourage parents to practice high standards of hygiene when handling the infant's food and also to maintain sanitation standards and food/water safety
National Water Policy (2010); National Food and Nutrition Policy (2006)	Zambia	National Water Policy (2010)	The benefits from supply of sufficient quantities and good quality water and sanitation are important for the sustenance of health	N/A	N/A	National Food and Nutrition Policy (2006). Poor access to adequate quantity and quality of domestic water and poor sanitary conditions contributes to outbreaks of waterborne and other diarrhoeal diseases. These are closely associated with malnutrition

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Table 3. (*Continued*)

Ref	Country	Water Policy	Link to Health/Nutrition	Sanitation Policy	Link to Health/Nutrition	Other WASH and Health/Nutrition Links
National Water Policy (2012); National Sanitation and Hygiene Policy (2017); National Nutrition Strategy (2014)	Zimbabwe	National Water Policy (2012)	The Ministry of Health and Child Welfare (MHCW) is a key player in the Rural WASH subsector responsible for water quality monitoring, promoting safe water supply and household sanitation. MHCW is responsible for promoting improvements in domestic hygiene, specifically through adoption of safe self-supply drinking water systems, and household investments in improving excreta disposal and safe sanitation	National Sanitation and Hygiene Policy (2017)	The Ministry responsible for health will be tasked with sanitation and hygiene subsector leadership on policy and standards. Poor access to sanitation and hygiene increases the disease burden leading to loss of productive time and increasing health costs	National Nutrition Strategy (2014): Government is committed to ensuring nutrition security for all through the implementation of evidence-based nutrition interventions that are integrated within a broad public health framework including health services, water and sanitation

specific health or nutrition outcomes that policies are evaluated against, especially not when it comes to children, and that each component of the WASH triad also have their own unique intricacies.

The link between WASH and nutrition is not one that should come as a surprise. WASH has long been part of the UNICEF conceptual framework, which provides a lens through which maternal and child undernutrition can be examined. This is achieved through providing a scalar model that incorporates immediate causes such as disease and dietary intake, underlying causes including household environment, food security and health services, as well as basic causes, referring to socio-economic and political context.[31]

Advocating for multi- and inter-sectoral approaches are therefore not new.[31,35,47,90,91] Fundamental to these kinds of grand challenges is the integration of various actors and the effective governance of resources and services as a precondition for the effectiveness and sustainability of WASH programmes and services.[29] Overwhelmingly, it seems that governments are committed, at least in principle and in policy, to linking WASH to health and/or nutritional outcomes (Table 3).

When it comes to dealing with the nexus between governance, WASH and nutritional status in children in SSA, scalability and sustainability depend on good governance and technical factors such as infrastructure and improved knowledge, and the availability of financial resources. However, while actors and stakeholders at various levels in the policy and governance arena advocate for multi- and inter-sectoral approaches, most nutritional status indicators show disappointing results. In 2013, for example, global estimates put the number of stunted children in LMIC at 161 million.[48] African prevalence's have stagnated since 1990 at about 40% and current trends suggest little improvement with business as usual.[1] Countries in SSA continue to make headway in terms of increased access to WASH services, financial resources however remain a critical issue.[92] Current levels of WASH financing are not sufficient to fund the achievement of SDG 6, estimated to cost an approximate $122 Billion between 2016 and 2030.[18,92] Important gaps in financing still exist with SSA countries, on average, committing 0.52% GDP to WASH expenditure. When excluding South Africa, this figure drops to a mere 0.27% GDP. Aid commitments for WASH to SSA have also declined from US$ 3.8 billion to US$ 1.7 billion from 2012 to 2015.[92]

Governance issues therefore include limited managerial capacity, poor financial resource administration, corruption and weak institutions, which all limit the capacity of the national sector to deliver sustainable results at scale.[93] No blueprints for WASH governance exist and no easy answers can be found on what constitutes the best governance model. Every country has its own set of governance systems, stakeholder dynamics and institutional structures, and therefore faces different problems and priorities.[29] The primary responsibility for service delivery of water and sanitation, as both a basic service and a human right, lies with the State; however, even if the State holds ultimate responsibility, a number of stakeholders take part in the implementation. The Commission on Global Governance defines governance as follows: 'the sum of many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting and or diverse interests may be accommodated and cooperative action may be taken. It includes formal [. . .] as well as informal arrangements that people and institutions have agreed to or perceive to be in their interest'.[94] Importantly is the distinction that governance is not exclusively

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government, as it includes non-governmental (NGO), inter-governmental organisations (IGOs), as well as civil society.[94] With 2025 WHO Nutrition Targets[25] and 2030 SDG[28] deadlines looming, concerted efforts to actively facilitate the necessary inter-sectoral approaches require efforts from all stakeholders to engage so that interventions are not logistically and/or financially prohibitive.

One possible model is that of the South African context where a minister in The Presidency is appointed, overseeing the Department of Planning, Monitoring and Evaluation in order to coordinate planning, monitoring and evaluation of government programmes aimed at improving service delivery, outcomes and impact on society. The main objective of which is to rally around a common set of objectives and priorities to drive development and crosscutting issues.[95] Furthermore, it gathers people from different departments to discuss inter-sectoral issues. Multi- and inter-sectoral approaches require a significant degree of political will, and while gaps across SSA persist in terms of addressing specific sociocultural and political contexts, on a positive note, for the most part across SSA, there are policies concerned with water and sanitation, which furthermore make explicit reference to health and/or nutrition as seen in Table 3.

Moreover, studies linking governance, WASH and nutritional status are increasing, providing a more nuanced perspective on associations on the various components of WASH (Fig. 3). However, much grey literature was not included in this systematic review, most likely due to the peer-reviewed format of scientific publications, thus limiting the body of knowledge included in this review. The authors searched grey literature databases including, the Grey Literature Report in Public Health,[40] African Index Medicus,[41] the WHO Virtual Health Sciences Library,[42] as well as conference proceedings and websites and furthermore reviewed reference lists and where appropriate contacted experts and authors and found that the grey literature concerned with WASH, nutritional status and governance was predominantly located within the IGO and development sector and associated agencies. Examples of this includes the UN through the WHO,[3,39] UN Water,[92] UNICEF,[3,29,31,93] NGOs such as Save the Children[96] and foreign development cooperation agencies such as United States Agency for International Development (USAID).[3]

Grey literature also tended to be narrowly focused on a particular WASH component (either water, or sanitation or hygiene – in particular hand washing) and particular disease context, for instance, tuberculosis, HIV or helminth infections, and while acknowledging the role that nutrition plays, rarely made an explicit link between WASH, nutritional status and governance. WASH is in itself a composite concept comprising individual components each with its own body of research and associated complexities. Part of the complexity for WASH as a consolidated concept and topic for research as well as for service delivery seems to be agreeing upon a common nomenclature and standardised definition of what is being discussed. In this regard, the UN JMP[43,97] and the WHO and UN Water[39,98] have made significant progress in establishing a set of indicators, classifications and units of analysis.

In addition, the bulk of discussions concerned with the nexus between WASH, governance and nutritional status in this systematic review is situated in observational studies and reviews (Fig. 2), thus highlighting the need for more in-depth knowledge on the topic in the various SSA contexts. Surprisingly, no trials were found to form part of the literature under review. This may, in part, be due to the specificity of the search terms. Involvement of various stakeholders and implications for implementation, scalability and policy may not have been reported, specifically in a scientific forum. Furthermore, trials are expensive and while not methodologically required to report on the various interactions with stakeholders are perhaps not explicitly focused on the links to governance structures and civil society as oppose to exploring the biological pathways and determinants.

A 2013 Cochrane Review on the effect of WASH interventions on nutritional status in children highlighted the low number of studies and low methodological quality of studies conducted in the past.[24] As such, the production of high-quality data beyond observational associations is a relatively recent development. Despite recent trial results indicating a marginal effect of WASH interventions on linear child growth,[21,23,24] further exploration of the data from these and forthcoming trials[20,22] will provide a more nuanced perspective on what does and does not work. Broader questions emerge from these results such as, while the microbial quality of drinking water available may be improved, the quantity of water long argued to be a key driver in water-related health gains remains an important consideration.[99,100] Population density and proximity to sanitation facilities are significant drivers in improving environmental conditions around children while delivering community-wide interventions are important for showing an effect of sanitation on linear growth.[21] Other pathways such as nutrition, animal waste and complementary foods as pathways for enteric infection cannot be overlooked. These results show how little we know about the transmission of enteric pathogens, the causes of symptomatic infections and the significance of asymptomatic infections, while at a policy level business as usual in the WASH sector will not be enough to significantly improve child growth.[99]

Conclusion

This systematic review sought to examine the literature linking governance, WASH and childhood nutritional status, in sub-Saharan African settings. The authors found that policy makers would benefit from integrating this emerging evidence-based information into their respective policies in order to better articulate and address the intricacies of WASH in various contexts. Utilising consistent and established terminology when referring to the challenges and recommendations for service provision would allow for a more targeted discussion around which particular aspects of the WASH components require further consideration. The importance of early-life exposures and associations with disease risk in adulthood provides further impetus for tackling WASH from a governance perspective. Neither observational studies nor intervention studies included components exploring the role of governance of WASH in their design nor described if and how actors in the field of WASH were incorporated into the research process. Integrating the role of governance through the involvement of civil society, communities, IGOs, government as well as development agencies would be a recommendation for future studies on the topic. The scientific and research community could further contribute by considering the manner in which study findings could or should be operationalised and gain real-world application. Incorporating WASH components in line with consistent and established terminology and definitions will make study design as well as the results that emanate from such studies more pertinent and reproducible. At the same time, more trials are also needed to determine and to evaluate more effective WASH interventions to halt the vicious cycle of exposure to poor WASH

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conditions in early childhood, repeated infections, inflammation and disease risk in adulthood.

Undernutrition has a complex set of political, social and economic causes, none of which are amenable to easy solutions. Important knowledge gaps still remain concerning critical aspects of child undernutrition, including environmental risks in the neonatal and infant periods, especially in sub-Saharan contexts. Vast differences inevitably occur between communities, between urban and rural, between socio-economic and political landscapes, and between regional and global contexts. The complexity of this is further compounded with the realisation that access to water and sanitation is problematised through an increasingly resource and climate-constrained context. Water resources are found in a variety of geographic settings that transcend geopolitical boundaries. Given the complex spatial context and transboundary nature within which water is situated, a number of dichotomies emerge when attempting to analyse national, regional and even continental or global WASH strategies and initiatives.

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Conflicts of Interest. None.

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Original Article

Intersectoral (in)activity: towards an understanding of public sector department links between water, sanitation and hygiene (WASH) and childhood undernutrition in South Africa

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Abstract

Associations between different forms of malnutrition and environmental conditions, including water, sanitation and hygiene (WASH), contribute to poor child health, nutritional status and physical growth. The primary responsibility for the provision of water and sanitation, as a basic service and human right, lies with the State, as such, a number of stakeholders are involved. Despite relatively high levels of WASH infrastructure coverage in South Africa, enteric infections and stunting remain high for a middle-income country. The aim of this study is to elucidate the landscape of WASH in South Africa in relation to nutritional status of children under the age of 5 years in the South African, Gauteng and City of Johannesburg contexts. The authors detailed the national and provincial public sector departments and through purposive sampling proceeded to map the various departments and associated policies that are responsible for the provision of WASH facilities, as well the nutritional status of children. Of the six policies identified for review, three mentioned WASH, nutrition and children; however, none explicitly linked WASH to nutritional status in children. An in-depth review and analysis of these three crucial policy documents was conducted. Finally, a set of expert interviews were conducted and a consensus development conference convened, with experts at the intersection between WASH and nutritional status. The authors found that the public sector would benefit from better integration of the concept of WASH into their policy, planning and implementation frameworks. The WASH sector should emphasize the role in which WASH plans consider the impact of WASH on the nutritional status of children. The various public sector departments involved in WASH service provision, and other WASH stakeholders, including community-based organizations, non-governmental organizations and intergovernmental organizations, should be involved in the decision-making of the nutrition sector.

Keywords: South Africa, WASH, nutrition, policy, children

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Key Messages

- Biological links between water, sanitation and hygiene (WASH) and nutritional status in children are well known; however, there is no clearly defined link between the various WASH components in government departments, and as such no defined responsibility.
- Government departments would benefit from better integrating the concept of WASH into their policy, planning and implementation frameworks.
- Gaps remain in relating governance and public policy analysis to health-related outcomes.

Introduction

Undernutrition stems from a range of biological, contextual and structural determinants, including antenatal, intrauterine and postnatal malnutrition. Undernutrition is the outcome of inadequate macro- and micronutrient intake and repeated infections, defined as <2 SD from the median of the reference population, and includes underweight (low weight-for-age; WAZ < −2 SD), stunting (low height-for-age; HAZ < −2SD) and wasting (low weight-for-height; WHZ < −2SD) (Fernandez *et al.*, 2002; Members of the WHO Multicentre Growth Reference Study Group, 2006; Black *et al.*, 2008). Undernutrition in children is of particular concern from a public health perspective because of its association with health and risk of diseases such as diabetes, hypertension and cardiovascular disease in adulthood and is also a predictor of physical growth, mental and cognitive development in childhood (Victora *et al.*, 2008; de Onis *et al.*, 2012; Spears *et al.*, 2013; WHO/UNICEF/USAID, 2015; Piper *et al.*, 2017). In this regard, childhood physical growth is used as a proxy for childhood nutritional status. Studies indicating that growth cannot be entirely improved by optimized diet have shown that environmental factors, including water, sanitation and hygiene (WASH), contribute to poor child growth and nutritional status (Mbuya and Humphrey, 2016). The composite concept of WASH is comprised the three spheres of WASH. While each represents a separate field of work, each is dependent on the presence of the other. For example, without toilets, water sources become contaminated and, without clean water, basic hygiene practices are not possible (UNICEF, 2016). Aspects of water include focus on the quantity and quality, as well as type of, and distance to, infrastructure, while the sanitation component includes focus on the access to, type of, and distance to, infrastructure; finally, the hygiene component emphasizes access to handwashing facilities with soap and nurturing good hygiene practices (UNICEF, 2016). Exposure to poor WASH during early childhood has been associated with higher risks of infections and poor nutritional status, including stunting (McDade, 2012; Guerrant *et al.*, 2013). Stunting is the result of a cyclical process of chronic exposure to undernutrition and repeated infections where women who were themselves stunted are at higher risk of having stunted offspring, creating an intergenerational cycle of poverty, reduced human capital and disease that is difficult to break (Prendergast and Humphrey, 2014; Norris *et al.*, 2017). Specific faeco-oral pathways are proposed by the so-called 5-F diagram, whereby faeces and associated pathogens are transmitted via fluids, fields/floors, flies and fingers to foods and then to the infant, which causes disease and infection, which in turn leads to growth faltering (Cumming and Cairncross, 2016). Growth faltering is one of the physical consequences of undernutrition stemming from an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein or micronutrients that negatively affect growth and development (Victora *et al.*, 2010; Leroy *et al.*, 2014; Nabwera *et al.*, 2017; McAlpine *et al.*, 2019). An analysis of Demographic and Health Survey data from 70 low- and middle-income countries (LMIC) found that increasing access to and use of improved water sources reduced the risk of stunting in children under the age of 5 years (Fink *et al.*, 2011).

The United Nations Children's Fund has advocated for the link between WASH and nutritional status for ∼30 years and through the Conceptual Framework (1990), for Improved Nutrition of Children and Women in Developing Countries (The United Nations Children Fund, 1990), and provides a lens through which maternal and child undernutrition can be analysed. A scalar model is presented that highlights immediate, underlying and basic causes, incorporating the circumstances and determinants of maternal and child undernutrition from disease and dietary intake, to household environment and food security, to socio-economic and political context (The United Nations Children Fund, 1990). The Lancet Series on Maternal and Child Nutrition (2008) highlighted the link between WASH and nutritional status by reviewing evidence-based interventions that affect maternal and child nutrition-related outcomes, emphasizing the importance that WASH plays in preventing undernutrition (Bhutta *et al.*, 2008). The 2013 follow-up series provided an updated framework including recommendations for intersectoral approaches to the challenges of malnutrition in LMIC settings, including an emphasis on WASH (Bhutta *et al.*, 2013; Black *et al.*, 2013).

While the WASH concept was permeating the public health arena, from a policy perspective, the United Nations (UN) formally declared the right to water in 2002, noting it as indispensable to human dignity and a prerequisite for the realization of other human rights. The right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use (United Nations High Commissioner for Human Rights, 2003). This provided the first reference to the responsibilities that Governments and service providers have in delivering clean water and sanitation to everyone (Mwebaza and Kotze, 2009). In 2010, the UN General Assembly extended this remit and adopted a resolution including and recognizing sanitation as a human right (Dugard, 2016). In the African context, Article 14 of the African Charter on the Rights and Welfare of the Child (ACRWC) (African Union, 1990) ensures the provision of adequate nutrition and safe drinking water and that all sectors of society are informed and supported in the use of basic knowledge of child health and nutrition and the importance of hygiene and environmental sanitation.

Despite the ACRWC having been ratified by 49 member states, the situation is most critical in sub-Saharan Africa (SSA), where at the closing of the Millennium Development Goals cycle in 2015, the portion of people relying on untreated surface water for drinking was eight times higher than any other region. During this period,

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>70% of SSA populations were living without adequate sanitation and the total number of people practising open defaecation actually increased (Markle and Donnenfeld, 2016). Conversely, between 2000 and 2017, the percentage of people in SSA using safely managed sanitation and drinking water increased from 20% to 32% and from 18% to 27%, respectively (UNICEF/WHO, 2019). However, these improvements did not significantly reflect in the nutritional status of African children. While stunting among children in Africa has decreased in percentage terms from 38.3% (2000) to 30.3% (2017), over the same period, due to population growth, the actual number of stunted children has risen (UNICEF, WHO and World Bank, 2017; Independent Expert Group of the Global Nutrition Report, 2018).

The South African setting is characterized by various transitions resulting in a multiple burden whereby the population faces under- and over-nutrition as well as micronutrient deficiencies (Norris *et al.*, 2014). Over-nutrition exists when the amount of nutrients exceeds the amount required for normal growth, development and metabolism.

With regard to WASH infrastructure, in 2015, the national percentage of households with access to piped or tap water in their dwellings was 89.4. In terms of national sanitation coverage, 270 000 South African households were reliant on buckets, while one in five households did not have access to improved sanitation facilities (Statistics South Africa, 2016; Parliamentary Monitoring Group, 2017).

National budgetary data suggest that spending on water and sanitation is increasing, accounting for 15.3% of public sector expenditure amounting to a total of R132 billion disbursed via various infrastructure grants (National Treasury: Republic of South Africa, 2019). At the provincial level, due to service provision for water and sanitation not being administered at this level, but rather national and local levels, there are sparse budgetary data for this.

Despite the high coverage levels of WASH infrastructure in South Africa, diarrhoeal diseases are the second leading cause of mortality in children under 5 years of age (Rispel and Padarath, 2018). The aetiology of diarrhoea in the South African context is closely linked to socio-economic status, and illnesses such as HIV/AIDS, access to vaccinations and poor environmental conditions (Chola *et al.*, 2015). Between 2011 and 2016, in children under 5 years of age, the prevalence of stunting was 27.4% and, over the same period, 5.9% were underweight and 2.5% were wasted (Statistics South Africa, 2017; Rispel and Padarath, 2018). Worryingly, despite the provision of social grants, free primary health care and vitamin supplementation, this prevalence rate has been unchanged since 1994 (Said-Mohamed *et al.*, 2015; Devereux, *et al.*, 2019). The relationship between WASH at household level and infant growth has received little attention in the South African context, which drastically limits our capacity to disentangle which installations and/or caregiver practices expose infants to such risks (Padarath *et al.*, 2016).

Intergovernmental organization (IGO) and regional organization, national governments and academic research at global, regional and national levels have recognized the importance of the link between WASH and nutritional status in children. Disappointingly, however, continued siloed efforts to reduce the prevalence of undernutrition in SSA, and in particular, South Africa, one of the most economically developed countries of the region, via improving infrastructure and access to WASH, have not been sufficient. Globally, much of the literature concerned with health policy analysis has focused exclusively on the content of policy documents and has neglected the actors involved in policy implementation and reform, while emphasis on health policy analysis in LMIC settings is still lacking (Walt and Gilson, 1994). In SSA settings, gaps remain in relating governance and public policy analysis to health-related outcomes (Momberg *et al.*, 2020), while in the South African context, there is no clear delineation of roles and responsibilities relating to the integration of WASH and nutritional status, including intergovernmental relations (IGR) on how to address the nutritional status of children.

The aim of this study is therefore to elucidate the landscape of WASH in South Africa in relation to nutritional status of children under the age of 5 years. While interested in the broader South African context, emphasis is placed on the specific manner in which this manifests in Gauteng and the City of Johannesburg (CoJ). Of particular interest was to learn which public sector departments were involved at the confluence of WASH and nutritional status in children, their level of co-ordination, barriers to the implementation of strategies designed to address the link between WASH and nutritional status and, finally, make recommendations to address these barriers.

This study has three interrelated objectives: first, to map public sector departments that are responsible for the provision of WASH facilities, as well as the nutritional status of children; second, to identify and examine policy documents related to the confluence of WASH and nutritional status to explore the extent to which they address the link between WASH and nutritional status in children; and finally, to engage with experts at the intersection between WASH and nutrition to understand the vertical and horizontal co-ordination of public sector departments.

Methods

Study design

This study, initiated in 2019, used an exploratory qualitative study design (Walt and Gilson, 1994; Gilson, 2012) to reflect on the nexus between WASH and nutritional status in children, in the public sector in South Africa focusing on the Gauteng province and the CoJ.

Study site

The study site, the CoJ metropolitan council, is situated in the Gauteng province and is home to the largest township in South Africa, Soweto. Soweto's population is officially estimated at 1.3 million, with between 600 000 and one million people in the township regarded as living in extreme poverty (Harrison and Harrison, 2014). In 2015, Gauteng had 97.7% piped water coverage and 91.0% sanitation coverage (Statistics South Africa, 2016; Parliamentary Monitoring Group, 2017). The CoJ, in 2016, reported that 99.5% of inhabitants had access to sanitation facilities and 99.9% had access to water (Statistics South Africa, 2018). The CoJ, which is an urban area, is better resourced as compared to other parts of South Africa, and although the provision of infrastructure is well covered, the provision of operation, maintenance and repair services can become a risk factor for infant nutritional status/growth. In terms of water quality, 2019 data from Johannesburg Water indicate a total of 12 incidents of non-compliance for microbiological safety requirements (presence of *Escherichia coli*) and 10 chemical and physical incidents of non-compliance (related to turbidity). Despite these incidents of non-compliance, overall compliance targets were maintained (Johannesburg Water, 2019). For the CoJ, spending on water and sanitation infrastructure is decreasing, however so too are the absolute number of people without access to basic water and sanitation services. Spending,

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however, for repair, maintenance and upgrading of existing infrastructure is increasing (City of Johannesburg, 2019). The South African Health Review reported that, in Gauteng, between 2011 and 2016, the prevalence of children under the age of 5 years who were wasted was 1.3%, 4.6% were underweight and 34.2% were stunted, representing the highest prevalence of stunting in the country (Rispel and Padarath, 2018).

Data collection

Institutional mapping

The authors detailed all national and provincial government departments in South Africa. South Africa is constituted on a quasi-federal system with three spheres of government at national, provincial and local levels (Butler, 2009; Muthien, 2014; Mahlangu *et al.*, 2018). National government is responsible for developing policy frameworks, defining norms and standards for service provision and distributing revenue in an equitable manner; provincial and local governments are responsible for implementing most public functions and for putting into effect the policies developed at national level (Department of Public Service and Administration, 2003; Butler, 2009; Mahlangu *et al.*, 2018). Provincial government enjoys legislative and executive powers concurrent with national government; local government on the other hand can take the form of either metropolitan councils or district or local municipalities and have varying degrees of legislative and executive authority (Republic of South Africa, 1998).

After collating the national and provincial government departments in South Africa, purposive sampling (Gilson, 2012) and an institutional analysis and development framework (Aligica, 2006) were used to select and include public sector departments that are responsible for the provision of WASH, as well as nutrition, presented in Table 1. The following inclusion criteria were used: participants (the public sector departments tasked with responsibility for the provision of WASH facilities and those tasked with ensuring the adequate nutritional status of children); scale (level at which the particular departments work, either national, provincial, or local); mandate (the department's responsibility in the provision of WASH facilities, as well as the nutritional status of children); and finally, scope for action (the department's agency to act in a co-ordinating or independent capacity to address the link between WASH and nutritional status in children).

Document review

Electronic searches for each of the departments included were conducted to identify and examine current policies and to determine whether any explicit link between WASH and nutritional status in children was present. A document review guide was developed to structure the review process and was informed by the Walt and Gilson (1994) model for health policy analysis, focusing on understanding the content of policy documents, actors, context and process of interaction between public sector departments (Walt and Gilson, 1994).

Expert interviews

Key informants, informed by the institutional mapping and document review, located at national, provincial and local levels, in government departments, community-based organizations (CBO), non-governmental organizations (NGO) and IGO with unique insight and experience of the confluence between WASH and nutrition as it relates to nutritional status in children in South Africa were identified. The authors approached respondents and, in the process, identified alternative key informants from those that did not consent to participate. Those that were approached were also asked if they themselves were not able to participate if they could recommend others that the authors could contact.

An open-ended interview guide was used to conduct key informant in-depth interviews as well as a consensus development conference reflecting upon: (1) the perceived links between WASH and nutritional status; (2) barriers to the implementation of strategies designed to address the link between wash and nutritional status; and (3) solutions and/or recommendations to the aforementioned barriers.

In addition to key informant in-depth interviews, a modified consensus development conference method (Jones and Hunter, 1995; James and Warren-Forward, 2015) was convened providing a forum for discussion and deliberation and was comprised an expert panel of representatives from academia, public sector departments, CBO, NGO and IGO. The panel was presented with evidence pertaining to the institutional mapping and document review. The discussion was moderated by an independent chairperson ensuring that all panel members had an opportunity to contribute.

Data analysis

The authors identified and mapped actors and their respective mandates and identified factors that determine patterns of interaction (Aligica, 2006). The information gathered was analysed following the World Health Organization's methodology for mapping governance and health for well-being (World Health Organization, 2018) outlining the public sector departments included in this study. This provides a graphical representation of the structure and processes within a system and a map reflecting the relationships between the different components within the system.

Within the policy documents, the content was analysed by identifying actors, both individual and groups, implicated in the

Table 1 Institutional and development framework for departments purposively sampled

IAD framework	Purposive sampling		
Scale	National	Provincial	Local
Participants	National Department of Water and Sanitation National Department of Social Development National Department of Health	Gauteng Provincial Department of Health Gauteng Provincial Department of Social Development	Johannesburg Water CoJ Department of Health
Scope for action	National Sanitation Policy Food and Nutrition Security Policy Integrated Early Childhood Development Policy		

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confluence between WASH and nutritional status in children. The processes of how these policies are realized were considered in terms of the particular mechanisms that provide for horizontal co-ordination between departments on the same level and vertical co-ordination between departments at different spheres of government. Finally, the environment within which these documents came into existence and that which they are meant to address was contextualized. This process was conducted by DJM and BCN and checked by RSM and PM.

Data from the document review were analysed using Walt and Gilson's policy analysis framework, which provides information about actors, process, content and context (Walt and Gilson, 1994). Data from the key informant interviews and the consensus development conference were minuted and analysed using the thematic content analysis. Both the data-driven inductive method and a deductive method drawing from the Christensen framework of co-ordination were used (Christensen and Lægreid, 2008). Christensen's framework was selected because it allows for reflection on co-ordination vertically between spheres of government and horizontally between departments as it relates to WASH and nutritional status in children. Data from the *a priori* selected themes were extracted from the document review, expert interviews and consensus development conference. Theme 1: link between WASH and nutritional status in government departments; Theme 2: complexity and lack of cross communication between government departments; and Theme 3: recommendations. All minutes and recordings were analysed by DJM and the findings from the analysis further discussed and reviewed with RSM and PM.

Results

Institutional mapping

Table 2 presents all national and provincial government departments and highlights the various public sectors as delineated by national departments and displays overlaps and/or absence of certain public sector departments in the various provinces. It demonstrates how each province has their own unique constellation of departments and that not all national departments are represented at provincial and/or local levels. Responsibility for the provision of water and sanitation does not reside at provincial level but rather directly with local government (Republic of South Africa, 1998). Thus, responsibility is located with the CoJ metropolitan council rather than the Gauteng provincial government. Health, on the other hand, falls under the purview of provincial government, except where the responsibility for service provision is shared, as is the case with metropolitan councils such as the CoJ (Republic of South Africa, 1998; Butler, 2009).

Nationally, it was determined that the National Department of Water and Sanitation (DWS), National Department of Social Development (DSD) and the National Department of Health (DOH) should be included. At the provincial level, the following departments were included: Gauteng Provincial DOH and the Gauteng Provincial DSD. Within the Metropolitan Council of the CoJ, Johannesburg Water and the CoJ Department of Health were identified for inclusion.

The results of the World Health Organization's methodology for mapping governance and health for well-being (World Health Organization, 2018) are presented in Figure 1 outlining the public sector departments included in this study.

The DSD finds its core legislative mandate in terms of Sections 27 and 28 of the Constitution and aims to ensure protection against vulnerability by creating an enabling environment for the provision of a comprehensive, integrated and sustainable social development service (National Department of Social Development, 2019). The DWS states its responsibility in terms of the formulation and implementation of policy governing the water and sanitation sector, while striving to ensure that all South Africans gain access to clean water and dignified sanitation (National Department of Water and Sanitation, 2019). Finally, the DOH is concerned with improving health status through the prevention of illnesses and the promotion of healthy lifestyles (National Department of Health, 2019b).

The scope of action, vertical and horizontal, for each of these departments is provided for, in principal, through the 1996 Constitution and the IGR Framework Act of 2005. The Constitution (1996) states that the three spheres of government should function in a cooperative, interrelated and interdependent manner and ensure that there are IGR, formal and informal processes and institutional arrangements and structures for co-ordination within and between spheres of government (Government of South Africa, 1996; Butler, 2009; Mahlangu *et al.*, 2018). Chapter 3 of the IGR Framework Act (2005) outlines the process to be followed to ensure co-ordination in service delivery between national, provincial and local governments. The extent to which this is operationalized was explored through the document review and expert interviews.

Document review

The following key policies were identified, sourced and reviewed: National Development Plan 2030 (National Planning Commission, 2012), National Sanitation Policy (National Department of Sanitation, 2016), National Water Policy (National Department of Water Affairs, 2013), National Policy on Food and Nutrition Security (Department of Social Development and Department of Agriculture Forestry and Fisheries, 2017), National Integrated Early Childhood Development Policy (Department of Social Development, 2015) and the National Environmental Health Policy (National Department of Health, 2013).

Of the policies reviewed, three mentioned WASH, nutrition and children, however, none explicitly linked WASH to nutritional status in children. An in-depth review and analysis of these three crucial policy documents was conducted.

With regard to the National Sanitation Policy (National Department of Sanitation, 2016), children, irrespective of age, are mentioned in the policy in so far as sanitation contributes to the fight against child mortality and that basic sanitation should be safe for children to use. The policy explicitly mentions the link between sanitation, nutrition and health and acknowledges hygiene education and the importance of systematic approaches to encourage the widespread adoption of safe hygiene practices to reduce diarrhoeal and other WASH-related diseases. Communication and education-related activities are delegated to local government. While overall policy co-ordination is emphasized to achieve these objectives, responsibility for co-ordination and compliance is deferred to the Department of Cooperative Governance and Traditional Affairs as the regulator of local government.

The Food and Nutrition Security Policy (Department of Social Development and Department of Agriculture Forestry and Fisheries, 2017) acknowledges the constitutional mandate that guarantees every citizen the right to have access to sufficient food and water. With reference to children, no particular age range is proposed; however, the policy notes that the existence and extent of malnutrition is an important proxy indicator of access to food and in

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Table 2 National and provincial government departments

National government	Gauteng	Western Cape	Eastern Cape	Northern Cape	KwaZulu-Natal	North West	Limpopo	Free State	Mpumalanga
Health									
Social Development									
Office of the Presidency	Office of the Premier					Office of the Premier			
Human Settlements					Human Settlements	Local Government and Human Settlements		Human Settlements	
National Treasury	Provincial Treasury			Provincial Treasury			Provincial Treasury		
Basic Education	Education			Education		Education and Sports Development	Education		
Higher Education and Training									
Agriculture, Land Reform and Rural Development	Agriculture and Rural Development	Agriculture	Rural Development and Agrarian Reform	Agriculture and Land Reform	Agriculture and Rural Development	Rural, Environmental and Agricultural Development	Agriculture and Rural Development		Agriculture, Rural Development, Land and Environmental Affairs
Environment, Forestry and Fisheries		Environmental Affairs and Development Planning		Environment and Nature Conservation	Economic Development, Tourism, and Environmental Affairs		Economic Development, Environment and Tourism		
Economic Development		Economic Development and Tourism	Finance, Economic Development, Environmental Affairs and Tourism	Economic Development and Tourism		Finance, Economy, and Enterprise Development			Economic Development and Tourism
Tourism						Tourism			
Public Works and Infrastructure	Infrastructure Development	Transport and Public Works	Roads and Public Works			Public Works, Roads, and Infrastructure	Public Works and Infrastructure		Public Works, Roads and Transport
Transport	Roads and Transport		Transport	Transport, Safety and Liaison	Transport	Community Safety and Transport Management	Transport and Community Safety	Police, Roads and Transport	
Police	Department of Community Safety		Department of Safety and Liaison		Department of Community Safety and Liaison				Community Safety, Security and Liaison
Sports, Arts and Culture	Sports, Arts, Culture, and Recreation	Cultural Affairs and Sport	Sports, Recreation and Arts and Culture	Sports, Arts and Culture	Arts and Culture Sports and Recreation	Culture, Arts, and Traditional Affairs	Sports, Arts and Culture	Sports, Arts, Culture, and Recreation	Culture, Sport and Recreation
Cooperative Governance and Traditional Affairs		Local Government	Cooperative Governance and Traditional Affairs	Cooperative Governance, Human Settlements, and Traditional Affairs	Cooperative Governance and Traditional Affairs		Cooperative Governance, Human Settlements, and Traditional Affairs	Department of Cooperative Governance and Traditional Affairs	
Water and Sanitation									
Justice and Correctional Services									
Mineral Resources and Energy									

(continued)

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Table 2 (continued)

National government	Gauteng	Western Cape	Eastern Cape	Northern Cape	KwaZulu-Natal	North West	Limpopo	Free State	Mpumalanga
Health									
Social Development									
Office of the Presidency	Office of the Premier					Office of the Premier			
Communications and Digital Technologies									
Home Affairs									
International Relations and Cooperation									
Employment and Labour									
Defence and Military Veterans									
Public Enterprises									
Science and Technology									
Small Business Development									
State Security									
Telecommunications and Postal Services									
Trade and Industry									
Public Service and Administration									

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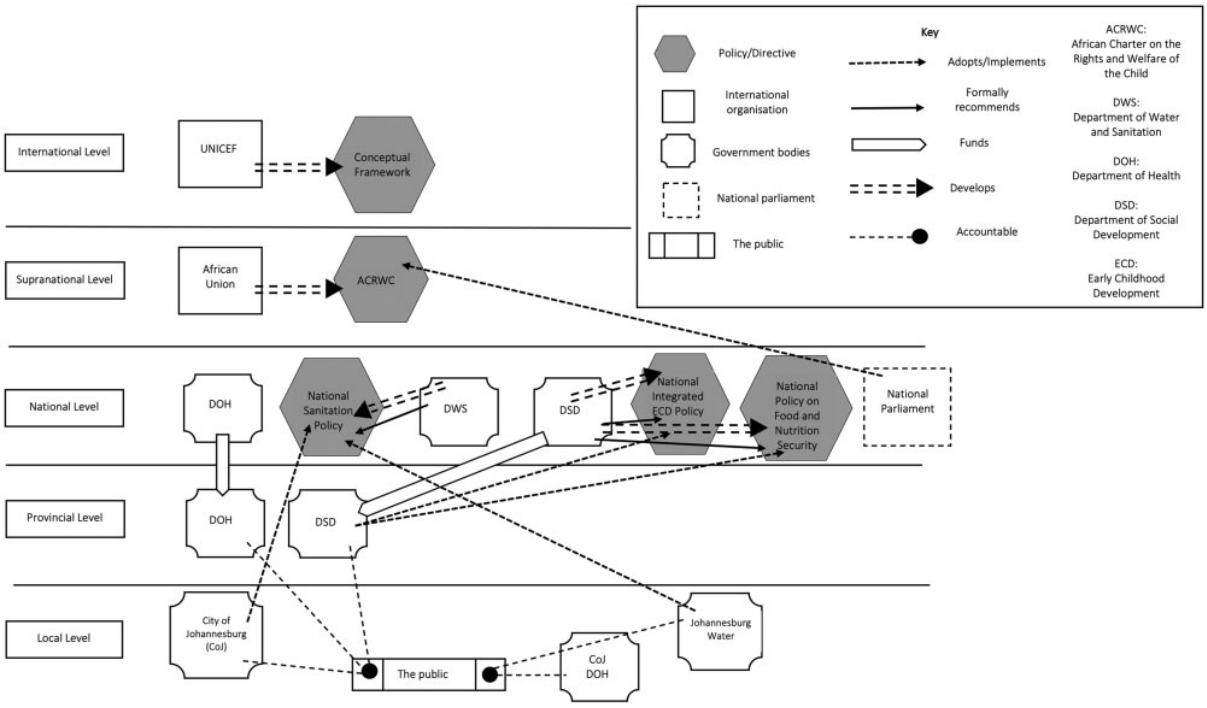

Figure 1 National mapping.

particular that health-related measures such as stunting and wasting are particularly concerning when it comes to urban informal settlements. The policy also states that food and nutrition security requires well-managed intersectoral co-ordination and the integration of existing policies and programmes in health, education and environmental protection and calls for the involvement of CBO and NGO. Furthermore, the policy advocates for a comprehensive Food and Nutrition Security and Vulnerability analysis, which would serve as a national data set including health, nutritional status and sanitation. Water and hygiene are not explicitly included.

The final policy that was reviewed, the Integrated Early Childhood Development Policy (Department of Social Development, 2015), states that it aims to provide an overarching multisectoral enabling framework of early childhood development services, inclusive of national, provincial and local spheres of government. The policy covers the period from conception until the year before children enter formal school, or until age 6 years. Essential components that need priority attention as a government obligation include healthcare and nutrition programmes, water and sanitation. The policy recognizes that early childhood development programmes result from a series of mutually dependent partnerships of role players responsible for the well-being and development of children in South Africa, which include different government departments, organizations, agencies and individuals. The national DSD is responsible for policy development; national planning; regulation and development of norms and standards for service provision; and evaluation of efficiency and effectiveness while the provincial DSD is responsible for provincial population-based planning and management of the services described above. The DOH is responsible for the provision of the health and nutrition programmes. The DWS is responsible for formulating and implementing policy governing this sector and has an overriding responsibility for water and sanitation services provided by local government. It is thus responsible for ensuring that national water and sanitation policies and laws securing the rights of young children to access to sanitation and clean piped water. The policy goes so far as to delegate specific roles and responsibilities to all government departments as it pertains to early childhood development.

Expert interviews

Invitations to 15 respondents from government, NGO, IGO and academia were extended to participate as key informants. Three of those approached were from academia, six were from the government sector, four were from NGO and two were from IGO.

Of those approached, two consented to participate for in-depth interviews: one respondent came from an international NGO and the other from the governmental health sector.

Important points made by the key informants targeted the need for training around early identification of chronic forms of malnutrition in early childhood through regular clinic visits and that parents need to have a better understanding of the Road-to-Health Card (an instrument used by doctors and nurses to monitor and record growth rate, development and immunizations—given to mothers when their infant is born) and the anthropometric measurements being conducted. The respondents noted that the policy environment is very complex and that a lack of cross communication between departments both horizontally and vertically hinders planning and implementation. Another key challenge relates to the lack of data sharing, between provinces as well as between departments. Integration of data with indicators that are relevant for particular outcomes based on shared concerns was also highlighted. For instance, clinicians may not be immediately concerned with the environmental causes of diarrhoea over and above if the child presents with acute malnutrition. One respondent commented that 'there is a lack of agency in tracing and addressing WASH-related issues from

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a clinical standpoint, however from a disease surveillance perspective the incidence of diarrhoea at various scales is important to identify and address potential outbreaks as well as more pervasive and chronic issues including growth faltering'.

A panel for the consensus development conference was convened from a pool of stakeholders and experts comprised professionals from the public health sector, NGO, IGO, CBO and academia. Invitations to participate in the consensus development conference were extended to 20 respondents, of whom 13 agreed to participate. The panel acknowledged that there is a strong link between WASH and nutritional status in children and that the biological pathways are well defined. The complexity of mapping the public sector departments is however made difficult due to the fact that there is no clearly defined link between the various WASH components in a public sector setting and as such no defined responsibility. The panel highlighted that there is a lack of advocacy for the link between WASH and nutritional status in children due to a survival-driven agenda, which is more concerned with childhood mortality than morbidity. The panel noted that the extent that WASH affected nutritional status children and the cost of inaction needed to be quantified at various scales to increase the political will around addressing WASH and chronic undernutrition in children. The panel pointed to a number of policies, including those reviewed in this exposition, that include WASH. They highlighted that none clearly define or create a causal link between governance, WASH and nutritional status in children and that there are competing priorities between the various levels of government both in terms of mandate and in terms of party politics. It was furthermore suggested that national government is much better it seems at cooperation than the provinces; however, implementation and operationalization is key at local level.

Discussion

After the institutional mapping and review of policy documents, key informant interviews and consensus development conference, the study found that the key actors involved in addressing WASH and nutritional status in the study site include the national DWS, national DSD and national DOH, Gauteng provincial DOH, Gauteng provincial DSD, Johannesburg Water and CoJ Department of Health. The research has also highlighted the limited integration and co-ordination around service provision of these key areas related to WASH. Departments function in silos, and there are limited efforts and implementation of efforts that are meant to allow for co-ordinated service delivery. IGR between levels of government are also poor, and there is limited harmonization of efforts between the national, provincial and local levels of government.

The WASH landscape is comprised a complex set of actors from various sectors that engage with one another on an *ad hoc* basis, and while acknowledging that there are biological associations between WASH, morbidity, nutrition and growth, the precise pathways are not well articulated in the policy sphere. The horizontal and vertical intersectoral collaborations are also particularly difficult to delineate.

The South African Constitution provides for the provision of health care, food, water and social security under Section 27 of the Bill of Rights, and Section 28 further extends the right to basic nutrition in the case of children; however, no explicit mention is made to the provision of sanitation (Government of South Africa, 1996; Dugard, 2016; Durojaye and Chilemba, 2018). This has led to the South African Human Rights Commission to link the right to sanitation to the right to human dignity, privacy and a clean environment (National Department of Water Affairs, 2012; Dugard, 2016; South African Human Rights Commission, 2018). Furthermore, the National Development Plan (National Planning Commission, 2012) aims to achieve compliance with sustainable development goal (SDG) 6 (clean water and sanitation for all) by 2030 (Parliamentary Monitoring Group, 2017). If these are to be achieved, a more co-ordinated effort will need to be leveraged at policy, planning and implementation levels. WASH is furthermore among the strategic priorities for the WHO Thrive Agenda 2030 (WHO *et al.*, 2018). The report details the fact that, while most countries have a policy for WASH in healthcare facilities or infection prevention and control, <25% of these are fully funded and being implemented. As of 2017, 75% of the 75 countries that participate in the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water initiative indicated that financial data were available and utilized for decision-making around WASH and health issues. Of these countries, over two-thirds indicated the existence of a financing plan or budget for WASH, but less than one-third reported that a financial plan was in place and consistently followed. The report details the fact that, while most countries have a policy for WASH in healthcare facilities or infection prevention and control, <25% of these are fully funded and being implemented. Thus, advocating for the strengthening of nutrition and WASH sectors, which enable improvements in newborn and child health (WHO *et al.*, 2018).

Theme 1: link between WASH and nutritional status in government departments

WASH is a complex concept, with many components, both individual factors (WASH) and within each component (quality, quantity, access, infrastructure, etc.), interacting in the system, while the individual WASH components occur in different governmental spheres. As such, articulation of the link between the various WASH components and nutritional status in children is sparse and, although the various components, namely WASH, are mentioned, the relationship between them is rarely elaborated upon.

The various departments are primarily concerned with their core mandates. As such they are restricted in addressing crosscutting issues that fall outside of their immediate remit. For instance, the DOH (and/or clinicians and allied medical services) is responsible and concerned with direct/acute clinical issues and is not necessarily empowered to address the underlying and environmental causes of clinical conditions that they are confronted with. While the link between WASH and nutritional status is not new and the pathways are well established, given the complex public sector landscape, it is difficult to translate these into the policy realm. The public sector would therefore benefit from better integrating a consolidated concept of WASH (UNICEF, 2016) that coherently incorporates the various individual components namely WASH into their policy, planning and implementation frameworks, rather than dealing with each component in isolation as well as ensuring that consistent, co-ordinated and complementary indicators across clinical and service provision sectors may also help co-ordination between sectors.

Theme 2: complexity and lack of communication between government departments

The 1996 Constitution provides that the three spheres of government national, provincial and local should function in a cooperative, interrelated and interdependent manner (Government of South Africa, 1996; Butler, 2009; Mahlangu *et al.*, 2018). The arrangement of government departments is by no means static and has gone

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through many functional and structural iterations at all levels since the transition to democracy in 1994 (Naidoo, 2018).

In the South African context, there is a lack of a guiding framework to operationalize and address the link between nutritional status and WASH and to guide and inform implementation at national, provincial or local levels. There is also a lack of clarity about roles and responsibilities of various sectors that need to be involved and how the link between WASH and nutritional status should be monitored. This is perpetuated by a constellation of departments at various levels, which complicates vertical and horizontal co-ordination, cooperation and collaboration.

While municipalities hold the mandate to deliver services, politics, both party and personal, intrude into co-ordination within municipalities (across wards and between departments), between municipalities and the province (and cutting across different departmental mandates) and with national government. The impact of politics intensifies the closer the authority is to the councillors and ward committees who are lobbying for resources, and party affiliations matter as much as personal connections. Municipal debt, which across South Africa totalled R72.4 billion in 2019, is another issue that should be mentioned in this regard (Statistics South Africa, 2019; Nkadimeng, 2020). The various wards that cumulatively comprise the municipal jurisdiction are often purchasing utilities from the national service providers and are tasked with recouping those costs from residents. Recent protests about service delivery and the shutting down of services due to mounting municipal debt in the CoJ further demonstrate the tension between the various levels of government and the various levels of service provision (Charles, 2020; Seleka and Grobler, 2020).

On a positive note, the public sector involvement in the HIV and AIDS response in South Africa has had many successes, suggesting that such co-ordination is possible. Among the biggest gains has been the prevention of mother to child transmission and important lessons can be learned as to how best to leverage a multisectoral response (Padarath *et al.*, 2016; Mahlangu *et al.*, 2018; Rispel and Padarath, 2018). Progress in this regard has been achieved through mainstreaming HIV in the public sector, in both health and non-health sector departments (Mahlangu *et al.*, 2018). In addition, deeper vertical co-ordination at international and supranational levels could further assist in developing strategies for addressing the burden of undernutrition from a WASH perspective. In recent years, countries such as Brazil, Peru and Senegal have found success in reducing undernutrition significantly through tailored multisectoral approaches, ascribing successful interventions by agriculture, health care and WASH to jointly targeted populations and geographic areas (Skoufias *et al.*, 2019).

Theme 3: recommendations

During the course of this study, it became evident that providing recommendations on how best to address the challenges faced by the various public sector departments was not an easy task. However, a few recommendations were echoed through a number of sources. The establishment of a database of tools, policies and implementation strategies around best practice, relating to successful attempts at combining WASH and nutritional status, at all levels of government would help leverage experience of successful programmes. Use of the National Dashboard of priority indicators was also noted as a powerful tool for driving implementation as there is visible monitoring and accountability for specific indicators (National Department of Health, 2019a). Integration of data with indicators that are relevant for particular outcomes based on shared concerns is essential. For instance, clinicians may not be immediately concerned with the environmental causes of diarrhoea over and above if the child presents with acute malnutrition, thus integrating a clear and defined set if indicators will be essential in trying to address the problem of growth from a WASH perspective. Harmonizing indicators across clinical and service provision sectors may therefore help co-ordination across sectors. Using consistent language for both WASH and nutritional status-related indicators is integral to harmonizing such co-ordination efforts. Understanding what each of term and indicator means, using them appropriately in the right context, is key to communication between actors but also measuring the impact of policies and other interventions. For instance, while the issues underpinning undernutrition could be addressed appropriately, seeing changes in linear growth can be seen at later stages, even in the next generation due to other determinants (including epigenetics), which can take two or three generations to overcome. Underweight is a poor indicator due to the fact that it does not distinguish between weight and height contributions. Furthermore, undernutrition includes hidden hunger, i.e. micronutrient deficiencies, which are hardly measured in routine or in survey assessments. Of the policies reviewed in this exposition, none clearly define or create a causal link between governance, WASH and nutritional status in children. There are competing priorities between the various levels of government both in terms of mandate and in terms of party politics, and because the various WASH and nutritional status components fall under different public sector departments, there is no defined responsibility for how WASH should be operationalized to help address the burden of malnutrition in children. The SDG indicators may therefore be of use for synchronizing targets from international to local scales, while providing a framework for linking policy to health-related outcomes. Localizing the SDGs is critical to align the competing priorities between departments at various levels of government.

Understanding the associations between WASH, growth and nutrition is integral, and the way that these pathways are articulated in the policy sphere has real-world implications. An important distinction is that it is in fact not WASH that will improve nutrition but rather WASH will improve growth, which is in this case a marker of nutritional status. In addition, low-cost WASH interventions often fail to improve health because they require much more user effort, time and compromise than is required from residents of high-income countries for WASH services (Humphrey, 2019). For instance, trial results showed that an intervention testing the effect of a device that automatically chlorinates piped water on child diarrhoea delivered less-than-perfect disinfection but required no user effort (or even awareness of its presence) significantly reduced child diarrhoea by 23% (Humphrey, 2019; Pickering *et al.*, 2019). Among the policies reviewed, there was little reflection on when during childhood, or at what age, it would be ideal to intervene. Timeous targeting of interventions, especially during the first 1000 days, is integral. In addition, while a conceptual understanding of what the links are, WASH interventions have had mixed success when it comes to improvements of linear growth. Policy is the first step, and to take WASH policies to the next level, it is important to acknowledge policy gaps and also focus attention on the complexities of implementation and communication, collaboration and cooperation between the various actors and stakeholders. Future studies would benefit from including an SWOT analysis focusing on strengths, weaknesses, opportunities and threats in the South African and study contexts to better understand the dynamics of addressing nutritional status through WASH.

Finally, it is imperative to note that governance is not only for government, but private sector involvement is also imperative in

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order to create sustainable solutions at scale. Furthermore, the role that CBO, NGO and IGO play in the intersection between WASH and nutritional status cannot be overstated.

While intersectoral collaboration is, in principal, facilitated at a national level through policy frameworks, there exists a deeper need to ensure that co-ordination around implementation is operationalized at provincial and local levels. Unfortunately, this is problematized in the case of metropolitan councils, which are politically highly contested due to the fact that they enjoy legislative and executive authority. In certain cases where the provincial and metropolitan council government are opposing political parties, or competing factions within parties, collaboration and cooperation can be particularly difficult.

While we have highlighted the institutional restraints of the public sector departments, this study has in itself a number of limitations. The authors reached out to a number of key informants within each of the government departments included; however, most declined to participate in this study. They indicated an appreciation for the importance of the topic but expressed a lack of confidence in commenting on the intersection between WASH components and links nutritional status in children. Although they considered the link between WASH and childhood malnutrition to be important, they did not consider themselves sufficiently competent to comment. This reinforces our contention that this is a neglected issue in SA policy and implementation.

While the authors have mentioned the specific mandates of the various government units, explicit indication and discussion about past, present and future programmes was outside the immediate scope of this exposition. The authors remain cognisant about the importance of describing and evaluating such initiatives in the context of the current research and suggest this as a focal point for future research on the topic.

A lack of data at local government level made an analysis across various scales difficult, and while this study utilized simplified models to describe complex systems and interactions, based on these findings, future research needs to focus on the barriers to implementation. Experiences may also differ in other municipalities and provinces that emphasize and feature WASH more prominently in their policy and implementation frameworks and as such further research and insight is required. Despite these challenges, the authors managed to compile data in each of the proposed fields providing insight into the status quo while presenting a novel use of methods offering critical advantages and strengthening the work conducted from traditional scoping and desk reviews.

Conclusion

This exposition sought to elucidate the landscape of WASH in South Africa in relation to nutritional status of children under the age of 5 years. The authors found that utilizing consistent and established terminology and indicators when referring to the challenges and recommendations for service provision would allow for a more targeted discussion around which particular aspects of the WASH components require further consideration. The public sector would benefit from better integrating the concept of WASH into their policy, planning and implementation frameworks.

The WASH sector should take stronger action to integrate nutrition; too few WASH plans consider the impact of WASH on nutritional status of children. The various public sector departments involved in WASH service provision, and other WASH stakeholders, including CBO, NGO and IGO, should be involved in the decision-making, monitoring and evaluation and implementation of policies and strategies within the nutrition sector.

In addition, further targeted research on the governance of WASH through the identification of the various role players and stakeholders at various levels, while understanding the policy environment in relation to particular health-related outcomes, is imperative to address the burden of child undernutrition.

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Water, sanitation, and hygiene (WASH) factors associated with growth between birth and 1 year of age in children in Soweto, South Africa: results from the Soweto Baby WASH study

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ABSTRACT

Interventions to reduce undernutrition and improve child growth have incorporated improved water, sanitation, and hygiene (WASH) as part of disease transmission prevention strategies. Knowledge gaps still exist, namely, when and which WASH factors are determinants for growth faltering, and when WASH interventions are most effective at improving growth. This study drew cross-sectional data from a longitudinal cohort study and used hierarchical regression analyses to assess associations between WASH factors: water index, sanitation, hygiene index, and growth: height-for-age (HAZ), weight-for-age (WAZ), weight-for-height (WHZ) at 1, 6, and 12 months postpartum among infants *a priori* born healthy in Soweto, Johannesburg. Household access to sanitation facilities that were not safely managed was associated with a decrease in HAZ scores at 1 month ($\beta = -2.24$) and 6 months ($\beta = -0.96$); a decrease in WAZ at 1 month ($\beta = -1.21$), 6 months ($\beta = -1.57$), and 12 months ($\beta = -1.92$); and finally, with WHZ scores at 12 months ($\beta = -1.94$). Counterintuitively, poorer scores on the hygiene index were associated with an increase at 1 month for both HAZ ($\beta = 0.53$) and WAZ ($\beta = 0.44$). Provision of safely managed sanitation at household and community levels may be required before improvements in growth-related outcomes are obtained.

Key words | children, growth, South Africa, WASH

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HIGHLIGHTS

- Provides evidence linking WASH and nutritional status in infants.
- Brings evidence regarding the associations between WASH and nutritional status in children in the South African setting.
- Highlights the importance of access to sanitation at household as well as community levels.
- Begins the process of developing indices related to WASH and nutritional status in children in the South African setting.

INTRODUCTION

Children under 2 years of age are considered as the most at-risk group for undernutrition due to their rapid growth and increased vulnerability to infectious diseases (Derso *et al.* 2017). The World Health Organization (WHO) defines three forms of undernutrition among children – namely stunting, underweight, and wasting – as being 2 standard

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deviations (SD) below the WHO age and sex-adjusted growth standard; for stunting, height-for-age (HAZ); for underweight, weight-for-age (WAZ); and for wasting, weight-for-height (WHZ) (Members of the WHO Multicentre Growth Reference Study Group 2006). *Z*-scores in this regard referring to a statistical measurement of a score's relationship to the median in a group of scores, measured in terms of a standard deviation from the median of the population.

The first thousand days (from conception to 2 years of age) is an integral phase of childhood development due to developmental plasticity and is among the most pertinent periods for interventions aimed at optimising growth and development (Victora *et al.* 2010; Adair *et al.* 2013; Prendergast *et al.* 2014; Norris *et al.* 2017). Developmental plasticity posits that environmental conditions experienced in early life, including nutrition, trigger permanent physiological adjustments that can profoundly influence human biology and long-term health outcomes (Kuzawa 2005; Hochberg *et al.* 2011; Said-Mohamed Pettifor & Norris 2018).

Inadequate nutrition and frequent illness, especially diarrhoea, are among the most commonly implicated causes of undernutrition (Humphrey *et al.* 2015; Cumming *et al.* 2019; Pickering *et al.* 2019a). Nutrition-sensitive interventions to improve undernutrition and child growth have therefore often incorporated water, sanitation, and hygiene (WASH) factors as a strategy to prevent disease transmission. However, recent results from large-scale randomised controlled trials (SHINE and WASH Benefits) have found no effect of basic WASH interventions on childhood stunting and only mixed effects on childhood diarrhoea (Cumming *et al.* 2019). Both studies concluded that more comprehensive WASH interventions may be needed to achieve a major impact on child health. Further, the authors argue that the results do not show that WASH cannot influence child linear growth, but rather that these specific interventions had no influence in settings where stunting remains an important public health challenge (Cumming *et al.* 2019).

In terms of specific WASH-related risk factors, a recent systematic review investigating WASH in sub-Saharan Africa and associations with undernutrition, and governance in children under 5 years of age, found that observational studies more often reported water as a significant risk factor while review articles tended to highlight sanitation as a significant risk factor (Momberg *et al.* 2020b). Across both observational and review studies included in the systematic review, hygiene was the least represented component (Momberg *et al.* 2020b).

The South African context is characterised by particularly high rates of stunting for a middle-income country where in 2016, the prevalence of stunting in children under 5 years of age was 27.4%, while at the same time, 5.9% of children under the age of 5 were underweight and 2.5% were wasted (Statistics South Africa 2017b; Rispel & Padarath 2018). In terms of water infrastructure in South Africa, it was reported in 2015, that 89.4% of South Africans had access to piped tap water, comprised of households having access to either piped water in their dwellings, piped water onto their property, communal and neighbours' taps, the remainder relying on water from rivers, streams, stagnant water pools, dams, wells, and springs (Statistics South Africa 2016; Parliamentary Monitoring Group 2017; Moeti & Padarath 2019). With regard to sanitation infrastructure in South Africa in 2018, 83% had access to improved sanitation facilities, with the final 17% unimproved sanitation facilities proving to be the most difficult to address (Statistics South Africa 2016; Parliamentary Monitoring Group 2017; Moeti & Padarath 2019). The Gauteng province in particular is reported to have the second-highest coverage of access to water (97.7%) and sanitation (91.8%) (Statistics South Africa 2016; Parliamentary Monitoring Group 2017; Moeti & Padarath 2019). In terms of water quality, 2019 data from Johannesburg Water indicate a total of 12 incidents of non-compliance for microbiological safety requirements (presence of *E. coli*), and 10 chemical and physical incidents of non-compliance (related to turbidity). Despite these incidents of non-compliance, overall compliance targets were maintained (Johannesburg Water 2019b; Momberg *et al.* 2020a). For the City of Johannesburg, spending on water and sanitation infrastructure is decreasing, however, so too are the absolute number of people without access to basic water and sanitation services. Spending however, for repair, maintenance, and upgrading of existing infrastructure is increasing (City of Johannesburg 2019; Momberg *et al.* 2020a). Soweto is serviced by three wastewater treatment works, Goudkoppies, Bushkoppies, and Olifantsvlei wastewater treatment works, which

remediate both industrial and household wastewater (Johannesburg Water 2019a). The precise configuration of sanitation provision across Soweto is quite diverse and ranges from flush toilets to pit latrines, and portable toilets that are typically arranged in latrine banks. The system of waste disposal, maintenance, and treatment associated with these facilities is decentralised to different outsourced service providers (Momberg *et al.* 2020a). Diarrhoea is still one of the leading causes of morbidity and mortality in South Africa, accounting for approximately 20% of all deaths in children under 5 years of age (Chola *et al.* 2015). Despite a number of initiatives to address the persistently high prevalence of stunting, including near-universal water and sanitation coverage in urban settings, the provision of social grants, and free primary healthcare, this prevalence rate has remained largely unchanged since 1994 (Said-Mohamed *et al.* 2015; Devereux Jonah & May 2019).

The relationship between WASH at the household level and infant growth has received little attention in the South African context, which drastically limits our capacity to disentangle which installations and/or caregiver practices expose infants to such risks (Padarath *et al.* 2016). Knowledge gaps still exist in terms of which WASH factors are risks for undernutrition, at what time during early childhood development WASH factors are implicated, and precisely when WASH interventions are most effective at improving growth.

This study therefore sought to identify specific WASH factors and subsequent associations with HAZ, WAZ, and WHZ scores in infants *a priori* born healthy in Soweto, Johannesburg. The study hypothesised that inadequate WASH is associated with a decrease in HAZ, WHZ, WAZ scores between birth and 1 year of age.

METHODS

Study design and setting

The study is based on cross-sectional data from 4 timepoints (delivery, 1, 6, and 12 months postpartum) drawn from a larger longitudinal prospective cohort study, entitled 'Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age.' Colloquially referred to as Soweto Baby WASH study, the aim was to document household environment, maternal and infant morbidity and illness, and infant feeding and care practices, and assess the association between these factors and infant growth and development in the first-year postpartum. The Soweto Baby WASH study had 37 timepoints over the course of 12 months, with weekly follow-up home visits from birth to 6 months, and fortnightly from 6 to 12 months postpartum. Visits at 6 and 12 months were conducted at the Developmental Pathways for Health Research Unit facilities at Chris Hani Baragwanath Academic Hospital. Data collected included maternal and infant anthropometric and body composition measurements; household WASH; maternal and infant morbidity, illness, and healthcare access; infant feeding practices; household socio-economic status and demographics; maternal social support, stress, and depression; quality of care in the home; infant temperament; and infant development.

Recruitment commenced in January 2018 and data collection ended when the last recruited infant turned 1 year of age in March 2019. All the participants were screened and recruited at the maternity services at Chris Hani Baragwanath Academic Hospital in Soweto, Johannesburg.

Soweto is the largest township in South Africa with an estimated population of 1.3 million residents and is situated in the City of Johannesburg in the Gauteng Province (Harrison & Harrison 2014; Government of the Republic of South Africa 2020). In 2018, it was reported that Gauteng had near-universal water and sanitation coverage with 97.7% of the population having access to piped tap water in their dwellings, and 91.8% having access to improved sanitation (Moeti & Padarath 2019; Government of the Republic of South Africa 2020). Despite the economic and infrastructure advantages of the province, in 2016, Gauteng reported the highest prevalence of stunting in the country at 34.2% (Rispel & Padarath 2018).

Ethical considerations

The study received clearance from the University of the Witwatersrand's Human Research Ethics Committee (Medical) (Certificates: M170753, M170872, and M170955). Written informed consent was obtained from all participants.

Participants

In order to identify which determinants affect growth at what time, infants who *a priori* had a better start at birth in terms of physical growth and health were recruited. Women who were 1–3 days postpartum were screened for eligibility. Mother–infant pairs eligible for inclusion were: ≥18 years of age at time of screening; singleton pregnancy; birthweight between ≥2,500 and <4,000 g, and term pregnancy between ≥38 and <42 weeks gestational age. Mother–infant pairs were not eligible for inclusion if infants were diagnosed with physical, mental, or congenital disorders at birth or if a mother was living with HIV.

Outcome variables

Infant growth

Anthropometric measurements were performed by trained research assistants using standardised techniques (Members of the WHO Multicentre Growth Reference Study Group 2006, 2007). Infant weight was measured to the nearest 0.01 kg using an infant scale (seca 367) and recumbent length to the nearest 0.01 cm using an infantometer (seca 416). Anthropometric related data (sex, age, length, weight) were analysed using the WHO Anthro Survey Analyser software to generate HAZ, WAZ, and WHZ scores (World Health Organization 2020).

Exposure variables

Table 1 summarises the variables and survey questions drawn from the Soweto Baby WASH study, as well as the coding of composite variables created for use in the analyses that follow.

Water, sanitation, and hygiene

Household WASH was assessed using a questionnaire adapted from the WHO/UNICEF Core Questions on Drinking-Water and Sanitation for Household Surveys (WHO/UNICEF 2006), the WHO/UNICEF Joint Monitoring Programme (United Nations Joint Monitoring Programme (JMP) 2015; WHO/UNICEF Joint Monitoring Programme (JMP) 2015), and the Global Analysis and Assessment of Sanitation and Drinking Water (World Health Organization 2019).

Variables pertaining to water source were aggregated into two categories, safely managed and not safely managed. Safely managed water sources were defined as: a basic drinking water source located on the premises (piped into the home/property), available when needed and free of faecal and chemical contamination (WHO/UNICEF Joint Monitoring Programme (JMP) 2015). Not safely managed water sources comprised all other installations. Variables including access to water source (coded 1 if the water source was on the property, and 0 if not), water treatment, and interruptions to water supply were also collected (Table 1). A water index (scored 0–4, with 0 representing the lowest level of water infrastructure and behaviours, and 4 the highest); was constructed as a sum of the items pertaining to water source, access, treatment, and supply (Manzoni *et al.* 2019).

Data on the type of sanitation infrastructure (Table 1) were aggregated into two categories, safely managed and not safely managed. Safely managed sanitation facilities were defined as a basic sanitation facility (flush/pour to piped sewer system) where excreta are safely disposed *in situ* or treated off-site (WHO/UNICEF Joint Monitoring Programme (JMP) 2015). Not safely managed sanitation facilities incorporated all other infrastructure installations.

In order to create a composite hygiene index (scored 0–5: with 0 representing the lowest level of hygiene behaviours and infrastructure, and 5 the highest), three indices to assess hygiene behaviours and circumstances were created (Webb *et al.* 2006). Firstly, a Household Hygiene Index – scored 0–2, (Table 1) included type of house, and presence of animals on the property (coded 0 if there were animals on the property, and 1 if not). Secondly, a Personal Hygiene Index – scored 0–2 (Table 1), included handwashing, and handwashing detergent. And thirdly, a Food Hygiene Index – scored 0–1 (Table 1), cleaning of the breast and cleaning of utensils prior to feeding. The Household Hygiene Index, Personal Hygiene Index, and Food Hygiene Index were calculated as the sum of the individual items and the overall hygiene index as the sum of the Household Hygiene Index, Personal Hygiene Index, and Food Hygiene Index (Webb *et al.* 2006; Manzoni *et al.* 2019).

Table 1 | Composite variables for water index, sanitation, and hygiene index

Descriptor	Description	Aggregated variable	Coding	Survey question
Type of water source	Piped into dwelling Piped into yard/plot	Safely managed	1	What are the most common (within past 2 weeks) sources of water you have access to?
	Bottled water Public tap Borehole Protected dug well Protected spring Rainwater Tanker/Cart with small tank Unprotected dug well Unprotected spring Surface water	Not safely managed	0	
Interruptions to water supply	Daily Once a week Once a month	> Once a month	0	How often do you have interruptions to your water supply?
	Rarely/Never Don't know	Rarely	1	
Water treatment	Bleach/Chlorine Boiling Strain it through a cloth Use a water filter Solar disinfection Let it stand/settle Other	Treatment	1	What methods do you use to treat your water?
	None	No treatment	0	
Type of sanitation	Flush/Pour to piped sewer system	Safely managed	1	What type of toilet facilities are available?
	Flush/Pour to septic tank Flush/Pour to pit latrine Flush/Pour to elsewhere Ventilated Improved pit latrine Pit latrine with slab Composting toilet Portable toilet Bucket Pit latrine without slab No facilities (bush or field)	Not safely managed	0	
Type of house	Shack/Zozo Hostel	Informal	0	How would you describe the home you are living in?
	Flat/Cottage House Room/Garage Residence (attached to education or employment) Government housing Other	Formal	1	
Handwashing	Before and after eating Before preparing food Before and after feeding	Before/After handling food	1	When do you wash your hands?
	After using toilet After changing diaper	Before/After using sanitation	1	
	When hands are dirty Never/Rarely Other	Other	0	

(*continued*)

Table 1 | continued

Descriptor	Description	Aggregated variable	Coding	Survey question
Handwashing detergent	Soap and water Water and ash Only water	Water and soap/ash	1 0	What do you wash your hands with?
Cleaning of breast/nipple	Yes, Always Yes, Sometimes	Food hygiene practices (Recommended)	1	Do you clean your breast or nipples before feeding? How do you usually clean the utensils used for feeding?
Cleaning of utensils	Cold Water and Soap Boiled Water Boiled Water and Soap Sterilisation Solution			
Cleaning of breast/nipple	No Don't Know	Food hygiene practices (Not Recommended)	0	
Cleaning of utensils	Cold Water Other			

For both the water and hygiene indices, each of the items was scored as either 0 or 1, with 1 representing a positive behaviour or circumstance. Positive behaviour or circumstance was defined as an activity or condition that is protective towards or acts as a barrier to the transmission of pathogens (Webb *et al.* 2006; United Nations Joint Monitoring Programme (JMP) 2015; WHO/UNICEF Joint Monitoring Programme (JMP) 2015; Cumming & Cairncross 2016).

Covariates

Maternal anthropometry

Maternal height, to the nearest 0.1 cm, was measured using a wall-mounted stadiometer (Holtain), and weight, to the nearest 0.1 kg using a digital scale (seca 877), was measured by trained research assistants using standardised techniques, from which maternal Body Mass Index (BMI) was calculated as (kg/m^2) (de Onis *et al.* 2014).

Morbidity and illness

Maternal and infant, morbidity, illness, and healthcare access were assessed using interviewer-administered surveys, validated in the study setting, and confirmed against clinic records (Said-Mohamed *et al.* 2019). Incidence of diarrhoea was recorded by 7-day recall from birth to 6 months, and 14 day recall from 6 months to 1 year of age.

Infant feeding practices

Infant feeding practices were assessed using a locally adapted version of the WHO/UNICEF Infant and Young Child Feeding Questionnaire (World Health Organisation 2008, 2010; Nieuwoudt Manderson & Norris 2018). Prevalence of exclusive breastfeeding (EBF) from birth to 6 months was determined using the WHO definition which allows the infant to receive breastmilk (either expressed or from a wet nurse), oral rehydration solution, drops, syrups (vitamins, minerals, medicines), but nothing else (World Health Organization 2008, 2010).

Household socio-economic status and demographics

The household socio-economic status questionnaire was developed based on the National Income Dynamics Study (University of Cape Town 2016), and the Living Conditions Survey (Statistics South Africa 2017a). Data pertaining to household crowding, maternal employment, and education were collected. A Household Wealth Index was calculated using latent household variables: household assets (bicycle, motorcycle, motor vehicle, fridge, microwave, washing machine, landline telephone, camera, cellphone, television, DVD-player, paid television subscription, computer/laptop, internet access), housing characteristics (home ownership, land ownership, and main type of energy) (Rutstein & Johnson 2004; Vyas & Kumaranayake 2006). The Household Wealth Index was built using principal component analysis

(Vyas & Kumaranayake 2006). Based on the Household Wealth Index, the sample was divided in half into two categories (the richest and the poorest)

Sample size

A total of 1,289 mothers were screened post-delivery at the maternity wards at Chris Hani Baragwanath Academic Hospital. Of those screened, 243 were eligible. Because 87 did not consent, 156 mother–infant pairs were enrolled in the study (Figure 1).

Statistical analyses

The statistical software used for analysis was Stata version 13.1 (StataCorp 2013). Descriptive statistics, including frequencies, proportions, means, and standard deviation, or median and range were used to summarise the variables. The Shapiro–Wilk test for normality, and tests of homogeneity of variance were performed to identify the type of distribution for continuous variables. Differences by sex were assessed using a Pearson's chi-squared test, or an independent Student's *t*-test.

Using the social-ecological model (Neal & Neal 2013) informed by the UNICEF Conceptual Framework (The United Nations Children Fund 1990), three hierarchical models were hypothesised in order to assess the associations between WASH components and HAZ, WAZ, and WHZ, while controlling for individual infant and maternal factors, as well as household characteristics at 1, 6, and 12 months postpartum (Victora *et al.* 1997). Model 1 (M1) investigated the unadjusted and independent association between WASH factors and growth outcomes. Model 2 (M2) examined the effect after controlling M1 for individual infant factors (birthweight, gestational age). Model 3 (M3) explored the effect after controlling M2 for maternal factors (age, height, BMI, employment, education). Finally, Model 4 (M4) investigated the effect after controlling M3 for household factors (crowding, wealth index). Collinearity between variables was tested by assessing the variable inflation factor and covariance correlation matrices. Significance levels were set at $p \leq 0.05$ with 95% Confidence Intervals.

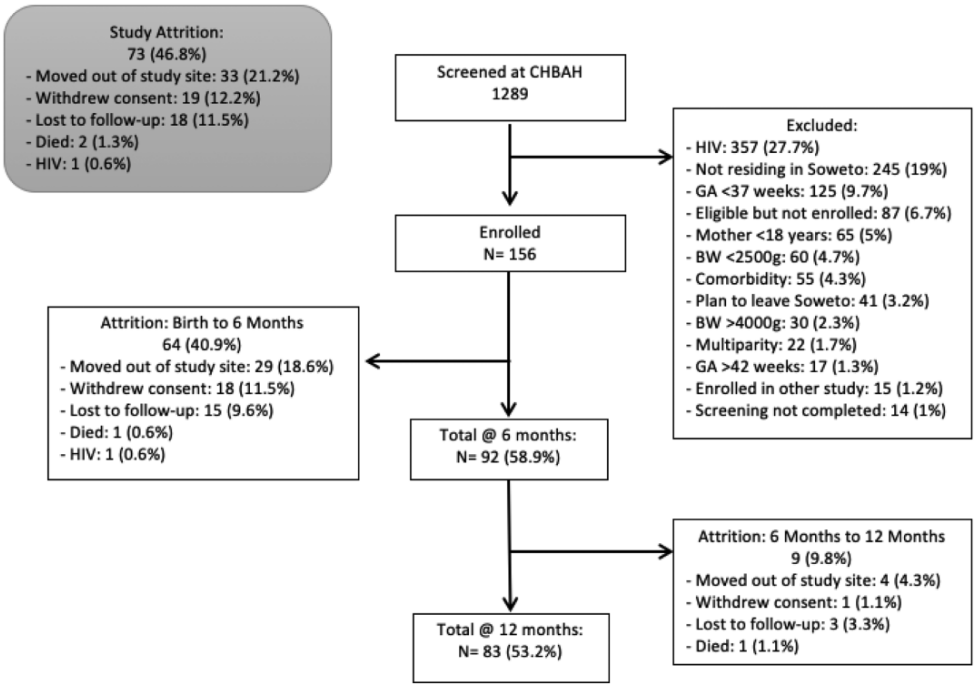

Figure 1 | Screening, follow-up and attrition flow diagram of the Soweto Baby WASH study.

RESULTS

Over the duration of the study, 73 (46.8%) participants were lost to follow-up. A total of 83 mother–infant pairs exited the study after 12 months of follow-up, comprising the final sample (Figure 1).

At birth (Table 2), despite having been born within normal ranges for birthweight (mean = 3.055 g, SD = 0.35) and gestational age (mean = 38.9 weeks, SD = 1.2), the prevalence of stunting was 9.7%, underweight 0.7%, and wasting 2%. Stunted largely persisted being at a higher prevalence than other forms of undernutrition as the study progressed with 10.2% of participants being stunted at 1 month, 10.1% at 6 months, and 11% at 12 months (Table 3). Mean maternal BMI values were as follows, 27.5 (SD = 5.9) at 1 month, 29.9 (SD = 6.1) at 6 months, and 29.9 (SD = 6.6) at 12 months (Table 3). At 1 month postpartum, more than two-thirds of mothers were employed, while conversely at 12 months postpartum, approximately two-thirds (65.3%) were unemployed.

Table 2 | Maternal and infant characteristics at birth in the Soweto Baby WASH study

		Delivery	
		Total	
		n	Mean, SD, or percentages
Infant characteristics			
Sex	Male	76	50.3%
	Female	75	49.7%
Age (mean, SD)	Months	154	0.039 (0.029)
Gestational age (mean, SD)	Weeks	151	38.9 (1.2)
Weight (mean, SD)	kg	151	3.055 (0.35)
Length (mean, SD)	cm	151	48.3 (1.7)
Stunted	Yes	14	9.3%
	No	136	90.7%
Underweight	Yes	1	0.7%
	No	149	99.3%
Wasted	Yes	3	2%
	No	144	98%
Maternal characteristics			
Age (mean, SD)	Years	153	27.7 (6.1)
Height (mean, SD)	cm	77	157.8 (6.9)

Additional participant characteristics are presented in Supplementary Material, Table 1.

The water index did not vary much over the course of the study with the sample mean remaining around 3.11 over a maximum score of 4 across all 3 timepoints (Table 3). With regards to sanitation, more than 90% of participants had access to a safely managed sanitation facility. The hygiene index did also not vary much over the course of the study with sample means remaining around 3.35 (SD = 0.87) at 1 month, 3.38 (SD = 0.89) at 6 months, and 3.14 (SD = 0.97) at 12 months.

Tables 4–6 show the results for the hierarchical regression analyses on HAZ, WAZ, and WHZ at 1, 6, and 12 months postpartum, respectively. All significant associations for the fully adjusted M4 models are diagrammatically displayed in Figure 2.

Using a safely managed sanitation facility was associated with an increase in HAZ scores by 2.24 (M4, $p = 0.03$), at 1 month, but this effect size decreased to 0.98 ($p = 0.04$), at 6 months postpartum and no association was detected at 12 months (Table 4). An improvement by 1 unit in the hygiene index was associated with a decrease of 0.53 in HAZ scores (M4, $p = 0.04$) at 1 month postpartum but no associations were detected at 6 or 12 months. No associations between the water index and HAZ scores were detected at any of the timepoints. At 1 month, 6 months, and 12 months, WASH factors (M1) explained 2, 10, and 6% of the variance in HAZ, respectively, while infant, maternal, and household characteristics (M4) at the same time points, explained, 56, 29, and 28% of HAZ variance, respectively.

With regard to WAZ (Table 5), a 1-unit improvement in the hygiene index was associated with a decrease in WAZ by 0.44 (M4, $p = 0.001$) at 1 month, while no associations were detected at either 6 or 12 months postpartum. Use of a safely managed sanitation facility was associated with an increase in WAZ by 1.21 (M4, $p = 0.01$) at 1 month, 1.57 (M4, $p = 0.01$) at 6 months, and 1.92 (M4, $p = 0.01$) at 12 months. No associations between the water index and WAZ scores were detected at either 1, 6, or 12 months in the fully adjusted models (M4). At 1 month, 6 months, and 12 months, WASH factors (M1) explained 1, 6, and 19% of the variance in WAZ scores, respectively, while infant, maternal, and household characteristics (M4) at the same

Table 3 | Maternal and infant characteristics at 1, 6, and 12 months postpartum in the Soweto Baby WASH study

		1 month postpartum		6 months postpartum		12 months postpartum	
		Total		Total		Total	
		n		*n*		*n*	
Infant characteristics							
Sex	Male	76	50.3%	42	52.5%	42	57.5%
	Female	75	49.7%	38	47.5%	31	42.5%
Age (mean, SD)	Months	59	0.961 (0.098)	79	5.752 (0.506)	73	11.931 (0.654)
Weight (mean, SD)	kg	59	4.088 (0.56)	79	7.498 (1.002)	73	9.250 (1.164)
Length (mean, SD)	cm	59	52.5 (1.9)	79	64.7 (2.4)	73	73.4 (2.1)
Stunted	Yes	6	10.2%	8	10.1%	8	11%
	No	53	89.8%	71	89.9%	65	89%
Underweight	Yes	2	3.4%	2	2.5%	2	2.7%
	No	57	96.6%	77	97.5%	71	97.3%
Wasted	Yes	2	3.4%	2	2.5%	2	2.7%
	No	57	96.6%	77	97.5%	71	97.3%
Exclusive breastfeeding	Yes	3	5.2%	0	–	–	–
	No	55	94.8%	78	100%	–	–
Maternal characteristics							
Age (mean, SD)	Years	57	27.5 (5.9)	74	27.9 (5.9)	70	28.7 (6.4)
Weight (mean, SD)	kg	57	71.2 (13.4)	74	74.3 (16.4)	70	73.9 (17.7)
BMI (mean, SD)		45	27.5 (4.9)	74	29.9 (6.1)	66	29.9 (6.6)
Education	No formal education, primary, and secondary	68	71.6%	61	77.2%	59	80.2%
	Tertiary	27	28,4%	18	22.8%%	14	19.8%
Employment	Yes	54	66.7%	55	70.5%	25	34.7%
	No	27	33.3%	23	29.5%	47	65.3%
Household characteristics							
Crowding (mean, SD)		97	4.4 (2.6)	79	5.9 (2.9)	73	5.8 (2.7)
Wealth Index	Poorest	42	47.7%	37	50.7%	35	50.7%
	Richest	46	52.3%	36	49.3%	34	49.3%
WASH characteristics							
Water source	Safely managed	69	74.2%	62	77.5%	51	69.9%
	Not safely managed	24	25.8%	18	22.5%	22	30.1%
Water source on premises	Yes	77	82.8%	62	77.5%	57	78.1%
	No	16	17.2%	18	22.5%	16	21.9%

(*continued*)

Table 3 | continued

		1 month postpartum		6 months postpartum		12 months postpartum	
		Total		Total		Total	
		n		*n*		*n*	
Water treatment	Treatment	18	19.4%	15	18.7%	11	15.1%
	No treatment	75	80.6%	65	81.3%	62	84.9%
Interruptions to supply	Rarely	70	75.3%	60	75%	57	78.1%
	> Once a month	23	24.7%	20	25%	16	21.9%%
Water storage	Bucket	20	90.9%	25	96.2%	19	95%
	Other (pot, bottle, tub, water can)	2	9.1%	1	3.8%	1	5%
Water Index	(mean, SD)	93	3.13 (0.91)	80	3.11 (0.84)	73	3.11 (0.68)
Type of sanitation	Safely managed	87	93.5%	77	96.3%	71	97.3%
	Not safely managed	6	6.5%%	3	3.7%	2	2.7%
Household hygiene characteristics							
Type of house	Formal	78	82.1%	63	80.7%	59	80.8%
	Informal	17	17.9%%	15	19.3%	3	19.2%
Type of flooring	Improved	–	–	75	96.2%	65	89%
	Unimproved	–	–	3	3.8%	8	11%
Animals on property	No	69	74.2%	59	73.4%	56	76.7%
	Yes	24	25.8%	21	26.3%	17	23.3%
Waste storage	Outside house/off property	87	94.6%	72	90%	66	90.4%
	Inside house	5	5,4%	8	10%	7	9.6%
Frequency of household cleaning	Everyday	88	94.6%	76	95%	66	90.4%
	<7 times a week	5	5.4%	4	5%	7	9.6%
Personal hygiene characteristics							
Hand washing	Before/after handling food	29	31.2%	32	40	41	56.2%
	Before/after using sanitation	48	51.6%%	38	47.5	26	35.6%
	Other (when hands dirty, rarely, after touching money, after cleaning)	16	17.2%%	10	12.5%	6	8.2%
Hand washing detergent	Water & soap/ash	66	71.7%	60	76.9%	52	72.2%
	Only water	26	28.3%	18	23.1%	20	27.8%
Food hygiene characteristics							
Food hygiene practices	Recommended behaviour[a]	46	86.8%	54	68.4%	33	44.6%
	Not recommended behaviour	7	13.2%	25	31.6%	41	55.4%
Main type of water used[b]	Tap water boiled	25	100%	36	100%	33	100%
Hygiene index	(mean, SD)	46	3.35 (0.87)	65	3.38 (0.89)	65	3.14 (0.97)

(*continued*)

Table 3 | continued

	1 month postpartum		6 months postpartum		12 months postpartum	
	Total		Total		Total	
	n		*n*		*n*	
Morbidity and illness						
Diarrhoea						
Yes	1	1.8%	6	8.3%	9	12.3%
No	55	98.2%	66	91.7%	64	87.7%

[a]This variable was constructed by combining two variables pertaining to the cleaning of the breast and cleaning of utensils prior to feeding. Recommended behaviour was defined as an activity that is protective towards, or acts as a barrier to, the transmission of pathogens.
[b]All respondents reported using boiled tap water. There were no observations of the other categories (mineral water boiled, tap water not boiled, mineral water not boiled).

time points explained, 90, 34, and 26% of the variation in WAZ, respectively.

Finally, in terms of WHZ (Table 6), use of a safely managed sanitation facility was associated with an increase in WHZ, at 12 months, by 1.94 (M4, $p = 0.02$) while no associations were detected at 1 or 6 months. No associations with WHZ were detected for either the hygiene or water indices at any of the timepoints. At 1 month, 6 months, and 12 months, WASH factors (M1) explained 2, 4, and 18% of the variance in WHZ respectively, while infant, maternal, and household characteristics (M4) at the same time points explained 55, 18, and 24% of the variation in WHZ, respectively.

DISCUSSION

This study aimed to identify specific postnatal environmental factors related to WASH, and subsequent associations with HAZ, WAZ, and WHZ scores in infants born healthy in Soweto, Johannesburg. This study identified statistically significant associations with each of the specific WASH components and growth outcomes, dependent on infant age. In summary, household access to sanitation facilities that were not safely managed was associated with a decrease in HAZ scores at 1 and 6 months (but not at 12 months) with WAZ at all timepoints; and finally, with WHZ scores at 12 months (but not at 1 or 6 months). The hygiene index was negatively associated with HAZ and WAZ scores at 1 month, but not at 6 or 12 months, or with WHZ scores at any of the timepoints. The evidence therefore suggests that the greatest impact relating to water is likely to affect WAZ around 12 months while the greatest impact of hygiene is around 1 month postpartum and is likely to affect HAZ and WAZ. Access to safely managed sanitation facilities is critical throughout the first year and impacts HAZ, WAZ, and WHZ.

Improvements in water, as it relates to WASH, are expected to have positive effects on diarrhoea which has been implicated as a major cause of undernutrition (Nabwera *et al.* 2017). However, interventions delivered in the WASH Benefits trials, in Bangladesh and Kenya, and the SHINE trials in Zimbabwe found no effect of basic water interventions on linear growth, or on childhood

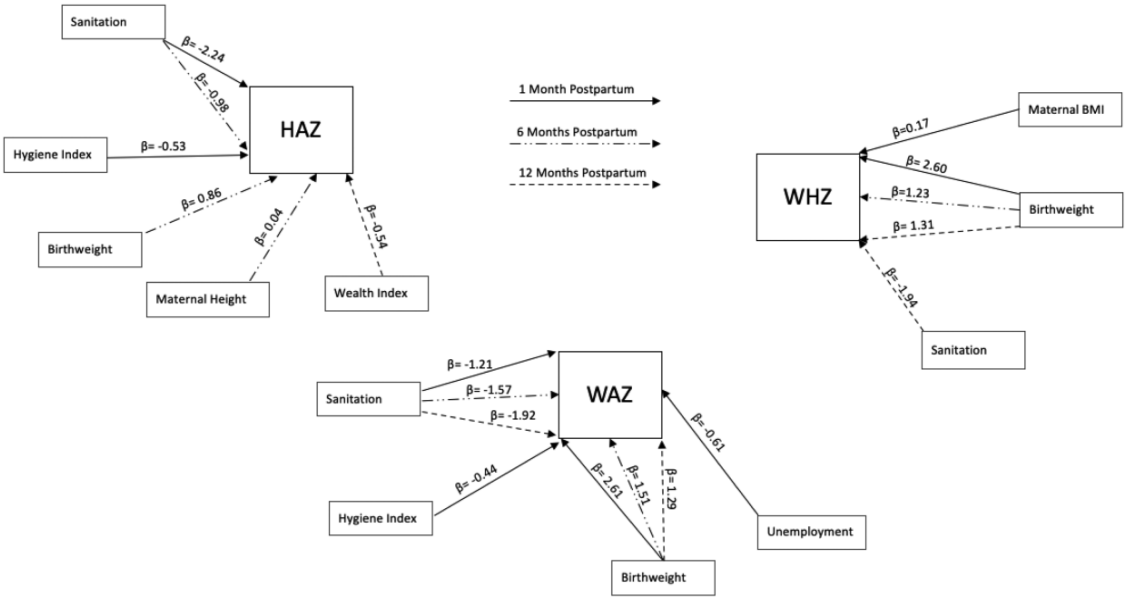

Figure 2 | Significant associations between HAZ, WAZ, WHZ, and WASH components, infant, maternal, and household factors in model 4.

diarrhoea (Null *et al.* 2018; Cumming *et al.* 2019; Pickering *et al.* 2019b). We found that in the current South African context, there was no association between water conditions and growth outcomes in the various models. Noteworthy, however, is the negative association between the water index and WAZ at 12 months after adjusting for infant characteristics at birth, but not after adjusting for maternal or household characteristics, which may mean that the effect might be relative to nutritional status at birth.

This finding was also consistent with a recent study in South Africa (Eastern Cape) which found that an increase in the prevalence of use of an improved water source was associated with an increase in systemic inflammation among children under 5 years of age (Voth-Gaeddert *et al.* 2019). Therefore, in the South African context, factors such as informal pipe connections, water quality, water removal devices, and household water storage practices may be associated with water source quality and to a certain extent affect infant growth.

In addition, early introduction of formula feeding and complimentary foods, as is seen in our study population through the extremely low rates of EBF may also result in infants being exposed to pathogens, resulting in impaired intestinal function, or environmental enteric dysfunction (EED) (Keusch *et al.* 2013; Mbuya & Humphrey 2016). EED is thought to explain a significant portion of unresolved and unexplained undernutrition in the developing world, through nutrient malabsorption and systemic inflammatory responses (Mbuya & Humphrey 2016). In Zimbabwe for instance, it was found that non-EBF may lead to faecooral transmission of bacteria among infants living in conditions of poor sanitation and hygiene; and that frequent exposure to potentially pathogenic organisms likely drives enteric inflammation (Prendergast *et al.* 2014).

In this study, we showed that household access to sanitation facilities that were not safely managed was associated with a decrease in HAZ, WAZ, and WHZ. Similar associations between sanitation and undernutrition have been seen in a number of African settings. In Ethiopia, for instance, unavailability of a latrine was associated with significant higher odds of stunting in children between 6 and 24 months (Derso *et al.* 2017) and poor household sanitary facilities were associated with undernutrition between 6 and 12 months (Medhin *et al.* 2010) and in Zimbabwe, poor sanitation was associated with stunting and chronic inflammation between birth and 24 months (Prendergast *et al.* 2014).

A peculiarity in this respect is the fact that the infants are not, at this early stage, using sanitation facilities, which

Table 4 | Hierarchical regression analyses of WASH components on HAZ at 1, 6, and 12 months postpartum, the Soweto Baby WASH study

		HAZ											
		1 month postpartum				6 month postpartum				12 months postpartum			
		M1 $n = 45$	M2 $n = 44$	M3 $n = 31$	M4 $n = 30$	M1 $n = 65$	M2 $n = 64$	M3 $n = 60$	M4 $n = 59$	M1 $n = 65$	M2 $n = 64$	M3 $n = 57$	M4 $n = 56$
Model 1: WASH characteristics													
Water Index		−0.10 (−0.44–0.24)	−0.02 (−0.31–0.27)	0.20 (−0.21–0.61)	0.20 (−0.27–0.66)	−0.20 (−0.46–0.05)	−0.17 (−0.41–0.08)	−0.16 (−0.41–0.08)	−0.12 (−0.37–0.13)	−0.20 (−0.52–0.12)	−0.25 (−0.56–0.06)	−0.24 (−0.57–0.09)	−0.21 (−0.53–0.12)
Sanitation	Safely managed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Not safely managed	−0.14 (−1.19–0.90)	−0.45 (−1.36–0.46)	−2.22* (−3.98– − 0.47)	−2.24* (−4.28– − 0.20)	−0.88 (−1.90–0.14)	−1.02* (−1.99– − 0.05)	−0.96* (−1.92– − 0.01)	−0.98* (−1.93– − 0.03)	−0.93 (−2.15–0.28)	−0.95 (−2.12–0.22)	−0.64 (−1.91–0.63)	−1.03 (−2.29–0.24)
Hygiene Index		−0.13 (−0.51–0.24)	−0.22 (−0.54–0.10)	−0.52* (−0.96– − 0.08)	−0.53* (−1.02– − 0.03)	−0.18 (−0.43–0.06)	−0.17 (−0.40–0.06)	−0.20 (−0.43–0.03)	−0.12 (−0.36–0.13)	0.00 (−0.22–0.23)	0.05 (−0.16–0.26)	0.11 (−0.12–0.35)	0.12 (−0.11–0.35)
R^2		0.02	–	–	–	0.10	–	–	–	0.06	–	–	–
F		0.83	–	–	–	0.08	–	–	–	0.28	–	–	–
Model 2: Addition of infant characteristics													
Birthweight		–	1.47** (0.65–2.29)	1.09* (0.05–2.13)	1.09 (−0.13–2.30)	–	0.83** (0.24–1.42)	0.81** (0.21–1.42)	0.86** (0.25–1.47)	–	0.73* (0.09–1.37)	0.65 (−0.06–1.36)	0.62 (−0.07–1.30)
Gestational age		–	0.09 (−0.12–0.30)	0.05 (−0.22–0.32)	0.04 (−0.31–0.39)	–	−0.04 (−0.22–0.14)	−0.03 (−0.22–0.16)	0.03 (−0.17–0.23)	–	0.02 (−0.16–0.19)	0.03 (−0.18–0.23)	0.00 (−0.19–0.20)
R^2		–	0.34	–	–	–	0.22	–	–	–	0.16	–	–
ΔR^2		–	0.32**	–	–	–	0.11*	–	–	–	0.10*	–	–
F		–	0.005**	–	–	–	0.01**	–	–	–	0.07	–	–
Model 3: Addition maternal characteristics													
Age		–	–	0.07 (−0.01–0.15)	0.08 (−0.04–0.19)	–	–	0.01 (−0.03–0.04)	0.01 (−0.03–0.05)	–	–	−0.03 (−0.07–0.01)	−0.03 (−0.07–0.01)
Height		–	–	0.01 (−0.05–0.08)	0.01 (−0.06–0.09)	–	–	0.04* (0.01–0.07)	0.04* (0.01–0.07)	–	–	0.03 (−0.00–0.07)	0.02 (−0.01–0.06)
BMI		–	–	−0.10* (−0.19– − 0.01)	−0.10 (−0.22–0.01)	–	–	0.01 (−0.02–0.05)	0.02 (−0.02–0.06)	–	–	0.01 (−0.02–0.05)	0.00 (−0.03–0.04)
Education	No formal education, primary & secondary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Tertiary	–	–	−0.17 (−0.94–0.59)	−0.17 (−1.02–0.68)	–	–	−0.14 (−0.63–0.35)	−0.03 (−0.53–0.47)	–	–	0.06 (−0.51–0.64)	0.04 (−0.52–0.60)
Employment	Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	No	–	–	−0.35 (−1.16–0.45)	−0.36 (−1.27–0.55)	–	–	0.24 (−0.23–0.71)	0.38 (−0.12–0.89)	–	–	−0.12 (−0.60–0.36)	−0.05 (−0.53–0.44)
R^2		–	–	0.58	–	–	–	0.36	–	–	–	0.25	–
ΔR^2		–	–	0.23	–	–	–	0.14	–	–	–	0.09	–
F		–	–	0.03*	–	–	–	0.009**	–	–	–	0.17	–

(*continued*)

Table 4 | continued

	HAZ											
	1 month postpartum				6 month postpartum				12 months postpartum			
	M1 $n = 45$	M2 $n = 44$	M3 $n = 31$	M4 $n = 30$	M1 $n = 65$	M2 $n = 64$	M3 $n = 60$	M4 $n = 59$	M1 $n = 65$	M2 $n = 64$	M3 $n = 57$	M4 $n = 56$
Model 4: Addition of household characteristics												
Family size	–	–	–	0.00 (−0.13–0.14)	–	–	–	−0.02 (−0.09–0.05)	–	–	–	0.00 (−0.08–0.08)
Wealth Index	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest	–	–	–	0.03 (−0.83–0.88)	–	–	–	−0.31 (−0.79–0.18)	–	–	–	−0.54* (−1.00– −0.07)
R^2	–	–	–	0.58	–	–	–	0.39	–	–	–	0.34
ΔR^2	–	–	–	0.00	–	–	–	0.03	–	–	–	0.09
F	–	–	–	0.11	–	–	–	0.01**	–	–	–	0.07

may allude to the importance of sanitation and hygiene at household as well as community levels, transmitted through the mother or caregiver. Results from a study conducted in an urban setting in Maputo, Mozambique, reported associations with risk factors for faecal contamination of water, soil, and surfaces in households sharing poor-quality sanitation, and described a setting impacted by pervasive domestic faecal contamination, including from human sources, that was largely disconnected from the observed variation in socio-economic and sanitary conditions (Holcomb *et al.* 2020).

It is noticeable that the effect size of sanitation decreased for HAZ between 1 month up until 12 months while the opposite effect was seen for WAZ and WHZ where the effect of sanitation increased from 1 month up to 12 months, with the greatest the effect size seen in WHZ.

This may be indicative of WASH factors, such as sanitation, having a greater impact on weight, rather than height, during this initial period of early childhood growth, with height generally being a marker of chronic undernutrition persisting over a number of years. This is consistent with literature that suggests that adiposity is more sensitive to fluctuations driven by external environmental factors, including food security, and recurrent infections, and therefore more likely to affect children over the course of months rather than years (Victora *et al.* 2010; Richard *et al.* 2013, 2014; Osgood-Zimmerman *et al.* 2018). As such, the extent of WASH factors on height may only become evident later on during childhood. In turn, WASH interventions targeted on linear growth, with limited effects on the burden of diarrhoea, may reduce the likelihood of catch-up growth in the first 2 years (Richard *et al.* 2013, 2014). This is seen in the contribution of WASH factors to the variation in *z*-scores being minimal for all indices at 1 month, increasing somewhat to around 6–10% for HAZ between 6 and 12 months; however, significant increases in explanatory contribution up to about 20% are seen when it comes to WHZ and WAZ at 12 months.

Negative associations for the hygiene index for HAZ and WAZ were detected at 1 month postpartum, contrary to the initial hypothesis, that an increase in the hygiene index would yield positive associations with the nutritional status outcomes. Given the significance of sanitation, during a period when infants are not themselves using sanitation facilities, a point of reflection that emerges is again whether

Table 5 | Hierarchical regression analyses of WASH components on WAZ at 1, 6, and 12 months postpartum, the Soweto Baby WASH study

		WAZ											
		1 month postpartum				6 months postpartum				12 months postpartum			
		M1 *n* = 45	M2 *n* = 44	M3 *n* = 31	M4 *n* = 30	M1 *n* = 65	M2 *n* = 64	M3 *n* = 60	M4 *n* = 59	M1 *n* = 65	M2 *n* = 64	M3 *n* = 57	M4 *n* = 56
Model 1: WASH characteristics													
Water index		−0.05 (−0.36–0.25)	0.02 (−0.15–0.20)	0.17 (−0.03–0.38)	0.17 (−0.04–0.37)	−0.10 (−0.42–0.23)	−0.03 (−0.32–0.27)	0.01 (−0.31–0.33)	0.07 (−0.25–0.39)	−0.36 (−0.73–0.01)	−0.41* (−0.74– – 0.07)	−0.33 (−0.69–0.03)	−0.35 (−0.73–0.03)
Sanitation	Safely managed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Not safely managed	0.17 (−0.78–1.11)	−0.35 (−0.91–0.20)	−1.32** (−2.19– – 0.44)	−1.21* (−2.12– – 0.30)	−1.28 (−2.57–0.00)	−1.50* (−2.69– – 0.31)	−1.51* (−2.75– – 0.26)	−1.57* (−2.78– – 0.36)	−2.21** (−3.63– – 0.79)	−2.12** (−3.39– – 0.84)	−1.84* (−3.24– – 0.45)	−1.92* (−3.39– – 0.46)
Hygiene Index		−0.06 (−0.40–0.28)	−0.21* (−0.40– – 0.01)	−0.39** (−0.61– – 0.17)	−0.44** (−0.66– – 0.22)	−0.04 (−0.34–0.26)	−0.03 (−0.31–0.25)	−0.06 (−0.36–0.25)	0.04 (−0.28–0.35)	−0.07 (−0.33–0.19)	0.01 (−0.22–0.25)	0.03 (−0.23–0.29)	0.00 (−0.26–0.27)
R^2		0.01	–	–	–	0.06	–	–	–	0.19	–	–	–
F		0.92	–	–	–	0.26	–	–	–	0.005**	–	–	–
Model 2: Addition of infant characteristics													
Birthweight		–	2.18** (1.68–2.68)	2.52** (2.00–3.04)	2.61** (2.06–3.15)	–	1.35** (0.63–2.07)	1.52** (0.73–2.31)	1.51** (0.72–2.29)	–	1.41** (0.71–2.11)	1.30** (0.52–2.09)	1.29** (0.50–2.09)
Gestational age		–	0.01 (−0.12–0.13)	−0.01 (−0.14–0.13)	−0.05 (−0.21–0.11)	–	−0.06 (−0.28–0.16)	−0.10 (−0.34–0.14)	−0.07 (−0.33–0.19)	–	−0.11 (−0.30–0.08)	−0.12 (−0.35–0.10)	−0.14 (−0.37–0.09)
R^2		–	0.71	–	–	–	0.25	–	–	–	0.37	–	–
ΔR^2		–	0.70**	–	–	–	0.19**	–	–	–	0.18**	–	–
F		–	0.000**	–	–	–	0.004**	–	–	–	0.000**	–	–
Model 3: Addition Maternal Characteristics													
Age		–	–	0.02 (−0.02–0.06)	0.02 (−0.03–0.07)	–	–	0.00 (−0.05–0.05)	0.01 (−0.04–0.05)	–	–	0.00 (−0.04–0.05)	0.00 (−0.05–0.05)
Height		–	–	0.03 (−0.01–0.06)	0.02 (−0.01–0.06)	–	–	0.02 (−0.02–0.06)	0.02 (−0.02–0.06)	–	–	0.03 (−0.01–0.07)	0.03 (−0.02–0.07)
BMI		–	–	0.03 (−0.02–0.07)	0.02 (−0.03–0.08)	–	–	0.02 (−0.03–0.07)	0.03 (−0.02–0.07)	–	–	0.00 (−0.04–0.04)	0.00 (−0.04–0.04)
Education	No formal education, primary & secondary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	tertiary	–	–	0.37 (−0.02–0.75)	0.36 (−0.02–0.74)	–	–	−0.06 (−0.70–0.58)	0.07 (−0.56–0.71)	–	–	0.17 (−0.46–0.80)	0.15 (−0.50–0.80)
Employment	Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	No	–	–	−0.53* (−0.93– – 0.13)	−0.61** (−1.02– – 0.21)	–	–	0.17 (−0.45–0.78)	0.39 (−0.25–1.03)	–	–	−0.27 (−0.80–0.25)	−0.30 (−0.87–0.26)
R^2		–	–	0.89	–	–	–	0.33	–	–	–	0.42	–
ΔR^2		–	–	0.18	–	–	–	0.08	–	–	–	0.05	–
F		–	–	0.000**	–	–	–	0.02*	–	–	–	0.002**	–

(*continued*)

Table 5 | continued

	WAZ											
	1 month postpartum				6 months postpartum				12 months postpartum			
	M1 $n = 45$	M2 $n = 44$	M3 $n = 31$	M4 $n = 30$	M1 $n = 65$	M2 $n = 64$	M3 $n = 60$	M4 $n = 59$	M1 $n = 65$	M2 $n = 64$	M3 $n = 57$	M4 $n = 56$
Model 4: Addition of household characteristics												
Family size	–	–	–	−0.01 (−0.07–0.05)	–	–	–	−0.09 (−0.18–0.00)	–	–	–	0.06 (−0.04–0.15)
Wealth Index Poorest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest	–	–	–	0.36 (−0.03–0.74)	–	–	–	−0.37 (−0.99–0.24)	–	–	–	−0.12 (−0.65–0.42)
R^2	–	–	–	0.91	–	–	–	0.40	–	–	–	0.45
ΔR^2	–	–	–	0.02	–	–	–	0.07	–	–	–	0.03
F	–	–	–	0.000**	–	–	–	0.01**	–	–	–	0.005**

95% Confidence interval in parentheses. Significance levels: *$p \leq 0.05$ and **$p \leq 0.01$.

undernutrition is driven through maternal and caregiver practices and health, with maternal and caregiver health being driven through WASH.

This study has a number of strengths. Firstly, using data-driven processes, this study produced water and hygiene indices which are the first step in exploring various methodologies for creating WASH indicators that relate to child growth in the South African setting. This contributes to broader issues surrounding the fact that current indices have not been sufficient to detect associations with growth (Null *et al.* 2018; Cumming *et al.* 2019; Pickering *et al.* 2019b).

Secondly, this study, as far as the authors can tell, is the first, in the South African setting, specifically aimed at providing detailed information about WASH exposures, and precisely when in early childhood they affect growth. Limited data exist looking specifically at the effect of timing in the role that WASH plays in determining nutritional status in the African context (Momberg *et al.* 2020b). Furthermore, only a handful of studies in this context have considered the link between WASH factors and nutritional status during early childhood (Momberg *et al.* 2020b). As such, this study begins to build the body of evidence in the South African setting and allows for the translation of existing evidence relating to WASH and nutritional status into the sub-Saharan context, particularly in South Africa (Momberg *et al.* 2020a, 2020b).

This study, like all studies investigating complex interactions, has a number of limitations. Despite attempting to validate respondents' answers with multiple questions, social desirability bias, whereby the participant is inclined to deny undesirable traits, may influence some of the variables that pertain to behavioural characteristics, including the hygiene index.

During the course of the study, unanticipated cultural dynamics were discovered, in terms of in- and out-migration of the child, where the child moved relatively frequently between caregivers and extended family in the urban Soweto setting and rural context (Ginsburg *et al.* 2009; Said-Mohamed *et al.* 2015; Hall *et al.* 2018). As a result, it was not always the mother responding to the various surveys but sometimes another caregiver, usually another family member, which is likely indicative of mothers seeking social and possibly economic support, in terms of childcare (Ginsburg *et al.* 2009; Said-Mohamed *et al.* 2015; Hall *et al.* 2018). This is consistent with our finding that maternal unemployment was associated with a decrease in WAZ at 1 month. Furthermore, infants were

Table 6 | Hierarchical regression analyses of WASH components on WHZ at 1, 6, and 12 months postpartum, the Soweto Baby WASH study

		WHZ											
		1 month postpartum				6 months postpartum				12 months postpartum			
		M1 $n = 45$	M2 $n = 44$	M3 $n = 31$	M4 $n = 30$	M1 $n = 65$	M2 $n = 64$	M3 $n = 60$	M4 $n = 59$	M1 $n = 65$	M2 $n = 64$	M3 $n = 57$	M4 $n = 56$
Model 1: WASH characteristics													
Water Index		0.06 (−0.33–0.45)	0.07 (−0.30–0.44)	0.02 (−0.48–0.52)	0.01 (−0.54–0.56)	0.04 (−0.32–0.40)	0.10 (−0.26–0.45)	0.15 (−0.25–0.55)	0.19 (−0.22–0.59)	0.35 (−0.75–0.06)	0.38 (−0.76–0.01)	0.29 (−0.70–0.11)	− 0.33 (−0.76–0.09)
Sanitation	Safely managed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Not safely managed	0.45 (−0.74–1.64)	0.05 (−1.10–1.21)	0.79 (−1.34–2.92)	0.93 (−1.49–3.35)	0.90 (−2.35–0.54)	1.06 (−2.48–0.35)	1.12 (−2.66–0.43)	1.18 (−2.71–0.35)	2.38** (−3.94– − 0.83)	2.25** (−3.72– − 0.79)	2.08* (−3.65– − 0.50)	− 1.94* (−3.59– − 0.30)
Hygiene Index		0.09 (−0.34–0.52)	0.01 (−0.42–0.40)	0.11 (−0.42–0.64)	0.05 (−0.54–0.64)	0.11 (−0.23–0.45)	0.11 (−0.23–0.44)	0.10 (−0.28–0.47)	0.15 (−0.24–0.55)	0.08 (−0.36–0.20)	0.01 (−0.28–0.26)	0.02 (−0.31–0.27)	− 0.06 (−0.36–0.24)
R^2		0.02	–	–	–	0.04	–	–	–	0.18	–	–	–
F		0.87	–	–	–	0.48	–	–	–	0.008**	–	–	–
Model 2: addition of infant characteristics													
Birthweight		–	1.41** (0.37–2.45)	2.46** (1.20–3.73)	2.60** (1.16–4.05)	–	1.05* (0.19–1.91)	1.29* (0.31–2.26)	1.23* (0.24–2.21)	–	1.32** (0.52–2.13)	1.30** (0.42–2.19)	1.31** (0.42–2.20)
Gestational age		–	0.12 (−0.39–0.15)	0.11 (−0.44–0.22)	0.16 (−0.57–0.26)	–	0.05 (−0.31–0.21)	0.10 (−0.41–0.20)	0.11 (−0.44–0.22)	–	0.16 (−0.38–0.06)	− 0.18 (−0.43–0.08)	0.18 (−0.44–0.08)
R^2		–	0.18	–	–	–	0.13	–	–	–	0.31	–	–
ΔR^2		–	0.16*	–	–	–	0.09	–	–	–	0.13**	–	–
F		–	0.17	–	–	–	0.14	–	–	–	0.0005**	–	–
Model 3: addition maternal characteristics													
Age		–	–	0.06 (−0.16–0.04)	0.07 (−0.20–0.07)	–	–	0.00 (−0.06–0.06)	0.00 (−0.06–0.06)	–	–	0.02 (−0.03–0.07)	0.02 (−0.03–0.07)
Height		–	–	0.03 (−0.05–0.11)	0.02 (−0.07–0.12)	–	–	0.01 (−0.06–0.04)	0.01 (−0.06–0.04)	–	–	0.02 (−0.03–0.07)	0.02 (−0.03–0.07)
BMI		–	–	0.17** (0.06–0.28)	0.17* (0.03–0.31)	–	–	0.02 (−0.04–0.08)	0.02 (−0.04–0.08)	–	–	− 0.00 (−0.05–0.04)	0.00 (−0.05–0.04)
Education	No formal education, primary & secondary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Tertiary	–	–	0.82 (−0.12–1.75)	0.81 (−0.19–1.82)	–	–	0.04 (−0.75–0.83)	0.13 (−0.68–0.93)	–	–	0.20 (−0.51–0.91)	0.19 (−0.53–0.92)
Employment	Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	No	–	–	0.32 (−1.30–0.66)	0.42 (−1.50–0.66)		–	0.02 (−0.74–0.78)	0.19 (−0.62–1.00)	–	–	− 0.26 (−0.86–0.33)	0.35 (−0.98–0.28)
R^2		–	–	0.57	–	–	–	0.18	–	–	–	0.38	–
ΔR^2		–	–	0.39*	–	–	–	0.05	–	–	–	0.07	–
F		–	–	0.03*	–	–	–	0.41	–	–	–	0.007**	–

(*continued*)

Table 6 | continued

		WHZ											
		1 month postpartum				6 months postpartum				12 months postpartum			
		M1 $n = 45$	M2 $n = 44$	M3 $n = 31$	M4 $n = 30$	M1 $n = 65$	M2 $n = 64$	M3 $n = 60$	M4 $n = 59$	M1 $n = 65$	M2 $n = 64$	M3 $n = 57$	M4 $n = 56$
Model 4: addition of household characteristics													
Family Size		–	–	–	0.02 (−0.18–0.14)	–	–	–	0.10 (−0.21–0.02)	–	–	–	0.07 (−0.03–0.18)
Wealth Index	Poorest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Richest	–	–	–	0.44 (−0.58–1.46)	–	–	–	0.24 (−1.02–0.53)	–	–	–	0.18 (−0.42–0.78)
R^2		–	–	–	0.57	–	–	–	0.22	–	–	–	0.42
ΔR^2		–	–	–	0.00	–	–	–	0.04	–	–	–	0.04
F		–	–	–	0.12	–	–	–	0.41	–	–	–	0.01*

95% Confidence interval in parentheses.
Significance levels: *$p \leq 0.05$ and **$p \leq 0.01$.

likely exposed to a number of different care practices and infrastructure installations during the first year. WASH interventions in this setting would therefore benefit from including considerations surrounding social support while reinforcing best WASH practices at the individual, household, and community levels.

Due to the relatively small sample size, not all of the variables that the authors would have hoped to include in the indices and covariates were possible due to the low number of observations for variables, such as water storage, EBF, and incidence of diarrhoea. Notwithstanding the small sample size, the fact that associations were detected allows the authors to postulate that these associations would be potentiated given a larger sample. Despite sample sizes being limited in-lieu of collecting more routine and detailed data, home visits allowed the study team to limit biases in participant answers by probing and having first-hand experience of the household.

In light of the evidence raised in this study, interventions focussed on sanitation during the first 1,000 days are likely to be most effective in improving infant length (and thus reducing stunting) between birth and 6 months, weight (and thus reducing wasting) around 12 months, and overall underweight between birth and one year postpartum. Given that these infants were *a priori* born healthy, yet started short, might allude to the need for WASH interventions to begin earlier than previously anticipated, perhaps as early as pre-conception, targeting women, as well as the household and surrounding community (Bhutta *et al.* 2008, 2013). These findings are particularly relevant for policy makers in so far as the importance of service provision of safely managed sanitation facilities is concerned; thus suggesting that radical changes and improvements to both household and community level sanitation may be required before meaningful impacts on targets related to undernutrition are achieved. In addition, within the South African setting, it is critical that these interventions are accompanied by universal promotion of EBF, and additional provision of social support to the most vulnerable.

CONCLUSION

The evidence suggests that the biggest impact relating to water is likely to affect WAZ around 12 months while the greatest impact of hygiene is around 1 month postpartum

and is likely to affect HAZ and WAZ. Access to safely managed sanitation facilities is critical throughout the first year and impacts HAZ, WAZ, and WHZ. Interventions intending to address issues surrounding WASH in early childhood and nutritional status would therefore benefit from taking this timing into account and recognising specific timepoints in early childhood, and associated WASH factors for intervention. WASH is an important factor influencing infant growth, and improvements to both household and community level sanitation may be required in order to achieve targets in terms of minimising undernutrition.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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