The compliance, monitoring and completeness of sanitation data in some Gauteng Municipalities in relation to Shit Flow Diagram requirements.

Maseabata Joyce Nama

Student Number: 1475243

A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg 2025

Date: 19/09/2025

DECLARATION

I Maseabata Joyce Nama (Student number: 1475243)

am a student registered for the degree of Msc Civil engineering in the academic year 2025.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.

Signature: J. Nama Date: 19 September 2025

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
Private Bag 3, Wits 2050, South Africa | Tel: +27 11 717 7104 | Fax: +27 11 717 7045
Excel . Together

WARNING ABOUT PLAGIARISM

The School of Civil and Environmental Engineering at the University of Witwatersrand upholds a strong commitment to integrity and ethical conduct in all academic work, including assignments and reports. We emphasise the importance of students understanding the proper use of secondary material and the scholarly methods for presenting and acknowledging references.

Plagiarism, the failure to credit the words or ideas of others, is considered academic theft and is treated as a serious offence. It occurs when someone uses another's work without proper acknowledgment, creating the false impression that those words or ideas are their own. To avoid plagiarism, you must always credit the original source of any borrowed content, whether it be words, ideas, tables or images.

If, after reading this notice, you are still uncertain about how to avoid plagiarism, it is essential to consult your lecturer before submitting your assignment.

Students who have committed plagiarism will be referred to the Academic Misconduct Committee of the School of Civil and Environmental Engineering.

Please view the links below for additional information:

- STUDENT ACADEMIC MISCONDUCT POLICY
- WITS FRAMEWORK FOR ACADEMIC INTEGRITY
- WITS PLAGIARISM POLICY DOCUMENT

Prepared by the Teaching & Learning Committee
February 2025

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
Private Bag 3, Wits 2050, South Africa | Tel: +27 11 717 7104 | Fax: +27 11 717 7045
Excel . Together

PLAGIARISM DECLARATION

Course code: [CIVN8000A
Name of assignment/report: [MSc Dissertation
Lecturer name: [Prof Adeshola Ilemobade
Date submitted: [19 September 2025

Plagiarism is the act of presenting someone else's ideas as my own. In this work, any material written by others, whether from printed sources or the internet, has been carefully acknowledged and referenced. Every contribution to, or quotation from, another person's work in this Choose one has been properly cited and referenced.

The signatory/s acknowledge:

- Plagiarism is wrong.
- Failing to credit sources, or copying sentences or paragraphs from a book, article, or internet source without proper citation, is plagiarism.
- Recognize that even altering wording slightly without citation still constitutes plagiarism when using someone else's ideas.
- Declare that all sentences and paragraphs in this submission are original work and that all ideas borrowed from others have been credited. I have familiarised myself with the University of the Witwatersrand Student Academic Misconduct Policy (LINK).

AI usage statement:

- Unless otherwise stated, all content generated by artificial intelligence (AI) software, tools, or models has been critically reviewed, edited, supplemented, and acknowledged.
- I have used the following AI software/tools/models: [pdf combiner, Grammarly, Chatgpt, Google AI searcher
  For the following purpose: [To check spelling, for formating reporting, and filtering the search for data that was specific to the research

Group number (if applicable) [	
Student number	Signature

ABSTRACT

This study investigated the compliance, monitoring and completeness of sanitation data in selected Gauteng Municipalities relative to Shit Flow Diagram (SFD) requirements—a critical tool for comprehensive sanitation service chain analysis. The research addressed data deficiencies that impede effective SFD implementation, a challenge that directly impacts progress toward Sustainable Development Goal 6.

Through rigorous mixed-methods analysis of Annual Reports, Integrated Development Plans, and Green Drop Reports, supplemented by practitioner surveys, the research revealed profound inconsistencies across municipal data ecosystems. Annual Reports demonstrated striking variations in data quality: Ekurhuleni Metropolitan Municipality achieved 34% compliance, completeness and active monitoring, Johannesburg Metropolitan Municipality 33%, and Tshwane Metropolitan Municipality 25%. Integrated Development Plans reflected similar disparities (15-43%), while Green Drop Reports showed consistently inadequate data quality (7%) across all metros.

The investigation identified critical systemic weaknesses, particularly in documenting faecal sludge containment, transportation processes, and treatment outcomes. These gaps were exacerbated by non-standardized terminology, fragmented recording systems, and insufficient real-time monitoring protocols. Survey responses from SFD practitioners confirmed these findings, highlighting transportation data as exceptionally problematic, necessitating extensive fieldwork and stakeholder interviews to overcome documentation inadequacies.

In response, the study developed a comprehensive framework built on five core principles: data availability, completeness, compliance, active monitoring, and standardization. Applied to Ekurhuleni Municipality, this framework demonstrated practical utility in prioritizing interventions and establishing progressive improvement pathways. By aligning with existing performance monitoring mechanisms like Green Drop certification, the framework creates accountability measures that strengthen reporting consistency while enhancing service delivery outcomes.

DEDICATION

I dedicate this dissertation to my nephews and nieces—Lerato, Bohlale, and the one yet to be born. May this work inspire you to pursue your dreams with determination and passion.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisors, Prof. Adeshola Ilemobade and Mrs. Xanthe Roux, for their unwavering guidance and support throughout the academic journey of this research.

Table of Contents

ACRONYMS AND ABBREVIATIONS

Acronym/ Abbreviation	Meaning
AR	Annual Report
CoEMM	City of Ekurhuleni Metropolitan Municipality
CoJMM	City of Johannesburg Metropolitan Municipality
CoTMM	City of Tshwane Metropolitan Municipality
CSE	Centre for Science and Environment
DALYs	Disability-Adjusted Life Years
DWS	Department of Water and Sanitation (South Africa)
FSM	Faecal Sludge Management
GDRs	Green Drop Reports
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HH	Households
IDPs	Integrated Development Plans
IRIS	Integrated Regulatory Information System
JMP	Joint Monitoring Programme (WHO/UNICEF)
NFSSM	National Faecal Sludge and Septage Management (Alliance)
NWMS	National Waste Management Strategy
SANDEC	Sanitation, Water and Solid Waste for Development
SBM	Swachh Bharat Mission (India)
SDG 6	Sustainable Development Goal 6
SFD	Shit Flow Diagram
SFD Lite	Simplified Shit Flow Diagram
SuSanA	Sustainable Sanitation Alliance
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit (toilet)
WEDC	Water, Engineering and Development Centre
WHO	World Health Organisation
WRC	Water Research Commission
WSAs	Water Services Authorities
WSP	Water and Sanitation Program
WW	Wastewater
WWTP	Wastewater Treatment Plant

1 INTRODUCTION

This study aims to investigate the relationship between data reporting by water and sanitation authorities (WSAs) and alignment with the Shit Flow Diagram (SFD). The SFD is a tool initially developed by the World Bank and further advanced by other organisations to support policy advocacy and sanitation planning. Studies have highlighted the benefits of SFDs, such as improving planning and decision-making processes (SuSanA, 2018). However, gaps in data capture and uniformity exist in many communities, and these need to be addressed in low- and middle -income countries (Safi *et al*., 2022). This study explores the availability, compliance, and completeness of sanitation data in Gauteng in relation to SFD requirements. As safe sanitation is essential to public health, this research is important (Pearl *et al*., 2020).

Basic sanitation, according to De Bruijne *et al*. (2007), is the most affordable technique for ensuring the sanitary disposal of excreta at the household level, resulting in a clean and effective way to prevent the transmission of waterborne illnesses. Sanitation is a fundamental human right, and its denial can have repercussions for other rights, such as those to dignity, education, health, and safety, as well as the environment (Winkler, 2015). It ensures users' protection and privacy, shields them from diseases, and allows for the disposal of excreta. In 2015, the United Nations General Assembly established Sustainable Development Goal 6, i.e., “clean water and sanitation for all by 2030” (UN, 2018). According to the WHO/UNICEF (2020), several nations have made significant progress in sanitation coverage, and therefore improving lives, the environment, and the economy.

Prior to 1994, in South Africa, middle- and high-income socio-economic groups generally received reliable sanitation services from municipalities, while basic sanitation services were extended to a limited number of black townships (Bond, 2003). This historical context has presented significant challenges for the post-1994 government in addressing the long-term impacts of inadequate sanitation on public health and the environment (Sutherland *et al*., 2014). Some municipalities in Gauteng Province continue to face difficulties in ensuring access to basic sanitation services for all residents. These challenges have contributed to hardships in low-income areas, as insufficient sanitation facilities increase the risk of water and land contamination (Majikijela, 2007).

The Department of Water and Sanitation highlights that many municipalities in the province contend with issues such as inadequate infrastructure, underperforming wastewater treatment plants, and insufficient maintenance, which exacerbate health and environmental risks (DWS, 2023). While the percentage of South Africans with access to improved sanitation has grown over the years, significant disparities remain, with many communities still reliant on inadequate systems that pose risks to public health and perpetuate inequalities (DWS, 2023; Africa Check, 2017). The spatial geography prior to 1994 is evident in regions lacking access to water and sanitation services (Sutherland *et al*., 2014). Many low-income communities, particularly those situated in areas previously classified as townships and informal settlements, continue to face barriers to accessing adequate sanitation services. To address these challenges requires tools designed to monitor and analyse the issues faced by cities and municipalities. One such tool is the SFD tool, which provides a comprehensive framework for understanding and addressing sanitation challenges.

An SFD is a simple advocacy and decision-support tool that consists of a report with a graphic representation of the paths of the faeces produced by the contributing population. It summarises service outcomes in terms of excreta flow and disposal in metropolitan areas, as well as a qualitative assessment of the context in which service delivery occurs and a complete list of data sources. The SFD was developed by Sustainable Sanitation Alliance (SuSanA) as part of a project funded by the Bill and Melinda Gates Foundation by the WSP, GIZ-GmbH, SANDEC, the research group at the University of Leeds, WEDC, and CSE. This advocacy tool's primary objectives are to (1) collect data on the sanitation chain and (2) provide an easily accessible and graphically clear picture of where the issues in faecal sludge management are located in any particular city. The SFD has the advantage of providing a unique means to involve relevant stakeholders in a coordinated discourse regarding excreta management (such as government leaders, sanitation specialists, and civil society organisations) (SuSanA, 2018). The graphic depicts places where issues exist along the sanitation value chain, as well as which parts are handled well. Articulation of SFD allows municipalities in South Africa to acknowledge the need for remedial action plans to aid in the management of difficulties raised by the SFDs (Moorgas, 2020). SFDs have also assisted municipal officials in India in prioritising investments by visualising how excreta is managed as it passes through a metropolis (Moorgas, 2020).

1.1 Significance and purpose of the study

This study aids in recognising the lack of and limited data collection and documentation in some municipalities in the province of Gauteng, and facilitates the creation of a reliable SFD that provides a realistic overview of sanitation conditions for the province. This SFD includes data to assist with monitoring the following: (a) containments that are not emptied and that encounter overflow, leakage, or offloading to the environment; (b) containments that are emptied but not delivered to treatment, (c) faecal sludge that is delivered to a treatment facility but is not treated. The SFD is significant not only because it provides a thorough overview of the issues associated with the delivery of wastewater and Faecal Sludge Management (FSM) services within the investigated municipalities but also because it identifies the aspects of service delivery that require improvement. It also provides stakeholders with a non-technical report to assist in sanitation planning. This study may assist public authorities and office bearers in understanding the dynamics and challenges they face in managing sanitation, particularly the issues related to missing or incomplete data that hinder the development of comprehensive plans to resolve sanitation problems. In particular, the existing body of research on the difficulties of providing basic services in Gauteng Province will be enhanced by new insights from this study. It will also contribute to scholarly and publications, offering additional reference and advancing the research agenda on sanitation.

1.2 Research questions

Based on the aforementioned sections, this study sought to answer the following research questions:

1. What proportion of the required data for developing an SFD is readily available in Gauteng municipalities?
2. What critical data gaps exist in meeting SFD requirements?
3. What are the key challenges faced in accessing the required data for SFD development across Gauteng municipalities?
4. To what extent is the available data compliant, actively monitored, and complete for SFD development?

5. How are data recording and documentation practices standardised or varied across Gauteng municipalities?
6. What data barriers were encountered previously during the development of existing SFDs in South Africa?
7. How can available tools and strategies resolve the lack of sanitation data in Gauteng municipalities?

1.3 Objectives

This study aims to assess the compliance, monitoring and completeness of sanitation data in Gauteng in relation to the SFD requirements. The following are the objectives of the research:

1. To undertake a literature review on different aspects of sanitation for example terminology, systems, management tools and challenges.
2. To collect publicly available sanitation data across municipalities in Gauteng.
3. To filter, collate and compare the data across selection of Gauteng municipalities.
4. To develop and administer questionnaires to selected respondents to assess if the gaps identified in the data are congruent with those experienced by those who have developed SFDs in South Africa.
5. To develop a framework to make the available data complete and compatible with the SFD requirements.

1.4 Research design and methodology

This research employs qualitative and quantitative data research methods and the objectives in section (1.3) were achieved using the methodology described in the steps below. Details for each step are presented in chapter 3.

Step 1: Literature Review (Refer to Section 3.1 for additional details)

To achieve Objective 1 to 5, a comprehensive review of the literature was conducted. This review explored various aspects of sanitation, including terminology, systems, management

tools, and global challenges. The findings provided a foundational understanding of the complexities of sanitation data and its alignment with SFD requirements.

Step 2: Data Collection (Refer to Section 3.2.2 for additional details)

To achieve Objective 2, sanitation data were collected from publicly available sources across Gauteng municipalities. The data collection process involved using relevant municipal department's online libraries and accessing published recorded reports and data.

Step 3: Data Collation and Analysis (Refer to Section 3.3 for additional details)

To achieve Objective 3, the collected data were filtered, collated, and compared across Gauteng municipalities. This process involved identifying patterns, inconsistencies, and variations in data availability, recording practices, and compliance with SFD requirements- it means that the data collected fully meets the standards and specifications set by the SFD tool. This includes covering all key stages of the sanitation service chain while being presented in the correct format and level of detail required. It also involves using consistent terminology and definitions aligned with SFD guidelines. Statistical methods and comparative analyses were used to highlight gaps and similarities.

Step 4: Questionnaire Development and Administration (Refer to Section 3.2.3 for additional details)

In line with Objective 4, the results from Steps 1 through 3 informed the development of questionnaires. These questionnaires were administered to selected respondents with expertise in SFD development to assess whether the identified gaps in data align with those experienced during previous SFD implementations in South Africa.

Step 5: Framework Development (Refer to Section 3.4 for additional details)

To achieve Objective 5, a framework was developed based on the outcomes gathered in the preceding steps. The framework aimed to bridge the gap between the SFD requirements and the publicly available data from selected municipalities in Gauteng.

1.5 Structure of the report

This dissertation is structured into eight chapters: an introduction (Chapter 1), a literature review exploring global and local sanitation challenges (Chapter 2), a detailed Methodology (Chapter 3), an analysis of results and discussion (Chapter 4), a proposed framework for data management (Chapter 5), a summary and conclusion with future research recommendations (Chapter 6), a comprehensive list of References (Chapter 7), and appendices providing supplementary data and materials (Chapter 8).

The dissertation began by establishing the context and importance of the study, introducing the background, rationale, research questions, objectives, and methodology, while contextualising the research within the broader goal of achieving universal sanitation access by 2030, as outlined in Sustainable Development Goal 6. It reviewed existing research on sanitation systems, management tools, and challenges, both globally and locally, with a focus on the use of SFDs and the specific issues faced in South Africa, culminating in an analysis of the Gauteng municipalities as the study area.

The methodology was detailed, covering the qualitative and quantitative approaches employed, including data collection, analysis, and framework development to address identified gaps. The findings presented an evaluation of sanitation data availability, compliance, and completeness, highlighting inconsistencies and challenges municipalities faced. Building on these findings, the dissertation developed a tailored framework for improving sanitation data management in Gauteng municipalities. The study concluded by summarising key findings, reflecting on research objectives, and offering recommendations for future research, supported by appendices that provided detailed results, timelines, methodologies, and records of dissemination.

2 LITERATURE REVIEW

To achieve objectives (1) to (5), outlined for this study, which focus on assessing the availability, compliance, and completeness of sanitation data in Gauteng in relation to SFD requirements, a comprehensive literature review is undertaken. This chapter provides a review of the existing body of knowledge on key aspects of sanitation, for example, terminology, systems, tools, data management, policy frameworks, and the role of various stakeholders in South Africa.

2.1 The structure of the literature review

The literature review provides an analysis of sanitation systems, with a particular focus on the SFD as a critical tool in urban sanitation management. It contextualises these within broader themes such as global sanitation challenges, FSM, and the regulatory frameworks shaping sanitation service delivery. It begins by defining and contextualising sanitation terminologies and categorising various sanitation systems based on their technologies and applications. The review then delves into the sanitation service chain, detailing its sequential components from containment to final disposal. It explores the role of SFDs in urban sanitation management, tracing their historical development, applications, and advancements in regions such as Latin America and India. Global sanitation challenges, including infrastructural inadequacies, financial constraints, sociocultural barriers, political and institutional issues, and environmental concerns, are critically analysed, alongside their impacts on health, the economy, and society. Issues specific to FSM and unique sanitation challenges in South Africa, such as infrastructural and policy limitations, are also examined. Furthermore, the review evaluates sanitation management policies, legislation, and regulations in South Africa, highlighting their influence on data governance and service delivery. It concludes by assessing sanitation data collection and reporting practices and defining the study area, focusing on Gauteng Province and its municipalities; Johannesburg, Tshwane, Ekurhuleni, Sedibeng, and West Rand.

2.2 Sanitation terminologies used

The definitions applied in this study are derived from the Sustainable Sanitation Alliance (SuSanA, 2018) and Tilley et al. (2014). This is necessary because sanitation terminology and management practices are not consistent globally, and the SFD tool uses its definitions, partially adapted from Tilley et al. (2014). Tilley et al. (2014), Compendium of Sanitation Systems and Technologies, is a book published by Eawag (Department Sandec), which is widely cited in the sanitation sector. The 2014 edition is the second, expanded edition, and it serves as a comprehensive reference on sanitation.

I. Containment: represents the first stage in the sanitation service chain and is a critical component of the SFD. It involves the collection and initial storage of waste, either on-site or off-site, depending on the sanitation system. For off-site sanitation, containment includes two key elements: (a) the toilet and (b) the infrastructure to which the toilet is connected, typically a pipe leading to a sewer network. In on-site sanitation, containment encompasses (a) the toilet, (b) the on-site sanitation technology receiving the toilet's discharge (e.g., septic tanks or pit latrines), and (c) any secondary technology connected to the on-site system, such as a soak pit or local sewer.

II. Effluent: refers to the liquid output that exits a sanitation technology, typically following the separation of solids from blackwater or faecal sludge, or after undergoing partial treatment.

III. Emptying: refers to the process of removing faecal sludge from on-site sanitation systems, such as septic tanks or pit latrines, either manually or using motorised equipment.

IV. Faecal Sludge (FS): refers to the waste material derived from on-site sanitation technologies or systems, such as pit latrines, septic tanks, or other storage-based facilities.

V. Off-Site Sanitation: refers to a system where excreta, commonly termed wastewater, are collected and transported away from the location where they are generated. This type of sanitation relies on a sewer network or similar infrastructure to convey waste to a centralised treatment facility.

   On-Site Sanitation: refers to sanitation technologies or systems where excreta, often termed faecal sludge, are collected, stored, and either emptied or treated directly at the location where they are generated. These systems are independent of sewer networks and

are commonly used in rural, peri-urban, or resource-constrained areas. Examples include pit latrines, septic tanks, and composting toilets.

VI. Pit Latrine: is a type of on-site sanitation technology consisting of a pit dug into the ground to collect and store excreta.

VII. Sanitation Service Chain: is the sequential stages involved in managing excreta, including containment, emptying, transport, treatment, and end-use or disposal.

VIII. Sanitation system: is a context-specific arrangement of sanitation technologies and services designed to manage faecal sludge and/or wastewater through the key stages of the sanitation service chain: containment, emptying, transport, treatment, and end-use or disposal.

IX. Septic Tank: is a watertight chamber, typically constructed from materials such as concrete, brickwork, fibreglass, PVC, or plastic, designed for the primary treatment of blackwater and greywater.

X. Blackwater: wastewater that includes a combination of urine, faeces, and flush water, along with anal cleansing water when applicable, or dry cleansing materials. It contains disease-causing organisms from faeces and nutrients from urine, both diluted by the flush water.

XI. Greywater: wastewater produced from activities such as washing food, clothes, and dishes, as well as from bathing, but excludes toilet waste.

XII. Sewer: is an underground pipe designed to transport blackwater, greywater, and, in some cases, stormwater (in the case of a combined sewer system) from individual households and other users to treatment facilities.

XIII. Wastewater: refers to used water that originates from sanitation technologies in households and other premises, including domestic, industrial, commercial, or agricultural locations. However, it excludes the wastewater generated directly by industrial, commercial, or agricultural processes. Wastewater also encompasses surface water runoff or stormwater, as well as any inflow or infiltration into sewer systems.

XIV. Open defecation: refers to the practice where individuals defecate in open spaces such as fields, forests, bushes, bodies of water, or other unprotected areas due to the absence of a toilet.

2.3 Sanitation systems categories

The categorisation of sanitation systems varies, influenced by factors such as technological design, service delivery methods, and the stages of the sanitation service chain. According to the Council for Scientific and Industrial Research (CSIR) and the Department of Human Settlement (2000), sanitation systems can be broadly grouped based on two primary criteria; (1) the use of water and (2) the requirement for conveyance.

Group 1: No Water Added – Requiring Conveyance

It includes sanitation systems where water is not used for human waste management, but the human waste must be conveyed off-site for treatment or disposal. An example is the chemical toilet, which is typically used for temporary applications such as construction sites, events, or during emergencies. These toilets rely on chemical solutions to break down human waste and control odours within a sealed holding tank. Once full, the tank is emptied and the human waste is transported to a treatment facility for processing (CSIR, 2000).

Group 2: No Water Added – No Conveyance

It includes sanitation systems where water is not used for flushing, and human waste does not require external conveyance for treatment, as it is treated and stored on-site. These systems are designed to operate efficiently in areas with limited water resources and infrastructure. Examples include the ventilated improved pit (VIP) toilet, ventilated improved double-pit toilet, ventilated vault toilet, and the urine-diversion toilet (CSIR, 2000).

Group 3: Water Added – Requiring Conveyance

It includes sanitation systems where water is used to flush human waste, and the wastewater is conveyed to a centralised treatment facility. Full waterborne sanitation is a prime example, involving the use of flush toilets connected to a sewer system that transports human waste to treatment plants. They require significant infrastructure investment, including sewer networks and centralised treatment facilities, and are reliant on a consistent water supply (CSIR, 2000).

Group 4: Water Added – No Conveyance

It includes sanitation systems such as flushing toilets with septic tanks and subsurface soil absorption fields and low-flow on-site sanitation systems like the Aqua-privy toilet, which use water for human waste removal but do not require external conveyance to a centralised

treatment facility. In these systems, human waste is flushed into a septic tank, where it undergoes initial treatment, with liquid effluent being filtered through the soil in an absorption field. The Aqua-privy toilet, a low-flow system, uses minimal water to flush human waste into a holding tank, where it undergoes primary treatment. Both systems treat human waste on-site, eliminating the need for extensive infrastructure like sewer lines and centralised treatment plants (CSIR, 2000).

2.4 Sanitation service chain

The sanitation service chain comprises five key stages: containment, emptying, transport, treatment, and reuse/disposal, as illustrated in Figure 1 (Harada *et al*., 2016). Notably, in some frameworks, the sanitation service chain is divided into six stages, incorporating capture as an additional stage before containment, followed by emptying, transport, treatment, and reuse/disposal (UNICEF, 2020). In this study first stage is containment, this stage focuses on the manner in which faecal waste is held, distinguishing between on-site and off-site sanitation facilities. On-site containment methods include latrines connected to piped sewerage or septic tanks, pit latrines, and container-based sanitation systems, and Off-site sanitation refers to systems where human waste is collected from individual households or facilities and transported to a centralised location for treatment or disposal. Unlike on-site systems (e.g., pit latrines or septic tanks), which manage waste at or near the point of generation, off-site systems typically involve a network of sewers or trucks to convey human waste to a treatment plant or other disposal facility. These diverse containment approaches set the foundation for the subsequent stages of the sanitation service chain (Valette and Colon, 2024; United Nations Children's Fund and World Health Organisation, 2024).

The sanitation service chain involves a series of interconnected stages designed to manage human waste safely and efficiently. Following the containment stage, the chain progresses to the emptying stage, where human waste that has accumulated in facilities such as pits, tanks, or containers is removed using efficient and hygienic methods (UNICEF, 2020). This is a critical step to ensure that human waste is handled safely without causing exposure to harmful pathogens. Honeysuckers (vacuum trucks) are commonly used for mechanised emptying of wastewater and faecal sludge from septic tanks, lined pits, or holding tanks. The truck uses a

suction pump to draw the contents through a hose into its storage tank, after which the load is transported to a designated treatment or disposal facility. This method is efficient for both liquid and semi-liquid waste, although thicker sludge may require agitation before pumping. In areas with limited access, smaller mechanised devices such as the Vacuum, Gulper, or MAPET may be used as alternatives. Once emptied, the collected waste is securely transported to designated treatment facilities, ensuring that it is moved in a manner that minimises risks of leakage or contamination, thereby preventing the spread of disease (UNICEF, 2020).

Efficient monitoring and regulation, enforced by governmental and regulatory bodies, play an integral role in maintaining health and environmental standards throughout the sanitation service chain (WHO, 2018). The harmonious function of these components, encompassing containment, emptying, transportation, treatment, and disposal/reuse, collectively contributes to public health, environmental sustainability, and the overall well-being of societies.

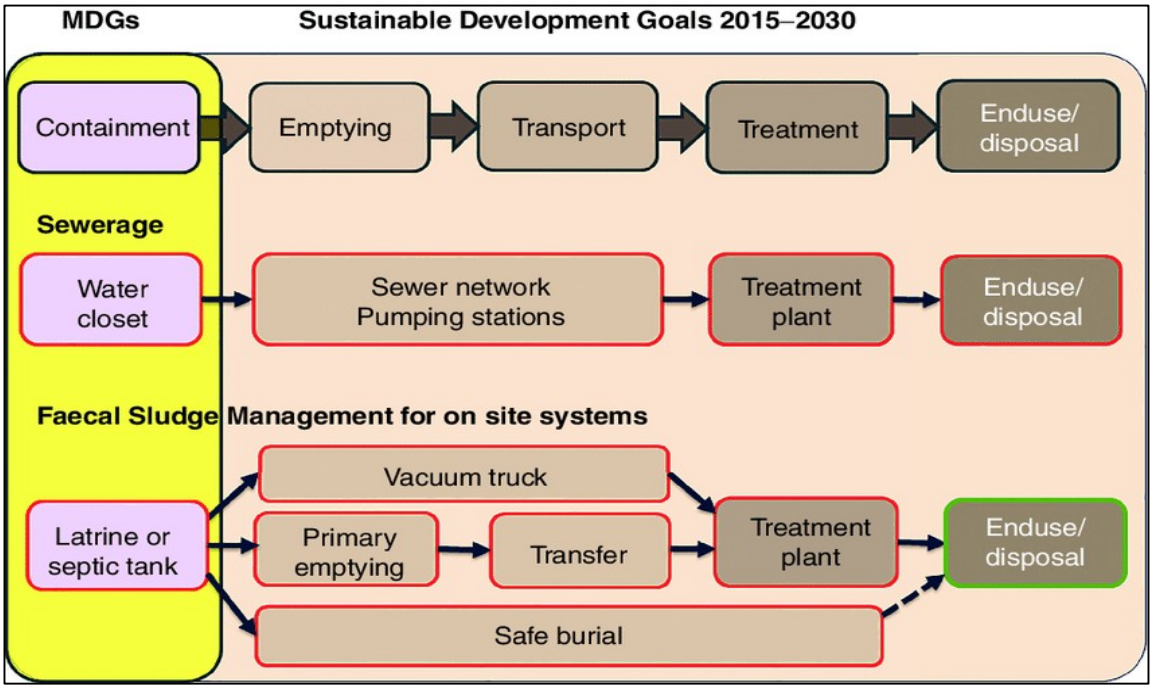


Figure 1: Sanitation service chain (Harada et al., 2016)

2.5 Shit Flow Diagram

The Sustainable Sanitation Alliance (SuSanA) defines the SFD as a snapshot of the general sanitation conditions throughout a city, including both on-site and off-site sanitation facilities (see Figure 2). It is a global network that aims to promote sustainable sanitation systems. It brings together individuals, organisations, governments, and researchers to collaborate, share knowledge, and develop innovative solutions to sanitation challenges worldwide. SFD traces the transit of excreta across the sanitation chain, which includes containment, emptying, transport, treatment, and reuse or/and disposal. It depicts the proportion of a city's excreta that is treated safely and the locations where faecal contamination occurs (SuSanA, 2018). Mapping these flows highlights areas of the sanitation system that are poorly monitored or unmetered. These areas are not routinely tracked, management and maintenance issues such as leaks or blockages often go unnoticed, despite their impact on overall system performance.

The illustration and layout are basic enough for non-sanitation specialists to interpret. This is essential for establishing a shared understanding and a common vocabulary to discuss the city's sanitation dilemma, such as where the primary difficulties lie and what it would take to achieve a city-wide inclusive sanitation. The SuSanA website, a global repository of SFDs, currently houses reports for over 150 cities in Africa, Asia, and South America which developed SFDs since 2014. It has assisted in the improvement of the planning framework for urban sanitation services for 150 million people (Susmita *et al*., 2022).

Figure 2 shows a visual representation of the sanitation chain, highlighting the various routes taken by faecal waste within a population. The width of the arrows and the percentages shown represent the proportion of the population whose faecal waste takes each route, and the colour of the arrows indicates whether the faecal waste is safely or unsafely managed. Green indicates safely managed faecal waste, which means that it is properly contained, transported, treated, and disposed of in a manner that protects human health and the environment. On the other hand, red indicates unsafely managed faecal waste, which means that the waste is not adequately contained, transported, or treated, posing risks of contamination and potential harm to public health and the environment. The direction of the arrow moves from one sanitation chain to another, ending at a safe disposal area or unsafe disposal area, which includes but is not limited to the neighbourhood or city.

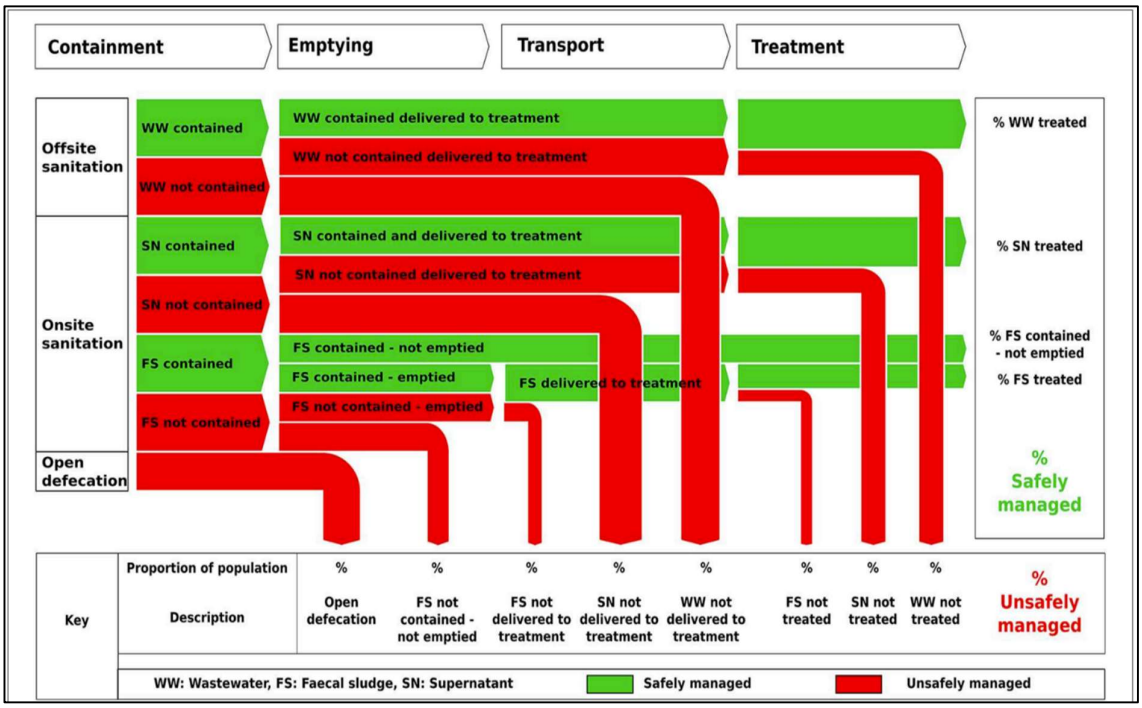


Figure 2: SFD example (SFD-PI, 2018a)

2.5.1 Uses of Shit Flow Diagrams (SFDs) in Urban Sanitation Management

The SFD is an essential tool, but does not solve problems on its own. Instead, it initiates crucial discussions among experts and stakeholders. The initial SFD developed was in 2014 as part of an assessment of FSM practices across 12 cities. When presented to the city's stakeholders, the SFD highlighted a critical concern: although only 1% of the population engaged in open defecation, an alarming 98% of the city's faecal waste was not being managed safely (Blackett *et al*., 2014).

SFD reports play a crucial role in enhancing diagnostics and facilitating targeted interventions at the city level. To maximise the value of a report, it should include a graphic along with a detailed set of critical information on the sanitation service delivery context of a city, transparently referencing all the data sources used. Without this comprehensive approach, sustainable solutions are difficult to achieve.

Presenting an SFD graphic to a key decision maker establishes the tone for productive discourse, providing a clear and common ground for discussion (SuSana, 2018). These discussions can occur against various backgrounds. For example, in Babati town, Tanzania, four key stakeholders of urban sanitation utilised the city's SFD as a starting point, fostering a

joint understanding of the status quo and informing discussions on possible futures for the city (Joseph and Priya, 2018). In India, the SFD has been seamlessly integrated into the ministry's toolkit, complementing the National Urban Sanitation Policy and enhancing communication among experts while providing valuable information for the public (Pearl *et al*., 2020).

2.5.2 Initial development of the Shit Flow Diagram

In a comprehensive study, Blacket *et al*. (2014) investigated FSM across 12 cities in diverse countries, including Bolivia, Honduras, Nicaragua, Mozambique, Senegal, Uganda, Bangladesh, India, Cambodia, Indonesia, and the Philippines. The aim was to analyse the difficulties of FSM in cities that vary in terms of geographical location, size, type, and level of service delivery. The researchers utilised the service chain concept as a framework to examine the physical flow of faecal waste within the system. This approach provides valuable understanding of the dynamics of faecal waste management across different urban contexts. Additionally, SFD were developed as tools to briefly summarise the outcomes at the city level and identify key bottlenecks in the management of faecal waste. The SFD proved instrumental in offering a visual representation of the faecal waste management process, aiding in the identification of areas requiring attention and improvement within urban sanitation systems.

The key findings of Blacket *et al*. (2014) study shown in Table 1 concerning FSM emphasise significant challenges and gaps in current practices highlighted in red. Notably, nearly two-thirds of the households in the examined cities relied on on-site sanitation facilities, but the safe FSM was achieved for only approximately 22% of the households on average. Furthermore, in just 2 of the 12 studied cities, (i.e., Palu city in Indonesia and Dumaguete in the Philippines), over 50% of households using on-site systems adequately managed their faecal waste indicated with brackets in Table 1. FSM, characterised by unsystematic and unplanned approaches primarily provided by informal private service providers, is not given attention by policymakers. While commonly perceived as a temporary solution for informal areas, FSM serves legal settlements as well. Policymaking tends to favour sewerage over FSM, and there is a notable scarcity of data and information on the subject (Peal *et al*., 2014). Technical and institutional challenges compound the issue, including poorly regulated faecal

sludge collection, prevalent illegal dumping, inadequately constructed toilets that do not consider emptying, widespread unhygienic manual emptying, and a lack of appropriate treatment and disposal facilities. Moreover, there are insufficient empirical data for estimating faecal sludge accumulation rates and the demand for management services, emphasising the pressing need for comprehensive improvements in current sanitation practices (Blacket *et al*., 2014).

Table 1: Overview of faecal sludge management services in the 12 cities

			% Households Using			% Fecal Waste Safely Managed		
Country	City	FSM Type	On-site Systems	Sewerage	Open Defecation	On-site Systems	Sewerage	Total
Latin America								
Bolivia	Santa Cruz	1—poor	51%	44%	5%	38%	100%	59%
Honduras	Tegucigalpa	1—poor	16%	81%	3%	31%	8%	11%
Nicaragua	Managua	1—poor	56%	40%	4%	38%	81%	52%
Africa								
Mozambique	Maputo	1—poor	89%	10%	1%	28%	12%	26%
Senegal	Dakar	3—improving	73%	25%	2%	39%	12%	31%
Uganda	Kampala	2—basic	90%	9%	1%	37%	80%	40%
South Asia								
Bangladesh	Dhaka	1—poor	79%	20%	1%	0%	10%	2%
India	Delhi	1—poor	24%	75%	1%	0%	46%	34%
East Asia								
Cambodia	Phnom Penh	1—poor	72%	25%	3%	0%	0%	0%
Indonesia	Palu	3—improving	91%	—	9%	95%	—	86%
Philippines	Dumaguete	3—improving	97%	—	3%	95%	—	92%
Philippines	Manila	2—basic	88%	9%	3%	41%	90%	44%
Totals			**64%**	**34%**	**2%**	**22%**	**42%**	**29%**

2.5.3 Advancements since the initial SFD: Latin America- Focus on Bolivia

The evolution of SFDs between 2013 and 2016 for Santa Cruz are shown in Figure 3 and Figure 4, respectively. In the Peal *et al*. (2014) SFD report, it was estimated that approximately 60% of faecal waste in Santa Cruz is safely disposed, primarily from households connected to sewers or those with safely covered pits. However, a considerable volume is discharged unsafely because of open defecation or inadequate on-site facilities. Furtlong's (2016) study, three years later, indicated a significant improvement, with 70% of excreta considered safely managed. The difference in findings is attributed to differing definitions of "safely managed." In Furlong's 2016 report, it referred to the low risk of faecal contamination entering the water

supply due to high piped water usage. However, the SFD report by Peal *et al*. (2014) adopted a broader perspective, classifying 29% of excreta as safely managed while emphasising a focus on broader environmental risks. This difference in definitions impacts the classification of on-site sanitation systems, highlighting the need for precise terminology in assessing management effectiveness.

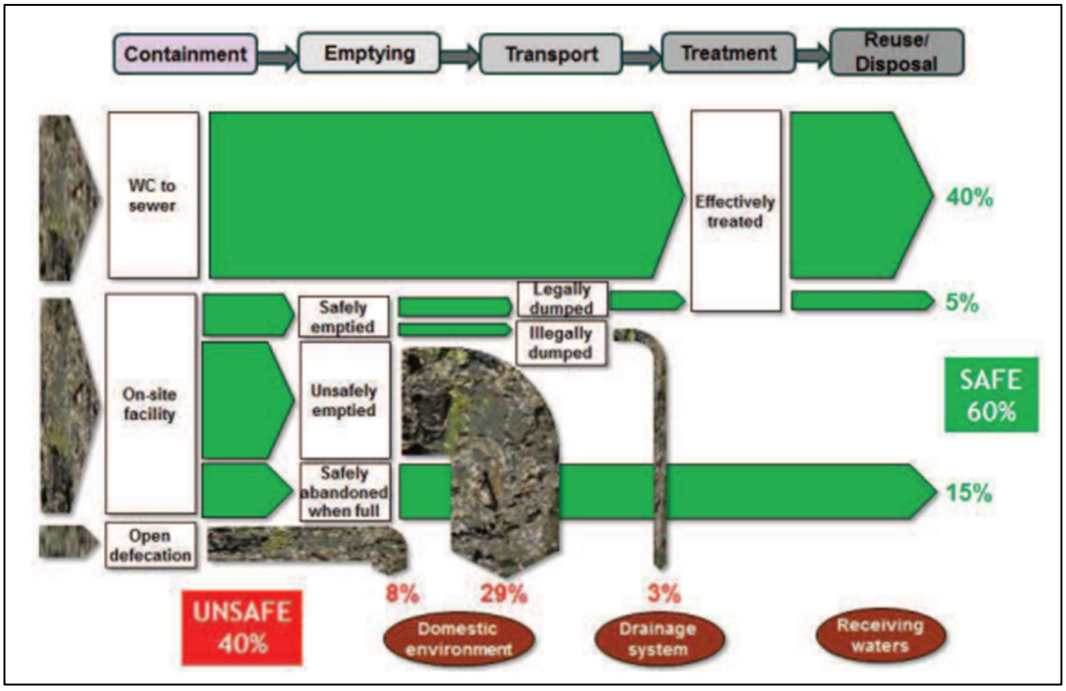


Figure 3: *Santa Cruz* SFD (Peal et al., 2014)

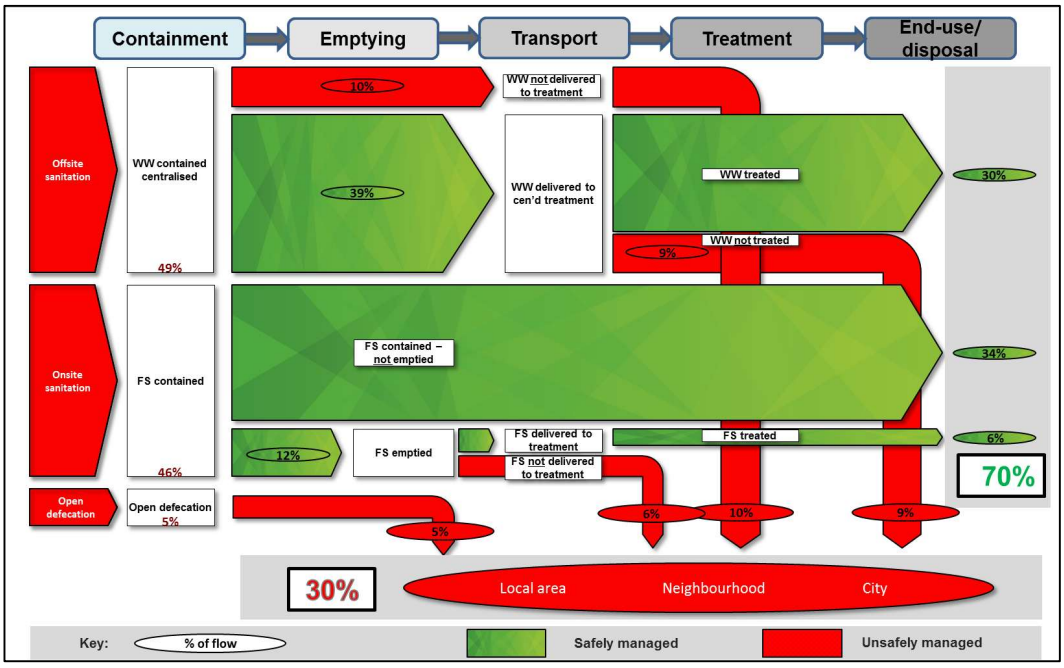


Figure 4: Santa Cruz SFD (Furlong., 2016)

2.5.4 Advancements since the initial SFD: India

The Indian government, with support from the Bill and Melinda Gates Foundation, utilised the SFD generated under the Swachh Bharat Mission to evaluate and implement alternatives for improving sanitation in India, aiming to eliminate open defecation (Susmita *et al*., 2022). The achievements in the previous decade paved the way for universal sanitation access in India (Sankara, 2022). Through training programs and dissemination initiatives, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), who manage the SFD on behalf of SuSanA, and the Centre for Science and Environment (CSE) in New Delhi took up the project in India to help government officials visualise the sanitation status in their cities (Furlong, 2016). In India, SFDs have been widely used as an advocacy tool. As at 2022, CSE has provided SFDs to 66 cities in Uttar Pradesh to kick off a state-wide project to manage faecal sludge (CSE, 2022). SFDs have since been developed for hundreds of Indian cities and towns.

Significant advancements following the initial SFD in South Asia, specifically Bijnor, India, have been observed (Rohila *et al*., 2020). The SFD reports for 2017 and 2020, represented in Figure 5 and Figure 6, respectively, reveal improvement of faecal waste management. According to Rohilla *et al*. (2017), the percentage of faecal waste unsafely disposed of was reported to be 98%. However, Rohilla *et al*. (2017) indicates a substantial improvement of faecal waste management, with the unsafely disposed faecal waste reduced to 59% in Bijnor, Uttar Pradesh.

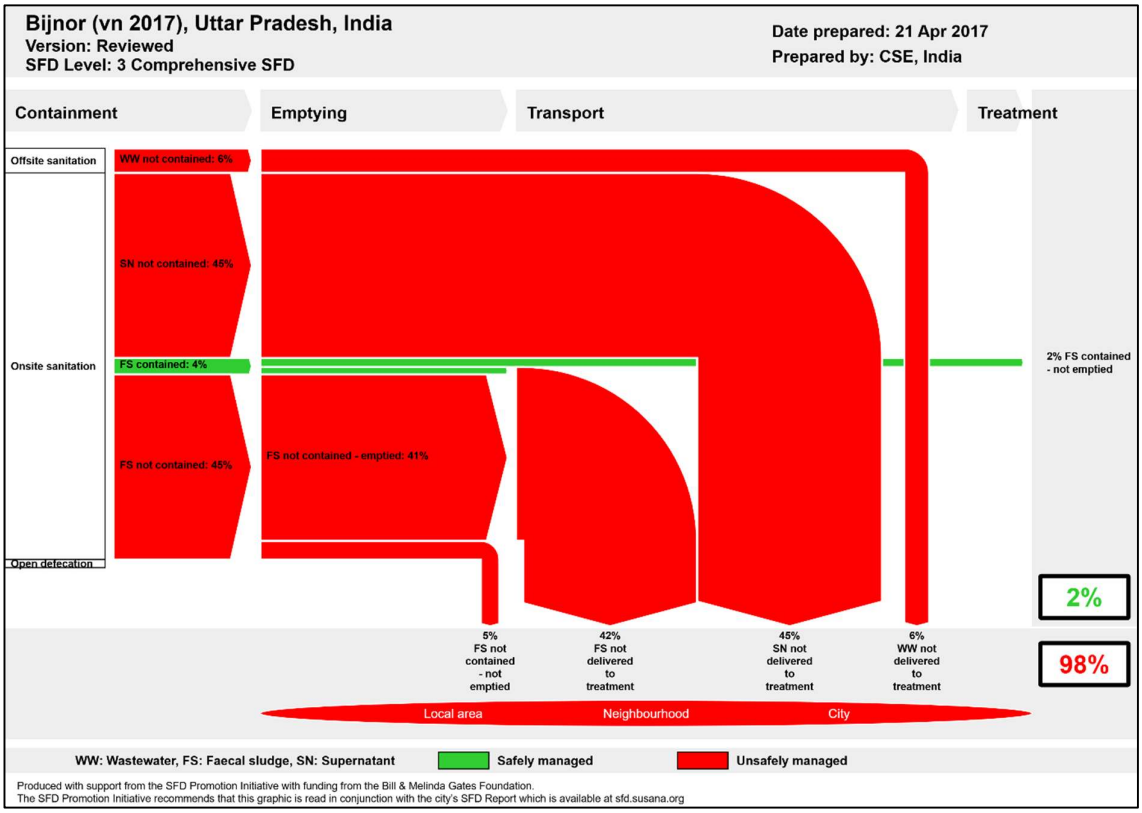


Figure 5: Bijnor India SFD (Rohilla et al., 2017)

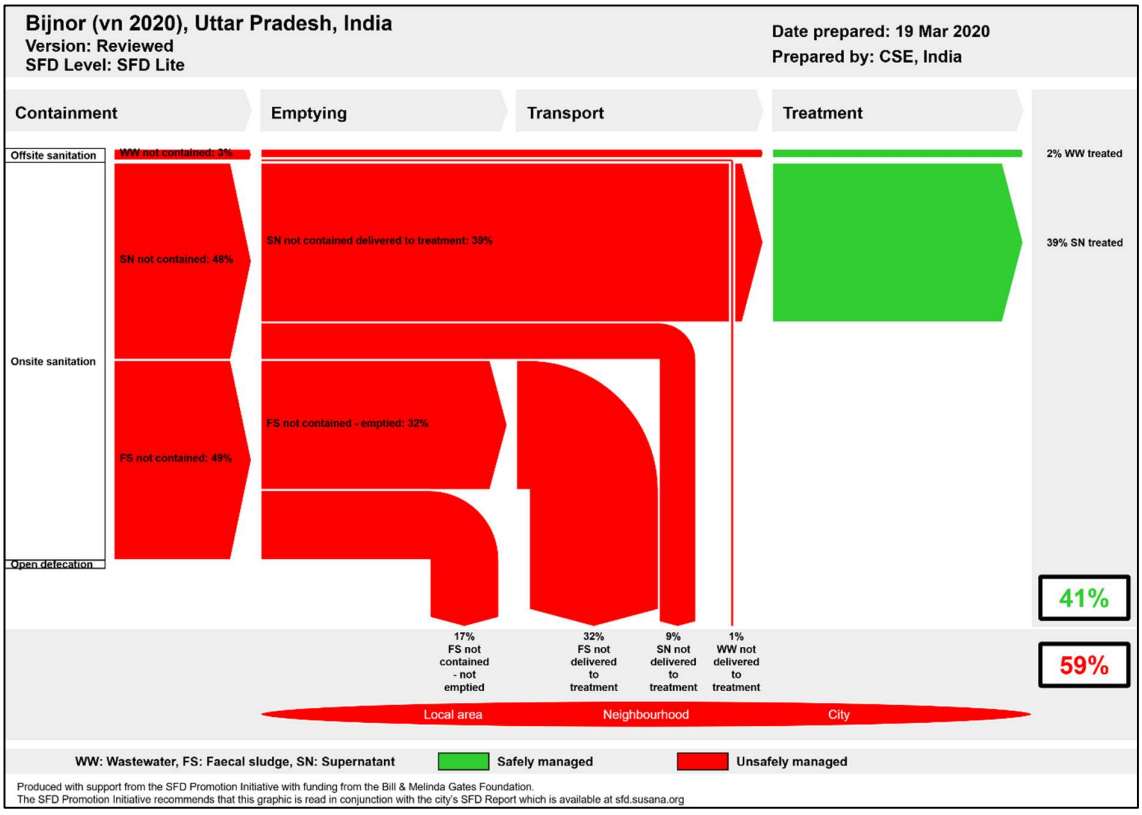


Figure 6: Bijnor India SFD (Rohilla et al., 2020)

2.6 Global sanitation challenges

The right to basic water and sanitation has been recognised as a fundamental human right (Beail-Farkas, 2012). It is also stated in UN SDG 6 and SDG 10 "to ensure that all people have equal access to water and sanitation services," "to eliminate inequality and promote inclusiveness" (UN, 2015). However, according to the WHO/UNICEF Joint Monitoring Programme 2020, 779 million people in Africa still lack basic sanitation, including 208 million who practice open defecation (WHO/UNICEF, 2022). According to Bayu *et al*. (2020), unequal access to sanitation services in developing countries is influenced by the social and political components of water governance.

Achieving SDG 6.2, which focuses on ensuring access to adequate and equitable sanitation and hygiene, requires more than just the development of sanitation infrastructure. While national organisations often prioritise building sanitation facilities, the critical aspects of service delivery—such as effective monitoring and maintenance—are frequently overlooked (Department of Water and Sanitation, 2023). This lack of attention to the sustainability of sanitation services can lead to deteriorating infrastructure, insufficient access in underserved communities, and increased health risks due to poor sanitation (Majikijela, 2007). Focusing solely on infrastructure without adequate post-construction management hinders long-term progress toward meeting sanitation goals (Winkler, 2015). As a result, it is imperative to adopt a holistic approach that includes regular monitoring, maintenance, and data collection to ensure that sanitation services are sustainable and meet the needs of all communities (DWS, 2023). The lack of knowledge and a culture of poor sanitation management significantly contribute to the ongoing sanitation challenges in many regions, particularly in developing countries. As Biswas *et al*. (2021) highlight, inadequate understanding of proper sanitation practices, coupled with cultural attitudes that do not prioritise sanitation, often leads to poor hygiene, mismanagement of waste, and inefficient waste disposal methods. These issues are exacerbated when communities do not see sanitation as a fundamental right or a priority, further hindering efforts to improve infrastructure and services.

2.6.1 Inadequate Infrastructure

Inadequate infrastructure is one of the most pressing challenges in global sanitation, particularly in low- and middle-income countries. The infrastructure required to support safe sanitation—such as sewer systems, wastewater treatment plants, and clean water supplies—is either underdeveloped or non-existent in many regions. This deficit is especially severe in rural areas and informal urban settlements, where the cost of installing and maintaining sanitation systems is often prohibitive (Hutton & Chase, 2016). In such settings, people frequently rely on unimproved sanitation facilities, such as pit latrines or open defaecations, which pose significant health risks due to the contamination of water sources and the spread of diseases such as cholera and diarrhoeal illnesses (Graham & Polizzotto, 2013).

The infrastructure challenge is exacerbated by rapid urbanisation, particularly in developing countries. As cities expand, the demand for sanitation services grows, often outpacing the capacity of existing infrastructure. This leads to overcrowding, increased waste generation, and strain on already inadequate sanitation systems. Urban areas in sub-Saharan Africa and South Asia, for example, are struggling to manage the waste generated by rapidly growing populations, leading to widespread public health issues (UNICEF, 2020). Moreover, many governments lack the financial resources and technical expertise to expand and maintain sanitation infrastructure effectively, further complicating efforts to improve sanitation coverage (World Bank, 2016).

2.6.2 Financial Constraints

Financial constraints are a significant barrier to improving global sanitation. The costs associated with building and maintaining sanitation infrastructure, implementing sanitation programs, and providing sanitation services are substantial. Many low- and middle-income countries lack the necessary financial resources to meet these costs, resulting in significant gaps in sanitation coverage (Hutton & Varughese, 2016). According to estimates by the World Bank, achieving universal access to basic sanitation by 2030, as outlined in the Sustainable Development Goals (SDGs), will require an annual investment of $114 billion in capital alone (World Bank, 2016). However, current funding levels fall far short of this target, leaving many countries unable to provide even basic sanitation services to their populations.

In many low-income countries, reliance on external aid and donor funding to finance sanitation projects is common. While such funding is crucial, it is often unpredictable and insufficient to meet long-term needs (Hutton & Chase, 2016). The dependence on external funding can also lead to a lack of ownership and commitment from local governments, undermining the sustainability of sanitation projects. Moreover, the allocation of funds is frequently skewed toward urban areas, where infrastructure investments are seen as more cost-effective, leaving rural and marginalised communities without adequate resources for sanitation improvement.

Furthermore, the prioritisation of sanitation within national budgets is often low. Competing demands for limited public resources mean that sanitation often receives less attention than other sectors do, such as education, healthcare, or defence. This underinvestment is a major obstacle to progress in achieving global sanitation targets and addressing the needs of the most vulnerable populations (Bartram & Cairncross, 2010).

2.6.3 Sociocultural and behavioural barriers

Sociocultural and behavioural factors significantly influence sanitation practices and pose substantial challenges to improving global sanitation. In many communities, traditional beliefs, taboos, and social norms shape attitudes toward sanitation and hygiene, often leading to resistance to change (Jenkins & Scott, 2007). For example, in some cultures, discussions about sanitation, particularly concerning human waste, are considered taboo, making it difficult to promote the adoption of safe sanitation practices. Additionally, in many societies, gender dynamics play a critical role in access to sanitation. Women face significant challenges in accessing sanitation facilities because of privacy concerns, safety issues, and cultural restrictions that limit their mobility and use of shared facilities (Sommer *et al*., 2015).

Behavioural factors such as a lack of awareness about the importance of sanitation and hygiene further complicate efforts to improve sanitation. In many low-income settings, people may not fully understand the health risks associated with poor sanitation, leading to a low demand for improved sanitation facilities (Bhagwat *et al*.,2022). For example, the practice of open defecation remains prevalent in many parts of South Asia and sub-Saharan Africa, not only because of a lack of access to sanitation facilities but also because of deeply ingrained cultural practices (Coffey *et al*., 2014). Efforts to change behaviours through sanitation

marketing, education, and community engagement are crucial but often require significant time, resources, and cultural sensitivity.

Sociocultural barriers also intersect with economic and educational inequalities, further complicating efforts to improve sanitation. For example, households in poorer communities may prioritise immediate survival needs over investments in sanitation, whereas low levels of education may limit the understanding of the health benefits of improved sanitation (Harris *et al*., 2017). Addressing these barriers requires a multifaceted approach that includes not only infrastructure development but also community-based interventions that respect and incorporate local cultural practices.

2.6.4 Political and Institutional Challenges

Political and institutional challenges are significant obstacles to improving global sanitation. In many countries, sanitation is not prioritised as a public health issue, leading to a lack of political will and inadequate policy frameworks (Bartram & Cairncross, 2010). Even where sanitation policies exist, they are often poorly implemented due to weak governance structures, corruption, and a lack of coordination among different government agencies. This can result in fragmented and ineffective sanitation programs that fail to reach those most in need.

The lack of political commitment to sanitation is often reflected in national budgets, where sanitation typically receives minimal funding compared with other sectors. This underinvestment hampers efforts to expand sanitation coverage and improve service delivery, particularly in rural and marginalised areas. Moreover, political instability in some regions further complicates the implementation of sanitation programs, as changing governments and policies can disrupt long-term planning and investment in the sector (Cronk & Bartram, 2018).

Institutional challenges also include the capacity limitations of local governments and agencies responsible for sanitation services. In many low- and middle-income countries, the institutions tasked with managing sanitation are under resourced, understaffed, and lack the technical expertise needed to design and implement effective sanitation programs (Hutton & Chase, 2016). This institutional weakness is compounded by a lack of data and monitoring systems, making it difficult to assess the effectiveness of sanitation interventions and to hold service providers accountable.

Coordination between different government agencies, NGOs, and the private sector is often lacking, leading to inefficiencies and duplication of efforts. For example, in many countries, multiple agencies are responsible for different aspects of water and sanitation, leading to overlapping mandates and unclear lines of responsibility (Bartram *et al*., 2014). This lack of coordination can result in fragmented service delivery, with some communities receiving multiple interventions while others are neglected.

Additionally, corruption and mismanagement of resources pose significant challenges to improving sanitation. In some countries, funds allocated for sanitation are siphoned off or misused, leading to delays in project implementation and substandard infrastructure (Transparency International, 2008). Addressing these political and institutional challenges requires stronger governance structures, greater transparency and accountability, and a commitment to prioritising sanitation as a key component of public health.

2.6.5 Environmental challenges

Environmental challenges are increasingly complicating efforts to improve sanitation worldwide. Climate change, for example, has had profound impacts on water resources and sanitation systems worldwide. Rising temperatures, changing precipitation patterns, and more frequent extreme weather events, such as floods, droughts, and storms, disrupt water supplies and damage sanitation infrastructure (Howard *et al*., 2010). Floods can overwhelm sanitation systems, leading to overflow of latrines and septic tanks, the contamination of water sources, and the spread of waterborne diseases. Droughts, on the other hand, exacerbate water scarcity, making it difficult to maintain adequate sanitation and hygiene practices, particularly in arid and semiarid regions.

The impact of climate change on sanitation is particularly acute in low- and middle-income countries, where infrastructure is often ill equipped to cope with extreme weather events. For example, many rural communities in sub-Saharan Africa rely on pit latrines, which are vulnerable to flooding and can easily contaminate local water sources (Graham & Polizzotto, 2013). In coastal regions, rising sea levels and saltwater intrusion threaten the viability of existing sanitation systems, leading to the need for costly and complex adaptations (Howard *et al*., 2010).

In addition to climate change, environmental degradation poses significant challenges to sanitation. Deforestation, land degradation, and the loss of wetlands reduce the availability of clean water and increase the vulnerability of communities to waterborne diseases. The pollution of water bodies by industrial waste, agricultural runoff, and untreated sewage further exacerbates the sanitation crisis, particularly in densely populated urban areas (Prüss-Ustün *et al*., 2019). In many cities in developing countries, untreated sewage is discharged directly into rivers and oceans, leading to the contamination of water supplies and posing significant public health risks (UNEP, 2016).

2.6.6 Collecting, Managing, and Reporting Sanitation Data

Sanitation data collection, management, and reporting are essential components of global health and environmental monitoring systems. However, these processes are fraught with numerous challenges that hinder the effective management and utilisation of sanitation data. These challenges are particularly pronounced in low- and middle-income countries, where infrastructure, financial resources, and technical expertise are often lacking.

1. Inadequate Infrastructure for Data Collection

One of the most significant challenges in collecting sanitation data is the lack of adequate infrastructure. In many regions, especially in low-income countries, the systems necessary for monitoring and recording sanitation data are either non-existent or poorly maintained (Hutton & Chase, 2016). For example, in rural areas and informal settlements, the absence of formalised sanitation facilities makes it difficult to gather accurate data on sanitation access and usage. Additionally, the lack of reliable water supply and sewage systems further complicates data collection efforts, as these are often key indicators of sanitation quality (Graham & Polizzotto, 2013).

2. Limited Financial Resources

The collection and management of sanitation data require substantial financial investments, which are often beyond the reach of many developing countries. Financial constraints can lead to underfunding of data collection initiatives, resulting in incomplete or outdated data (WHO, 2019). In some cases, the costs associated with data collection, such as employing field staff,

purchasing equipment, and maintaining databases, are prohibitively high, leading to reliance on sporadic surveys rather than continuous monitoring (JMP, 2021). This lack of consistent funding hampers the ability to develop comprehensive datasets that can inform effective sanitation policies and interventions.

3. Insufficient Technical Expertise

Another major challenge is the lack of technical expertise required for the collection, management, and analysis of sanitation data. In many developing countries, trained professionals who can design and implement effective data collection methodologies, manage large datasets, and conduct sophisticated analyses are lacking (Cronk & Bartram, 2018). These skill gaps often result in poor data quality, with errors in data collection, processing, and reporting. Furthermore, the limited availability of training programs and resources for building capacity in data management exacerbates this issue, resulting in many countries being ill equipped to handle the complexities of sanitation data.

4. Variability in Data Collection Methodologies

The lack of standardised methodologies for collecting sanitation data is a significant challenge globally. Different countries and regions often employ varying techniques and metrics for measuring sanitation indicators, making it difficult to compare data across different contexts (Bartram *et al*., 2014). This variability can lead to inconsistencies in reported data, complicating efforts to track global progress in sanitation targets, such as those outlined in the Sustainable Development Goals (SDGs). For example, while some regions may focus on access to sanitation facilities, others may emphasise the quality of these facilities, leading to discrepancies in the reported data (WHO & UNICEF, 2021).

5. Political and Institutional Barriers

Political and institutional barriers also play a significant role in hindering the effective collection, management, and reporting of sanitation data. In some cases, governments may lack the political will to invest in sanitation data collection or may prioritise other sectors over sanitation (WHO, 2019). Additionally, bureaucratic inefficiencies, corruption, and a lack of coordination between different government agencies can impede the flow of information and

result in fragmented or incomplete datasets. These barriers are particularly pronounced in regions with unstable governments or where sanitation is not seen as a priority.

6. Technological Constraints

While advances in technology have the potential to revolutionise sanitation data collection and management, technological constraints remain a significant challenge in many parts of the world. Limited access to modern data collection tools, such as geographic information systems (GISs), mobile data collection apps, and data management software, hinders the ability to gather, analyse, and report sanitation data efficiently (Crocker *et al*., 2017). In regions with poor internet connectivity, data transmission and real-time reporting are also severely constrained, leading to delays and potential data loss.

2.7 Impact of global sanitation challenges

Global sanitation challenges represent one of the most pressing public health and environmental issues, with significant implications for human well-being, economic development, and ecological sustainability.

2.7.1 Health Impacts

Owing to a lack of sanitation infrastructure, 9% of the world's population is forced to practice open defecation, resulting in faeces contaminating water sources, which exposes vulnerable communities to hazardous bacteria and viruses that can cause fatal infections; these places further strain on already overburdened healthcare systems (WaterAid, 2020). According to Kayembe *et al*. (2018), the microbiological analysis of water samples collected from the Kololo River of the Congo River, also known as Jerusalem River, revealed that during the rainy season, the wells and rivers are significantly contaminated with faeces and do not meet WHO guidelines for use. The introduction of microbes from rivers and wells into the urban environment raises the overall potential risk of human infection in one of several ways as indicated on Figure 7: through direct ingestion, through the presence of a potential source of

bacterial contamination in uncooked foods, or through contamination that occurs during recreational activities (Kayembe *et al*.,2018).

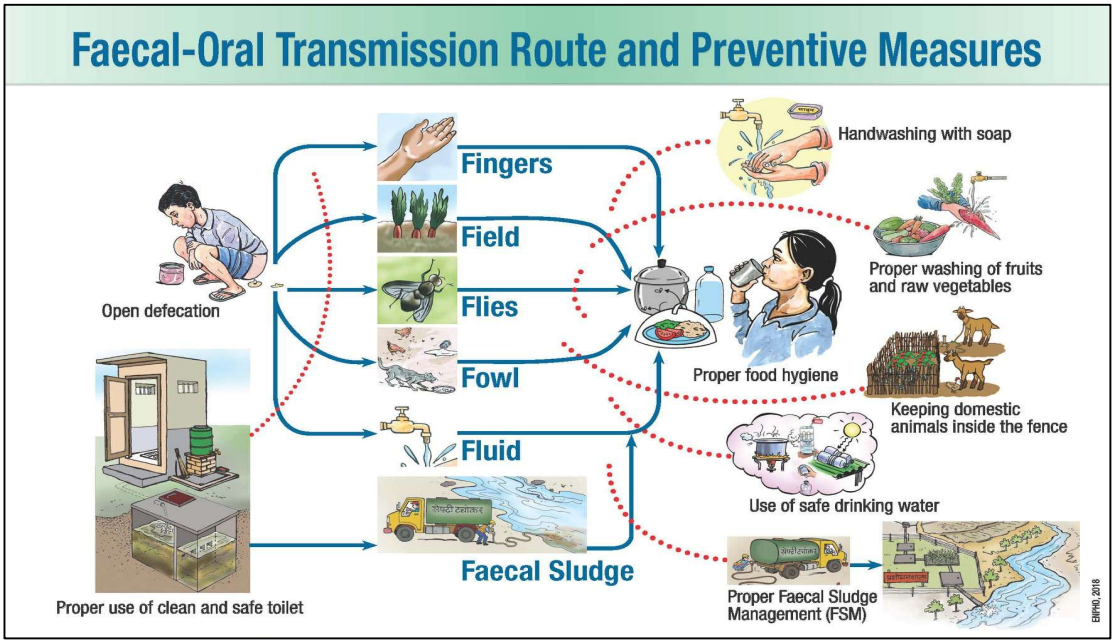


Figure 7: F Diagram (Environment and Public Health Organisation (ENPHO), 2018)

According to estimates provided by the WHO/UNICEF (2020), adequate WASH services could have saved 1.9 million deaths but resulted in the loss of nearly 120 million disability-adjusted life years. They also emphasise how improper sanitation is a factor in approximately 830,000 fatalities and over 49 million disability-adjusted life years (DALYs) lost owing to diarrheal infections, in addition to a great number of other factors (WHO/UNICEF, 2020). Unfortunately, owing to a lack of access to adequate sanitation, 525 000 children under the age of five lose their lives to diarrhoea-related illnesses each year (WHO, 2017). In Ethiopia, unsafe and inadequate water supplies, together with poor hygiene and sanitation practices, are the root causes of 60–80% of communicable diseases (Soboksa *et al*., 2020).

2.7.2 Economic impact

Oxford Economics (2016) conducted a study to explain the costs of inadequate sanitation and reported that the difficulty in accessing public sanitation facilities consumes time that could otherwise be spent on economic activities. As a result, these activities have a negative impact on the economy, or there may be a negative impact on productivity due to illnesses caused by

a lack of sanitation. Furthermore, premature death places economic strain on the family and country because the lost potential revenue from each life has not lived fully, and finally, sanitation-related sickness treatment, whether provided by the state or paid for by the individual, drains money from the economy that could have been spent elsewhere.

Van Minh *et al*. (2011) reported that poor sanitation can lead to significant financial expenditures associated with illness and mortality. Inadequate sanitation not only impacts health but also leads to inefficiencies, such as the waste of time and effort due to the location of sanitation facilities, which may be either too far away or insufficient in number. This can lead to significant inconvenience for communities, forcing individuals to spend excessive time searching for or traveling to these facilities, which could otherwise be spent productively (Sutherland *et al*., 2014). Moreover, the lack of accessible sanitation facilities can also result in a loss of revenue, particularly in areas dependent on tourism. Tourists are often deterred from visiting regions with poor sanitation infrastructure, which affects local economies by reducing the number of visitors and, consequently, revenue from tourism-related activities (Majikijela, 2007). According to research based on 2006 data, poor sanitation costs India approximately 6.4% of its GDP, which is more than the GDP of all but five of the country's states (WHO, 2014). This highlights the significant economic burden of inadequate sanitation infrastructure, which not only affects public health but also stifles broader economic development by diverting resources away from more productive uses. The Swachh Bharat Mission (SBM) was the largest campaign undertaken in India between 2014 and 2019, and its goals were to end the practice of open defecation and improve the management of solid waste. The National Faecal Sludge and Septage Management Alliance, Sustainable Sanitation Alliance, and International Water Association all partnered to make the campaign successful (NFSSM Alliance and NiTi Aayog, 2021). The SuSanA India chapter contributed to the Clean India Campaign Swachh Bharat Abhiyan of the Indian Government by promoting sanitation discussions and by integrating the Indian and global discourse on sustainable sanitation using the SFD to educate stakeholders from various backgrounds on the state of citywide sanitation (Panesar *et al*., 2022). This campaign was a success, and a subsequent study revealed annual cost reductions per household, with savings on medical costs (WHO/UNICEF, 2020).

2.7.3 Social impacts

The education and livelihoods of billions of people worldwide are directly impacted by inadequate or non-existent sanitary facilities, and some groups—such as women and girls—are disproportionately affected (WHO/UNICEF, 2020; WaterAid, 2020; Pearson *et al*., 2008). A lack of access to water for handwashing, sanitary pad disposal options, and WASH facilities puts women and girls at risk of facing challenges in maintaining their menstrual hygiene (Yongsi, 2021). According to a study by Krenz and Strulik (2019), which Nunbogu *et al*. (2022) mention, it is extremely difficult for women to manage their periods with the dignity and privacy they deserve, which has an impact on their involvement in school. This makes it difficult for them to be involved in their education. Nunbogu *et al*. (2022) also stated that the absence of sanitary facilities and services increases the risk of gender-based violence.

Inadequate sanitation services violate the dignity of people with disabilities and incontinence in various ways. Garofolo, (2022), shows that despite the Swachh Bharat Mission, the largest sanitation initiative in India, there are still issues with sanitation facilities accommodating everyone. For example, certain restrooms may be accessible for wheelchair users but not for those with other disabilities because of their varying layouts and absence of tangible elements, which makes them challenging for those who are visually impaired. According to Getahun *et al*. (2022), disabled people with low socioeconomic levels are more likely to live in areas with inaccessible toilets than wealthy people are.

2.8 Faecal Sludge Management issues

The term FSM is not used directly in Sustainable Development Goal 6, although it is encompassed by the phrase safely managed sanitation services (CAWST, 2016). Faecal sludge must be safely contained on-site, then emptied, transferred to a treatment plant, processed, and used for resource recovery or safe disposal (Hidenori *et al*., 2016). Failure to manage faecal sludge effectively is directly accountable for the negative consequences for human health and the environment worldwide. It is not enough to just construct a latrine to ensure proper sanitation and public health. Untreated faecal sludge penetrates the environment and contaminates drinking water sources in the absence of FSM services. CAWST (2016) suggests

that FSM is equivalent to poor open defecation as they have equal impact on society, economy and the environment.

Simiyu *et al*. (2021) reported that one of the problems with FSM in Nakuru town, Kenya, is the predominance of on-site sanitation facilities, which are constrained and shared by many families, resulting in filthy facilities that quickly fill up due to the large number of users. The study revealed that FSM in Nakuru is affected mostly by unfavourable community perceptions and attitudes (Simiyu *et al*. ,2021). In Kombolcha, Ethiopia, FSM problems include open defecation caused by a lack of facilities, pit overflow and leakage, and unauthorised septic tank or pit outlet connections to drainage canals and bodies of water (Endris *et al*., 2022). The FSM problems that developing nations encounter are as follows.

2.8.1 Awareness and skills issues

There is a knowledge gap regarding the proper procedures to follow to guarantee that faecal sludge can be discarded safely (CAWST, 2016). According to key informant interviews (KIIs) conducted by Maqbool *et al*. (2022) with officials in charge of sanitation facilities in various cities of Pakistan, there is a lack of information and awareness about FSM; hence, there is a failure to manage sanitation facilities. In India, only toilets with septic tanks are found with service holes, but pits are installed without means of emptying, and there is not enough space to accommodate the installation of the service hole over the pits (Shahriar *et al*., 2022).

2.8.2 Disposal Issues

The problem with the disposal of sludge from on-site sanitation facilities, including dry toilets, public toilets, and septic tanks, is that it is often mishandled and poorly managed. Every day, faecal sludge is either improperly discarded in open spaces or water sources or used in farming or aquaculture without adequate treatment (Ingallinella *et al*., 2002). Improper maintenance and emptying of septic tanks can lead to significant performance issues, which worsen when sludge is not handled or treated correctly (Hidenori *et al*., 2016). In larger cities, faecal sludge collection and transportation face substantial challenges. These include inaccessible pits for emptying vehicles, traffic congestion that hampers efficient operations, and poorly administered emptying services (Ingallinella *et al*., 2002). Additionally, some trucks emptying septic tanks discharge the sludge directly into the environment due to a lack of regulations and incentives. In Indonesia, for instance, trucks receive tokens as incentives, which can only

be redeemed after depositing the sludge at a treatment plant, which has helped curb illegal dumping (Foxon *et al*., 2011).

2.8.3 Access Control Issue

Simiyu *et al*. (2021) state that emptying services do not always have access to on-site sanitation systems because of space restrictions or because they might be situated too far from a service provider. Devaraj *et al*. (2021) indicated that the problem with emptying trucks is that the roads are frequently too narrow and badly designed. Additionally, many engineers neglect the emptying component when constructing on-site sanitation systems, making access to latrine pits or septic tanks difficult (Simiyu *et al*., 2021).

The difficulties in providing services to informal settlements in Kampala, Uganda, were identified through interviews and stakeholder consultations and included in the framework by Singh *et al*. (2022). These difficulties included high operational costs and the cost of providing services, among other factors. Many manual transport companies do not have funds to carry sludge to a faraway treatment facility; instead, they choose to dump the untreated sludge into the area immediately surrounding the sanitation site (Simiyu *et al*., 2021).

The lack of FSM services is primarily due to insufficient investment in the development, operation, and maintenance of faecal sludge facilities. These facilities are unable to function effectively because there is little to no financial support for their long-term operation and upkeep (United Nations Environment Programme, 2020). Without proper funding and infrastructure, managing the disposal and treatment of faecal sludge becomes a significant challenge, which leads to poor sanitation and environmental contamination. This issue is compounded in many regions where the need for such services far outweighs the available resources.

2.8.4 Policy Issues

According to the analysis of 12 cities by Peal *et al*. (2014), the formation of public policy continues to prioritise the installation of sewer networks above on-site sanitary facilities, which are frequently considered short-term solutions or services for informal settlements. Engineers and municipalities have long regarded on-site sludge management as a low priority, with little to no attention given to it (Strande *et al*.,2014). As a result, relatively few

countries have devised a FSM policy. According to Strande *et al*. (2014), the faecal sludge law in developing nations either does not exist or is inadequate. This leads to the illegal disposal of untreated sludge into the environment, but in places where regulations exist, enforcing such rules has proven challenging.

2.9 Sanitation issues faced in South Africa

Ensuring effective sanitation services is paramount for mitigating health risks and preserving the environment. Central to this effort is the establishment of sufficient sanitation facilities capable of efficiently collecting and treating sewage, thereby upholding human dignity and safeguarding public health. However, South Africa faces significant challenges in sanitation and wastewater treatment systems (Plessis, 2023). The persistent issue of limited access to safe and dignified sanitation facilities has become a longstanding concern for a substantial portion of the South African population. Recent reports highlight a distressing increase in the discharge of raw sewage into the Vaal River, which poses both environmental risks and contributes to public health crises. Notably, UNICEF (2023) reported that among fifteen people who died from a cholera outbreak in South Africa, two were children, as confirmed by the Gauteng Department of Health. Recent fatalities have occurred in Hammanskraal, Gauteng Province, with additional cholera cases reported in Free State Province (UNICEF, 2023).

Access to adequate sanitation facilities remains a critical issue in South Africa. Despite recent progress, a significant portion of the population, especially in rural areas and informal settlements, lacks access to basic sanitation services (DWS, 2021). According to a report by the DWS, approximately 4.3 million South Africans still rely on basic pit toilets, highlighting the persistent gaps in sanitation infrastructure. Figure 7 presents a sanitation facility documented by Eyewitness News in a report by Isaacs (2018), depicting an incident at Mahlodumela Primary School where a five-year-old pupil fell into a pit toilet and drowned. Figure 8 also features a sanitation facility covered by Times Live News, as reported by Skuy (2023). The news article addresses an incident where a four-year-old girl was found dead in a pit toilet at a school in the Eastern Cape.

Figure 8: Shows the sanitation facility conditions in Limpopo (Isaacs, 2018)

Figure 9: The sanitation facility in the Eastern Cape. (Skuy, 2023)

South Africa's wastewater treatment infrastructure is in critical condition, as indicated by the recent Green Drop 2023 report. This assessment revealed that more than 60% of the country's wastewater treatment facilities are classified as 'poor to critical' (Green Drop Report, 2023). The South African Department of Water and Sanitation (DWS) emphasised the severity of the situation, stating that 56% of the nation's 1,150 wastewater treatment plants are in either "poor or critical condition," with 265 of them specifically noted as 'in a state of decay.' Data from the DWS Integrated Regulatory Information System (IRIS) Dashboard show that 75% of the 910 municipal wastewater treatment plants assessed in 2020 had effluent compliance levels below 50%. In contrast, only 144 municipalities met the required standards, highlighting a significant gap in wastewater treatment performance nationwide (Green Drop Report, 2023).

2.10 Shit Flow Diagram in South Africa

The development of the initial SFD in South Africa was led by the WASH R&D Centre at the University of KwaZulu-Natal in collaboration with eThekwini Municipality. This initiative marked the first instance of an SFD being developed in South Africa as part of the broader SFD Promotion Initiative. Following this, the Water Research Commission (WRC) took up the task of expanding the implementation of SFDs across South Africa (WRC, 2021).

Since then, several key organisations have contributed to the growth of the SFD initiative within the country. Emanti – Water & Environmental Engineering Services, a consulting

company, has been instrumental in developing eight SFDs across South Africa. Additionally, the Centre for Science and Environment (CSE) in India partnered with the WRC to provide training to municipalities across South Africa. This collaboration aimed to develop local trainers for the SFD, thereby empowering municipalities with the necessary skills for future implementation (WRC, 2021).

One notable example is the SFD developed for the Amathole District Municipality in the Eastern Cape, where data collection was facilitated by readily available data from Statistics South Africa (Emanti Management, 2022). However, it was noted that the SFDs created after the initial development in South Africa lacked data reflecting more recent advancements in service provision. Gaps were observed between the Integrated Development Plan (IDP) and the Water Services Development Plan (WSDP), particularly concerning population size and the number of people served (Emanti Management, 2022). In terms of data collection, municipal officials from uMgungundlovu in Dalton Coolair were approached through a combination of email, formal letters, and phone calls prior to initiating data collection for the local municipality. Despite the challenges, the first SFD developed for Durban highlighted some of the data limitations, especially regarding the volume of wastewater that was not transported to treatment works. This data was primarily based on indirect sources, such as the frequency of blockages and estimates of wastewater overflow in certain areas, leading to gaps in the accuracy of the information (Cross *et al*., 2016).

The most recent SFD developed in South Africa was for the Ulundi Local Municipality in the Zululand District of KwaZulu-Natal, which was completed in 2018 by Emanti Management. As of now, KwaZulu-Natal and the Eastern Cape are the only provinces in South Africa to have developed SFDs (SuSana, 2023).

2.11 Sanitation management policies, legislation, and regulations in South Africa

2.11.1 Overview of Key Policy Documents

South Africa's sanitation management framework is shaped by a series of key policy documents that collectively establish the regulatory foundation for the sector. Among the

most significant are the White Paper on Water Supply and Sanitation (1994), the White Paper on a National Water Policy for South Africa (1997), and the White Paper on Basic Household Sanitation (2001).

The White Paper on Water Supply and Sanitation (1994) was a landmark document that highlighted the need for comprehensive sanitation services and set the stage for subsequent policies. It aimed to address the basic sanitation needs of the population and ensure equitable access to these essential services. The White Paper on a National Water Policy for South Africa (1997) expanded on these themes by providing a broader framework for integrated water resource management, which included sanitation as a critical component (Republic of South Africa, 1997).

In 2001, the White Paper on Basic Household Sanitation was introduced to address specific challenges in sanitation service delivery, particularly for low-income and marginalised communities. This policy document emphasised the importance of providing adequate sanitation facilities and outlined a clear strategy for achieving universal access to basic sanitation services (Department of Water and Sanitation, 2001).

National Sanitation Policy (2016) provides a comprehensive framework for managing sanitation services, emphasising universal access, sustainability, and equity. It establishes clear roles for the Department of Water and Sanitation and municipalities, promotes integrated planning, and prioritises underserved communities. The policy advocates for resource-efficient and environmentally sustainable solutions, aligning with public health and environmental safety goals. It emphasises infrastructure maintenance, appropriate technology use, and financial sustainability through mixed funding models while ensuring subsidised services for vulnerable groups.

2.11.2 Legislative and Policy Development

The National Sanitation Policy (1996), issued by the Department of Water and Sanitation (previously known as the Department of Water, Agriculture and Forestry), marked a significant development in South Africa's sanitation management landscape. This policy aimed to establish a national strategy for sanitation, addressing the gaps identified in the 1994 White Paper on Water Supply and Sanitation. The 2001 White Paper on Basic Household Sanitation reinforced the government's constitutional obligation to ensure access to adequate sanitation for all South Africans (DWAF, 2001).

Similar to many Metropolitan Municipalities, the City of Johannesburg Metropolitan Municipality has specific regulations related to sanitation in its bylaws. The primary objectives of these bylaws include minimising waste production, promoting recycling and recovery, and ensuring safe disposal practices. The bylaws aim to promote sustainable development and environmental justice by regulating waste management processes, including collection, transportation, storage, disposal, and recycling, within the Municipality's jurisdiction (City of Johannesburg Metropolitan Municipality, 2013).

The Midvaal Local Municipality's Sanitation Services By-laws align with national legislation, including the Water Services Act of 1997 and the National Environmental Management Act (NEMA), ensuring consistency with broader environmental and public health standards. The by-laws require all properties to connect to municipal sanitation systems or, where unavailable, to install approved on-site systems that meet specified safety and environmental standards. They also regulate the discharge of both industrial and domestic effluent into municipal systems, emphasising the need for permits and compliance with quality standards to mitigate pollution risks. Maintenance responsibilities are explicitly outlined, requiring property owners to maintain private sanitation systems while the municipality oversees public infrastructure. Pollution control measures within the by-laws prohibit unauthorised discharges and dumping, safeguarding local water resources from contamination. To enforce these regulations, the municipality conducts inspections, monitors compliance, and imposes penalties for violations, ensuring accountability. Furthermore, the by-laws establish clear tariff structures to support cost recovery and sustainable service delivery (Midvaal Local Municipality Sanitation By-laws, 2019).

2.11.3 Stakeholders and roles in sanitation management

2.11.3.1 Local Government Responsibilities

Local governments play a crucial role in sanitation management in South Africa. According to the Constitution and the Waste Act 59 of 2008, municipalities are responsible for waste management services, including garbage removal, waste storage, disposal, and treatment. Municipalities are required to appoint waste management officers to coordinate these activities and develop integrated waste management plans (IWMPs). These plans are

incorporated into each municipalities' Integrated Development Plans (IDPs) and reported annually (Municipal Systems Act 32 of 2000). The IDP framework allows for community engagement, ensuring that residents play a role in the development and implementation of waste management strategies. This participatory approach aims to increase local ownership and accountability in sanitation management (Mbelengwa, 2016).

2.11.3.2 Provincial Government Responsibilities

At the provincial level, the government is responsible for implementing and advancing the National Waste Management Strategy (NWMS) and ensuring adherence to national codes and standards. Provincial government appoint waste management officers and develop their own (Integrated Waste Management Plans) IWMPs, which require approval from the Minister. Provincial governments also act as the principal licensing authority for waste management activities not covered by national regulations (Waste Act 59 of 2008).

2.11.3.3 National Government Responsibilities

The Department of Water and Sanitation (DWS) oversees the national water and sanitation sector, coordinating the government's role in bulk water reticulation and sanitation services. The Department of Cooperative Governance and Traditional Affairs (CoGTA) manages the free basic services policy, which provides free basic sanitation to indigent households. The National Treasury regulates financial policies and performance for sanitation services across national, provincial, and municipal levels and provides funding to support various government ministries (Department of Water and Sanitation, 2016).

2.11.4 Gaps with the sanitation management policies

Although South Africa has made significant strides with the National sanitation Management Strategy and the National Sanitation Policy (2016), several issues undermine effective policy implementation. Firstly, infrastructure deficits remain a major constraint, as many municipalities lack adequate faecal sludge treatment plants, and wastewater treatment works are often ill-equipped to co-treat dense, high-solid sludge (Kirsten K, 2023). Institutional fragmentation further complicates the sector, with overlapping responsibilities between

national, provincial, and municipal bodies, and limited enforcement capacity at the local level. The financial constraints also hinder the development, operation, and maintenance of FSM services, particularly in rural and low-income areas where revenue recovery is low and subsidies are insufficient (*United Nations Environment Programme, International Water Management Institute, Global Wastewater Initiative and GIAR Research Program on Water, Land and Ecosystems*, 2020). The policy also struggles with weak regulation and compliance monitoring, resulting in frequent illegal dumping and unsafe disposal practices. Technical and operational challenges such as pits containing solid waste, inadequate equipment for emptying, and limited technical skills among operators, reduce service efficiency and safety (Kirsten K, 2023). Finally, social acceptance and awareness gaps limit the uptake of safe reuse practices for treated sludge, while occupational health and safety provisions for sanitation workers are often poorly enforced (Mamera *et al.,* 2020).

2.12 Sanitation data

Sanitation data encompasses a wide range of information that is critical for understanding, managing, and improving sanitation systems. These data typically include information on the water supply, waste management, sewage treatment, hygiene practices, and related public health indicators (WHO, 2019). Sanitation data play a pivotal role in tracking the progress of sanitation projects, assessing the effectiveness of interventions, and guiding policy decisions. In essence, reliable and comprehensive sanitation data form the backbone of effective sanitation management, ensuring that resources are allocated efficiently and that health risks associated with inadequate sanitation are minimised (UNICEF, 2020).

Sanitation data are important for monitoring global health goals, such as the United Nations' Sustainable Development Goals (SDGs), particularly Goal 6, which aims to ensure the availability and sustainable management of water and sanitation for all individuals (United Nations, 2020). Accurate sanitation data are essential for measuring progress towards these goals and for identifying areas where additional efforts are needed.

Sanitation data are often categorised into several key types, including access to sanitation facilities, the quality and safety of these facilities, the prevalence of open defecation, the effectiveness of wastewater treatment processes, and the impact of sanitation on public health (JMP, 2021). The collection and analysis of these data allow for a comprehensive understanding of sanitation challenges and enable stakeholders to develop targeted interventions that address specific needs.

However, the availability, accuracy, and completeness of sanitation data can vary widely between regions, particularly between high-income and low-income countries (Bain *et al*., 2014). In many developing regions, including parts of Africa, there are significant challenges in obtaining reliable sanitation data due to inadequate infrastructure, limited financial resources, and a lack of technical expertise. These challenges hinder the ability to develop effective sanitation strategies and exacerbate health disparities related to poor sanitation (Cronk & Bartram, 2018).

2.13 Sanitation Data Collection and Reporting

The collection and reporting of sanitation data have seen significant advancements in recent decades, driven by the recognition of the critical role that sanitation plays in public health and environmental sustainability. International organisations such as the WHO and UNICEF have been instrumental in promoting the systematic collection of sanitation data through initiatives such as the Joint Monitoring Programme (JMP), which tracks global progress in water and sanitation (WHO & UNICEF, 2021). The JMP provides a standardised framework for assessing sanitation coverage, enabling comparisons across countries and regions and highlighting areas where progress is lagging.

Despite these advancements, there are still substantial disparities in the quality and availability of sanitation data between different regions. In high-income countries, sanitation data collection is generally well established, with comprehensive systems in place for monitoring and reporting various aspects of sanitation (WHO, 2023). These countries typically have robust infrastructure, advanced technological tools, and well-trained personnel

dedicated to data collection and analysis, resulting in high-quality data that can inform effective decision-making.

In contrast, many low- and middle-income countries face significant challenges in sanitation data collection and reporting. These challenges often stem from a lack of financial resources, limited access to technology, and insufficient institutional capacity (Hutton & Chase, 2016). In Africa, for example, the collection of sanitation data is frequently hampered by inadequate infrastructure, political instability, and logistical difficulties in reaching remote areas (Graham & Polizzotto, 2013). As a result, the data that are available may be incomplete, outdated, or of questionable accuracy, making it difficult to develop effective sanitation policies and interventions.

Sanitation data management in South Africa faces several challenges, including capacity constraints in municipalities, fragmentation of data management processes, and difficulties in integrating data from informal settlements and rural areas. These challenges result in data gaps, inconsistencies, and issues with data accuracy and reliability (African Region, 2022; Paladh *et al*., 2018). Gauteng, as the most populous province in South Africa, faces significant pressure on its sanitation infrastructure due to rapid urbanisation, population growth, and economic disparities (Stats SA, 2018). Effective sanitation management in Gauteng requires reliable data on access to sanitation facilities, the condition and maintenance of these facilities, and the effectiveness of wastewater treatment processes.

However, like many other regions in Africa, South Africa faces challenges in collecting and maintaining high-quality sanitation data. These challenges are compounded by issues such as informal settlements, where access to sanitation facilities is often limited or non-existent and where data collection can be particularly difficult (Richards *et al*., 2021). Additionally, the lack of standardisation in data collection methods across different municipalities can lead to inconsistencies in the data, further complicating efforts to assess and address sanitation needs (Department of Water and Sanitation, 2019).

3 Defining the Study Area

The study area is Gauteng, South Africa as shown in Figure 9. This region was selected due to its significance in the Water Research Commission's (WRC) strategic initiatives aimed at enhancing collaboration with water service authorities nationwide. WRC has initiated projects to establish national excreta flows across South Africa, promoting the use of SFDs as tools for sanitation master planning. Gauteng is located on the Highveld and is South Africa's smallest province in terms of land area. It has a population of 16.1 million (Stats SA, 2022), accounting for 26% of South Africa's total population, and is also the fastest growing province, with a population increase of more than 33% between the 1996 and 2011 censuses. Gauteng is South Africa's and sub-Saharan Africa's economic hub, with significant contributions to finance, manufacturing, transportation, and technology, among others (Landau and Gindrey, 2008). It is divided into numerous provincial and local municipalities. The population of Gauteng is not equally spread; it is concentrated in three of the five municipalities: The City of Johannesburg Metropolitan Municipality (CoJMM) 37%, City of Ekurhuleni Metropolitan Municipality (CoEMM) 26%, and City of Tshwane Metropolitan Municipality (CoTMM) 22%, and the remaining 14% is shared among the other municipalities (Landau *et al*., 2008).

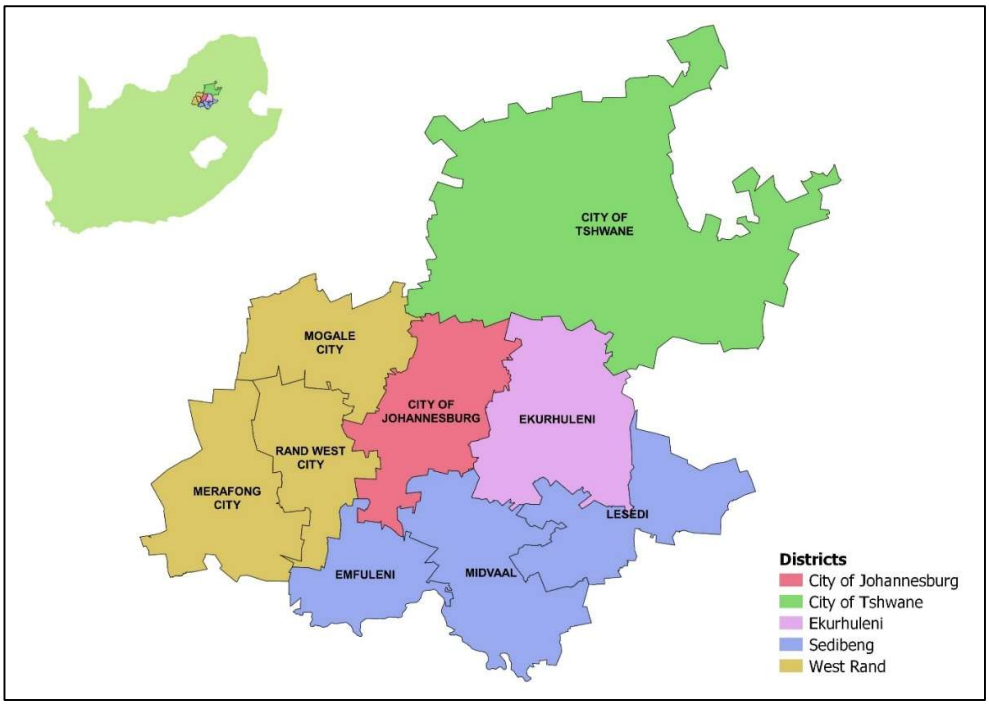


Figure 10: Gauteng Province (Bidassey-Manilal et al, 2020)

3.1.1 City of Johannesburg Metropolitan Municipality

The City of Johannesburg Metropolitan Municipality (CoJMM) is situated in the central part of Gauteng. It covers an area of approximately 1,645 square kilometres. The City of Johannesburg is the largest urban settlement in Gauteng and is characterised by a diverse mix of residential, commercial, and industrial areas. As an urban hub, the city boasts a high level of access to improved sanitation, with over 90% of households connected to basic sanitation facilities such as flush toilets linked to sewerage systems (Statistics South Africa, 2021). Approximately 4–5% of households rely on communal or temporary sanitation facilities, such as chemical toilets or ventilated improved pit latrines (VIPs) (Statistics South Africa, 2021). These areas often lack the necessary infrastructure to support formal sanitation systems, leading to service backlogs and increased demand for innovative solutions.

Johannesburg Water, the municipal entity responsible for sanitation services, oversees a diverse range of sanitation systems utilised within the city. The most prevalent system is the flush toilet connected to a sewerage network, which serves the majority of households in formal urban areas. In areas where sewer connections are unavailable, alternative sanitation systems are employed, including pit latrines with ventilation and chemical toilets, particularly in informal settlements (Stats SA, 2011). Septic tanks are also used in some peri-urban areas that lack access to centralised sewer networks, requiring regular emptying and maintenance to prevent environmental contamination.

In recent years, over 42Km of sewer pipelines have been replaced to enhance system reliability and reduce blockages (Johannesburg Water, 2023). The entity also ensures rapid response to reported sewer blockages, with a reported success rate of clearing over 95% of cases within 24 hours (Johannesburg Water, 2023). Despite these efforts, ageing infrastructure in established urban areas poses a further challenge, necessitating continuous investment to meet the needs of the city's growing population.

Table 2:Sanitation systems used in the CoJMM (StatsSA, 2011)

Toilet Facility	**Percentage**
None	0,80%
Flush toilet (connected to sewerage system)	87,10%
Flush toilet (with septic tank)	2,30%
Chemical toilet	1,10%
Pit toilet with ventilation	3,40%
Pit toilet without ventilation	2,60%
Bucket toilet	2%
Other	0,70%

3.1.2 City of Tshwane Metropolitan Municipality

The City of Tshwane Metropolitan Municipality (CoTMM) is situated in the northern part of Gauteng, surrounding the CoJMM and City of Ekurhuleni Metropolitan Municipality (CoEMM).It covers an area of approximately 6,368 square kilometres. Tshwane is home to the administrative capital of South Africa. It is characterised by a mix of urban, suburban, and rural settlements. In the central areas, such as Pretoria and surrounding urban zones, sanitation services are well-developed, with most households benefiting from flush toilets connected to the centralised sewerage system (Statistics South Africa, 2011). However, challenges in these areas are primarily related to aging infrastructure and increasing demand due to rapid urbanisation. Centurion, another urban hub, also has extensive sewerage networks and flush toilet.

Areas such as Soshanguve and Mamelodi, which have both formal and informal settlements, experience more variability in sanitation coverage. In formal areas of Soshanguve, flush toilets connected to sewerage systems are common, while informal settlements rely on VIPs, chemical toilets, or shared facilities (Statistics South Africa, 2011). Mamelodi faces similar disparities, with formal areas generally benefiting from flush toilets and informal sections relying on temporary sanitation solutions. Atteridgeville, located west of Pretoria, historically

faced sanitation challenges, but recent municipal efforts have improved service delivery. Informal areas in Atteridgeville, however, still rely on chemical toilets or shared facilities.

The northern outskirts of Tshwane, including Hammanskraal, Temba, and Winterveld, feature predominantly peri-urban and rural characteristics, where centralised sanitation infrastructure is limited. In these regions, many households use septic tanks or VIPs, with the maintenance of these systems posing a significant challenge, particularly in areas without access to regular emptying services (Department of Water and Sanitation, 2022). The municipality has prioritised addressing these service backlogs by providing alternative sanitation solutions, such as chemical toilets and communal facilities, and exploring decentralised wastewater treatment technologies to meet the growing demand in these underserved areas.

Table 3: Sanitation systems used in the CoTMM (StatsSA, 2011)

Toilet Facility	**Percentage**
None	1,30%
Flush toilet (connected to sewerage system)	76,60%
Flush toilet (with septic tank)	2,10%
Chemical toilet	0,70%
Pit toilet with ventilation	2,30%
Pit toilet without ventilation	15,10%
Bucket toilet	1%
Other	0,80%

3.1.3 City of Ekurhuleni Metropolitan Municipality

The City of Ekurhuleni Metropolitan Municipality (CoEMM) is situated east of Johannesburg, bordering the CoJMM. It covers an area of approximately 1,975 square kilometres. Ekurhuleni is a densely populated Metropolitan area comprising both urban and industrial settlements. It includes cities such as Germiston, Boksburg, Kempton Park, Benoni, and Alberton. The municipality is home to a large and diverse population, with varying levels of sanitation infrastructure and coverage across its regions. According to Statistics South Africa (2011),

approximately 97% of households in Ekurhuleni have access to sanitation facilities, which reflects a relatively high level of coverage. However, like many large municipalities, Ekurhuleni faces significant challenges in addressing the sanitation needs of its informal settlements and peri-urban areas.

In the formal urban areas of Ekurhuleni, the predominant sanitation system is the flush toilet connected to a centralised sewerage network. These areas, which include the city centre and well-established towns such as Germiston, Bedfordview, and Kempton Park, benefit from reliable and efficient sanitation services (Statistics South Africa, 2021). Most households in these regions are serviced through the municipal sewer system, which ensures the safe disposal of wastewater. However, rapid urbanisation and the increasing demand for sanitation services have placed considerable strain on the infrastructure, leading to occasional service disruptions and backlogs in maintenance.

Informal settlements and peri-urban areas in Ekurhuleni, such as those in Daveyton, Tembisa, and Katlehong, face more complex challenges. In these areas, households often rely on alternative sanitation systems, such as chemical toilets, pit latrines, and ventilated improved pit (VIP) latrines, due to the lack of access to sewerage infrastructure (Statistics South Africa, 2021). These systems, while crucial for addressing immediate sanitation needs, tend to have lower levels of hygiene and pose significant environmental and health risks if not properly maintained.

Table 4: Sanitation systems used in the CoEMM (StatsSA, 2011)

Toilet Facility	**Percentage**
None	1,2%
Flush toilet (connected to sewerage system)	85%
Flush toilet (with septic tank)	1,3%
Chemical toilet	1,4%
Pit toilet with ventilation	0,6%
Pit toilet without ventilation	7,3%
Bucket toilet	2,3%
Other	0,9%

3.1.4 Sedibeng District Municipality

Sedibeng District Municipality (SDM) is situated in the southern part of Gauteng, bordering the Free State province. It covers an area of approximately 4,192 square kilometres. Sedibeng is a predominantly rural district with few urban settlements. It consists of local municipalities, including Emfuleni, Midvaal and Lesedi. The district spans both urban and rural areas, with varying levels of sanitation coverage and infrastructure. According to Statistics South Africa (2011), Sedibeng has made significant strides in improving sanitation services, with a notable proportion of households in formal areas connected to sewerage networks.

In the urban areas of Sedibeng, particularly in towns such as Vanderbijlpark, Vereeniging, and Meyerton, flush toilets connected to sewerage systems are the predominant sanitation method. These areas benefit from well-established infrastructure, with most households having access to centralised wastewater systems (Statistics South Africa, 2011). In these regions, sanitation services are generally reliable, and the municipality has undertaken regular maintenance and infrastructure upgrades to ensure the continued functionality of the sewer systems. Many households in these regions rely on alternative sanitation systems such as pit latrines, septic tanks, and ventilated improved pit (VIP) latrines due to the lack of centralised sewerage infrastructure (Statistics South Africa, 2011).

Informal settlements in Sedibeng, particularly in areas like Sebokeng and Evaton, rely heavily on temporary sanitation solutions such as chemical toilets and communal pit latrines. These areas often lack the necessary infrastructure to support formal sanitation systems, resulting in sanitation backlogs and inconsistent service delivery. The municipality has adopted decentralised wastewater treatment solutions in certain rural areas, recognising that these systems can be more cost-effective and easier to maintain in areas where centralised infrastructure is not feasible (Sedibeng District Municipality, 2022).

Table 5: Sanitation systems used in the Sedibeng District (StatsSA, 2011)

Toilet Facility	**Emfuleni %**	**Midvaal %**	**Lesedi %**
None	1%	2%	1,10%
Flush toilet (connected to sewerage system)	88,20%	58%	84,30%
Flush toilet (with septic tank)	2%	18,40%	4,90%
Chemical toilet	0,30%	6,20%	0,30%
Pit toilet with ventilation	0,80%	1,60%	0,70%
Pit toilet without ventilation	6,20%	10,30%	6,70%
Bucket toilet	0,90%	2,20%	1,20%
Other	0,70%	1,40%	0,90%

3.1.5 West Rand District Municipality

West Rand District Municipality (WRDM) is situated west of Johannesburg, bordering the Northwest Province. It covers an area of approximately 4,848 square kilometres. The West Rand is a diverse district with a mix of urban, suburban, and mining settlements. The area has a history of gold mining, with some mining operations still active. It consists of local municipalities, including Mogale City, Rand West City and Merafong City. While the majority of the district's population has access to basic sanitation, there are notable disparities, particularly in informal settlements and rural regions, where access to sanitation services is limited or inconsistent (Statistics South Africa, 2021).

In the urban areas of the West Rand, particularly in towns like Krugersdorp and Randfontein, the predominant sanitation system is the flush toilet connected to a centralised sewerage network. These areas benefit from established infrastructure, with most households having access to reliable sanitation services. Municipalities in these regions have made significant investments in upgrading sewer systems to manage increasing demand due to urban growth and to prevent infrastructure breakdowns.

Informal settlements and peri-urban areas in the West Rand, such as those in parts of Krugersdorp, Westonaria, and Randfontein, face more significant challenges in terms of sanitation provision. Due to limited or non-existent access to centralised sewerage systems, residents in these areas often rely on alternative sanitation methods. The most common systems in these regions include pit latrines, septic tanks, and ventilated improved pit (VIP) latrines (Statistics South Africa, 2021). In some informal settlements, particularly those lacking access to adequate sanitation infrastructure, temporary solutions such as chemical toilets or communal pit latrines are provided by the municipality. The rural areas in the West Rand, including some parts of Westonaria and smaller villages, rely on basic sanitation systems such as pit latrines, septic tanks, or VIP latrines due to the lack of centralised sewer networks (Statistics South Africa, 2021).

Table 6: Sanitation systems used in the West Rand District Municipality (StatsSA, 2011)

Toilet Facility	**Mogale %**	**Merafong %**	**Rand west**	
			Randfontein %	**Westonaria %**
None	2%	1%	1,10%	2,60%
Flush toilet (connected to sewerage system)	78,20%	81%	79,30%	58,60%
Flush toilet (with septic tank)	5,80%	2,10%	5,50%	4%
Chemical toilet	2,90%	0,60%	0,30%	0,70%
Pit toilet with ventilation	2,30%	2,30%	1,50%	21,90%
Pit toilet without ventilation	4,80%	11,60%	11,30%	9,40%
Bucket toilet	3,20%	0,40%	0,60%	1,40%
Other	0,80%	1%	0,40%	1,30%

4 METHODOLOGY

This chapter outlines the methodology employed to achieve the objectives detailed in Chapter 1. The research methodology provides a systematic framework for collecting, analysing, and interpreting data to address the research questions articulated in section 1.2. Given the complexity of sanitation data availability and its compliance or non- compliance with SFD requirements, a multifaceted approach was required to ensure thorough and reliable results.

The methodology is structured to integrate both qualitative and quantitative techniques, allowing for a comprehensive understanding of the challenges and gaps in sanitation data capture across municipalities in Gauteng. The research was conducted in several phases, including an extensive literature review, desk research, surveys, and comparative data analysis. By combining these methods, the study aimed to identify inconsistencies in data recording practices, explore the underlying causes of gaps in data availability, and propose a framework that bridges the gap between municipal data and SFD requirements.

4.1 Literature review

To achieve objective (1) a comprehensive review of the literature on the alignment between data reporting by water and sanitation authorities (WSAs) and the SFD was undertaken. The review encompasses an evaluation of the benefits and limitations of the SFD in sanitation planning, highlights gaps in data capture and uniformity, and explores the implications of these gaps for sanitation management. This review consolidates findings from various reports, articles, and case studies related to basic sanitation, historical disparities in South Africa, and the role of the SFD in improving sanitation practices. A detailed discussion is presented in Chapter 2.

4.2 Data collection

Data for this study were collected using two primary methods: publicly available data and questionnaires. The both methods adhered to ethical protocols, ensuring the integrity and validity of the research process.

4.2.1 Data collection ethics

The study was conducted at the University of the Witwatersrand, Johannesburg, and adhered to the institution's ethics approval processes. Data collection for Methodology 1, which involved publicly available data, did not require ethical approval. However, the ethics clearance certificate, protocol H23/04/24, was obtained for Methodology 1 activities involving the use of questionnaires. Refer to Appendix C1 for further details on the ethics clearance certificate.

4.2.2 Methodology 1: Data collection using publicly available sources

This study employed a desktop research approach to collect publicly available data to achieve objective (2) to (5). This approach involved synthesising existing documents, datasets, and publications to derive foundational datasets and contextual understanding. The research process concentrated on sanitation-related materials published within South Africa to ensure that the findings were both relevant and applicable to the study area. The following approaches were used:

1. Direct Browsing

Direct browsing targeted sanitation related publications and retrieval of information from university websites, academic portals, and publicly accessible online databases. This approach is effective in cases where the researcher had a clear understanding of the type of data required and the potential sources of such data (Creswell & Creswell, 2018).

To ensure the acquisition of high-quality and relevant data, advanced search techniques were employed. These included the use of refined filters, strategic keywords, and Boolean operators to narrow down search results, thereby aligning the collected data with the research objectives as shown in figure 10 (Bell, Bryman & Harley, 2019). This approach enhanced the efficiency of the data collection process, ensuring that only credible and directly applicable information was obtained.

2. Government Records

Data from municipal and national government records played a critical role in this study, providing comprehensive datasets on various dimensions of water and sanitation. These datasets included demographic trends, economic indicators, environmental statistics, public health data, and details on the management of sanitation facilities (Ghauri & Gronhaug, 2020). The government sources facilitated a detailed data of sanitation practices within the Gauteng region, revealing critical understanding into the availability, quality, and management of sanitation facilities.

3. Non-governmental organisations Records

Non-governmental organisations (NGOs) provided supplementary data that enriched the study, particularly in instances where government datasets were incomplete or unavailable. NGOs often produce detailed reports and datasets on specialised topics, such as sanitation and public health, which added valuable context to the research findings (Babbie, 2020).

4.2.2.1 Mapping and filtration of data sources

The mapping and filtration criteria for data sources outline a structured approach to ensuring that the data collected is reliable, relevant, and aligned with the research objectives, refer to Figure 10. The first step in this process involved focusing on the geographical context and alignment with the field of study. Data sources were selected based on their relevance to South Africa to maintain contextual specificity, while ensuring that the data supported the research objectives. Sources such as academic journals, government publications, industry reports, and reputable websites such as SuSanA were prioritised.

The second filtration criterion emphasised consistency and relevance, focusing on data that was regularly updated and regionally specific to Gauteng Municipalities. This ensured that the study included sources with a reliable publication track record and data directly applicable to the study's geographical focus. Key sources at this stage included national, provincial, and local government publications, as well as region-specific reports from the Sustainable Sanitation Alliance (SuSanA). These materials provided a comprehensive view of sanitation practices, policies, and challenges specific to the Gauteng region.

The third criterion further refined the data selection process by prioritising sources that directly addressed the research questions. This targeted approach focused on materials offering understanding into sanitation data availability and its alignment with SFD requirements. Local municipality publications and national reports were particularly valuable at this stage, providing both micro- and macro-level perspectives on sanitation practices and challenges. The concluded data sources included annual reports, Integrated Development Plans (IDPs), and the Green Drop Report.

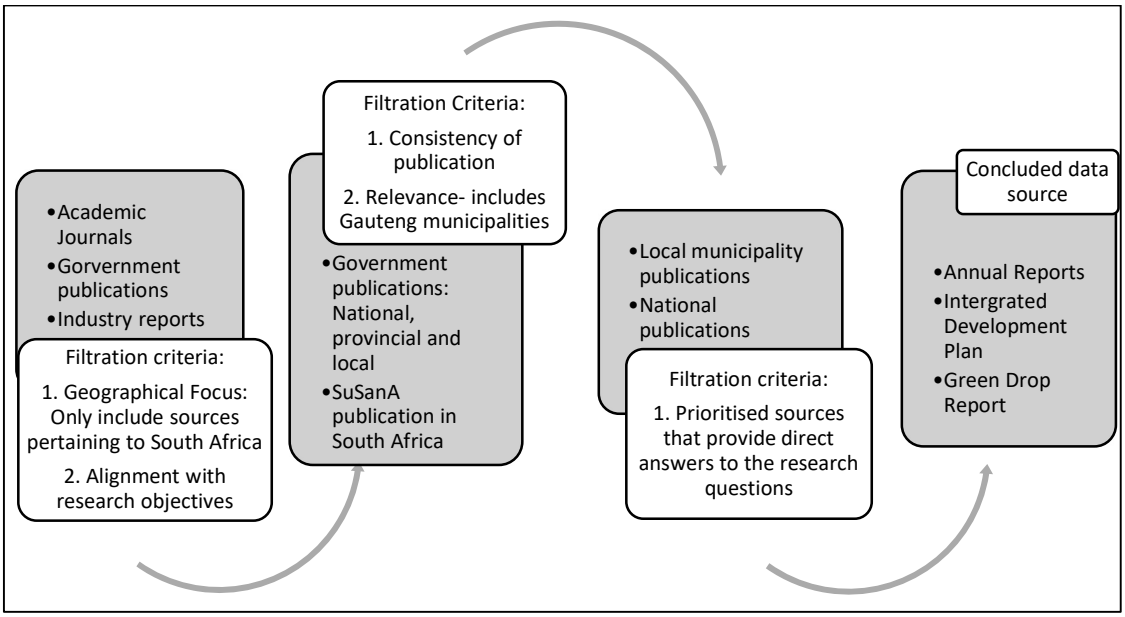


Figure 11: Mapping and filtration system data sources

4.2.2.2 Quality Assurance/Quality Control

A series of quality control measures were implemented to minimise potential errors and ensure the accuracy of the data. (1) standardised procedures for data collection were developed, with clear steps outlined to guide the process. (2) A detailed data collection plan was created, specifying the particular data points to be gathered, identifying data sources such as published reports, and outlining the methods for extracting relevant information. (3) To ensure familiarity with the terminology and concepts used in the SFD, the researcher attended a training course and workshop.

(4) A standardised data collection tool was developed in Excel, designed to align with the SFD data requirements. This template incorporated dropdown lists and data validation features to reduce the likelihood of entry errors. (5) All assumptions, notes, and changes made during the data collection process were thoroughly documented, and the associated files were saved in a single, well-organised directory, with separate subfolders for different municipalities. (6) To maintain the security of the data, strict protocols were followed to ensure that it was stored securely and that access was restricted to authorised personnel only. All data files were stored in a password-protected format, safeguarding the integrity and confidentiality of the collected information.

4.2.2.3 Data collection procedures

The procedure used in collecting data, and was broken down into four distinct steps. These steps are further elaborated below to provide a clear understanding of the data collection process.

4.2.2.3.1 Development of Excel Template for Data Checklist

In the first step of the data collection process a spreadsheet template was developed to serve as a data checklist for the SFD. This template organises the required information into distinct categories:

- Descriptive Data
- Sanitation systems,
- Containment
- Emptying and transportation
- Treatment.

1. Category 1 (Descriptive data)

The ”Descriptive Data” refers to data that provide a detailed description of the study area, encompassing various factors such as topography, types of settlements, climate, and soil conditions. As shown in Figure 11, these data serve to characterise the geographic and environmental features of the area under investigation. It provides data on the physical

characteristics of a region, including its terrain, land use patterns, weather patterns, and soil composition.

Section	The data checks
DESCRIPTIVE DATA	Area of city
	Population
	Population growth rate
	Topography
	Climate
	Ground Water level
	Vulnerability of the aquifer: rock type
	Source of water supply
	Water supply per capita
	water supply coverage
	No. of slums settlement
	No. of HH with municipal boundary

Figure 12:"Descriptive Data" checklist with respect to SFD requirements.

2. Category 2 (Sanitation systems)

Data in this category pertain to the type of sanitation system utilised in the area. The data regarding the infrastructure and technologies deployed for sanitation purposes, including but not limited to sewage systems, septic tanks, pit latrines, and other sanitation facilities, as shown in Figure 12. These data are essential for understanding the flow of waste within the area and help define the containment aspect of the SFD. They are used to map the various systems that manage waste and serve as the foundation for analysing the subsequent stages of waste management, such as emptying, transportation, and treatment. By accurately representing the existing sanitation systems, this data helps ensure the SFD reflects the true infrastructure landscape

SANITATION SYSTEMS USED	No. of HH and population with latrine facility
	No. of HH and population connected to sewerage
	No. of HH and population connected to Septic tank
	No. of HH and population dependent on community or public toilet
	Total no. of community and public toilet
	No. of HHs and population practicing open defecation

Figure 13: Sanitation system data checklist with respect to SFD requirements.

3. Category 3 (Containments)

Containment data include information regarding the containment of wastewater, detailing the design of containment structures, their management practices, and discharge processes into soak pits or drains, as shown in Figure 13. It includes details on the design and functionality of containment systems such as septic tanks or pit latrines, as well as the management practices employed to maintain their functionality and ensure safe sludge management. Containment data also include information on any associated charges or fees for sewer connections.

CONTAINMENT	Sewage system used (centralized or decentralized)
	Once off connection charges
	Monthly charges
	Functional status of the sewage network
	Feacal sludge contained
	Feacal sludge not contained
	No. of HHs and population connected to septic tank whose effluent discharge to drain
	No. of HH and population connected to septic tank whose effluent discharge to soakpit
	No. of HH and population connected to pit
	No. of HHs and population with no containment
	Type of septic tank prevalent in the city
	Septic tank design over time
	Containment state

Figure 14: Containment data checklist with respect to SFD requirements.

4. Category 4 (Emptying and transportation)

The data on emptying and transportation pertain to disregarding services available in the area, including details on service providers, costs, and whether they are offered by private companies or government entities, as shown in Figure 14. It also includes data on the transportation of sewage, including any instances of leakage or spills, as well as the transportation and disposal of sludge. The data also highlight efforts to monitor illegal and legal dumping of faecal sludge.

EMPTYING AND TRANSPORTATION	WW transported
	WW not transported
	sewer lines Leakage- State
	Desludging services given by government or private
	The emptying cycle
	Specify no. of trucks for each
	The manner how it is emptied
	Onsite emptying capacity
	Truck trips per day
	Trucks emptying capacity
	The percentage safely closed when full and relocated
	The Percentage of FS legally dumped
	The Percentage of FS illegally dumped

Figure 15: The emptying and transportation data checklist with respect to SFD requirements

5. Category 5 (Treatment)

The treatment data include data related to the management and capacity of treatment plants in the area as shown in Figure 15. Details on the operation and maintenance of treatment facilities, as well as their capacity. This category also provides data on the volume of wastewater treated on a daily basis. The efficiency of the treatment plant is also important, indicating how the facility functions to meet regulatory standards.

TREATMENT	waste water generated per day in MLD
	Capacity of Sewage treatment plant
	Treatment capacity utilized
	Sewage not treated
	Sewage treated
	FS safely closed when full and relocated facility
	Treatment efficiency
	FS treated
	FS not treated

Figure 16: Treatment of wastewater data checklist with respect to SFD requirements

4.2.2.3.2 Colour coded the extracted data

A color-coded key was established to signify the status and quality of the data obtained from various sources. This method was employed to enhance readability and provide a clear overview of data availability from different sources. It also facilitated the filtering of data sources for this study, offering a visual representation of how well the data aligned with the study's objectives. Green refers to the data that is compliant with SFD requirement, actively monitored, and includes complete data or figures while yellow is still compliant and actively monitored, but indicates that some data or figures are missing or incomplete. Light Brown shows compliance with SFD standards and lacks active monitoring, but no available data or figures. Dark Brown reflects compliance and completeness but lacks active monitoring. Red indicates the absence of data, where the information is neither integrated into the system and purple signifies that the data is present but fails to meet the SFD data requirements.

Compliance with the SFD data requirements is primarily determined by the alignment of the terminology used in the data with the definitions set forth in the SFD. This means ensuring that the terms and categories in the data reflect those specified by the SFD guidelines. Monitoring is determined by examining the frequency and regularity with which the data is updated or reviewed and data completeness is evaluated by checking the coverage of the data with comparison to SFD requirements.

Table 7: Shows the color-coded key

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

4.2.3 Methodology 2: Data collection through administered questionnaires

This study employed administered questionnaire approach to achieve objective (4). This approach for this research was specifically designed to survey individuals with significant experience and expertise in the development of the SFD for specific South African Municipalities. The primary aim of these expert surveys was to corroborate the findings by comparing data collected from various literature sources with first-hand knowledge and practical experience.

A questionnaire served as a crucial research instrument in this methodology, comprising a mix of close-ended and open-ended questions. Close-ended questions provided respondents with predefined answer choices, while open-ended questions allowed respondents to elaborate on their thoughts. This dual approach facilitated the collection of both quantitative and qualitative data. A copy of the questionnaire is included in Appendix C4.

The questionnaire also provided an opportunity to understand the data opportunities or challenges encountered during the development of SFDs. By engaging with the respondents, the study gained a deeper understanding of the specific constraints, limitations, and gaps in data availability that were faced in relation to SFD requirements.

The question types used in the questionnaire were:

a) Open-ended questions: Open-ended questions in the questionnaire facilitated the collection of qualitative data, and allowed respondents to provide free-form responses with minimal restrictions. As shown in Figure 16, the participants were encouraged to express their thoughts, opinions, and experiences in their own words. This approach

enabled a deeper understanding of the participants' perspectives, allowing for the exploration of diverse viewpoints and uncovering valuable data.

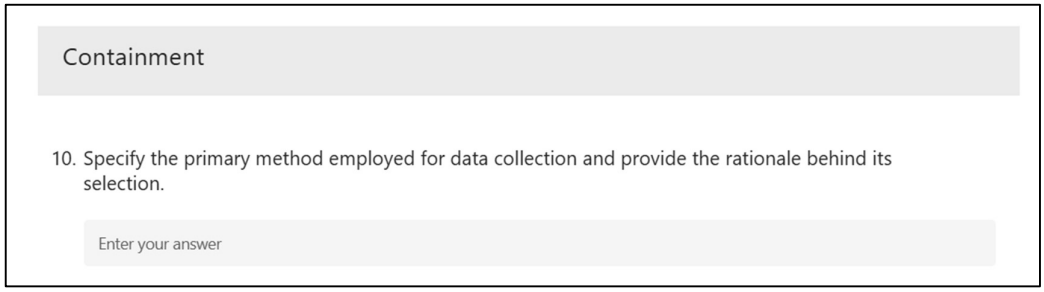


Figure 17 shows an example of an open-ended question used in the questionnaire.

b) Dichotomous questions: Dichotomous questions typically present respondents with a binary choice, as shown in Figure 17, commonly with a "yes/no" answers. This question format is often employed when precise validation is needed, providing a straightforward and direct approach to gathering data. Owing to its simplicity and clarity, the dichotomous question is considered one of the most natural forms of a questionnaire. Its usage provides researchers with a quick and efficient means of obtaining specific responses, particularly when seeking confirmation or validation of particular hypotheses or conditions.

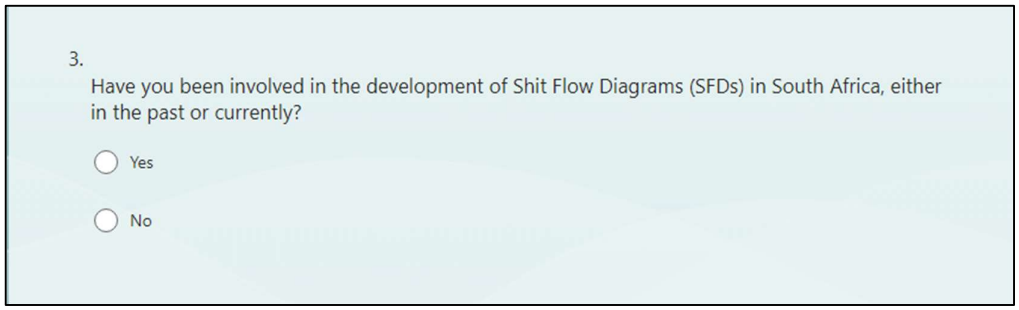


Figure 18 shows an example of a dichotomous question used in the questionnaire for the study.

c) Multiple-choice questions: Multiple-choice questions represent another form of close-ended question, wherein respondents are presented with a list of options and asked to select one (single-select multiple-choice question) or multiple (multiselect multiple-choice question) responses. As shown in Figure 18, participants are provided with a range of answer choices, and they are required to choose the option that best reflects

their thoughts, opinions, or experiences. Multiple-choice questions are valuable for standardising responses and facilitating comparisons across participants, making them widely utilised and effective tools in survey research.

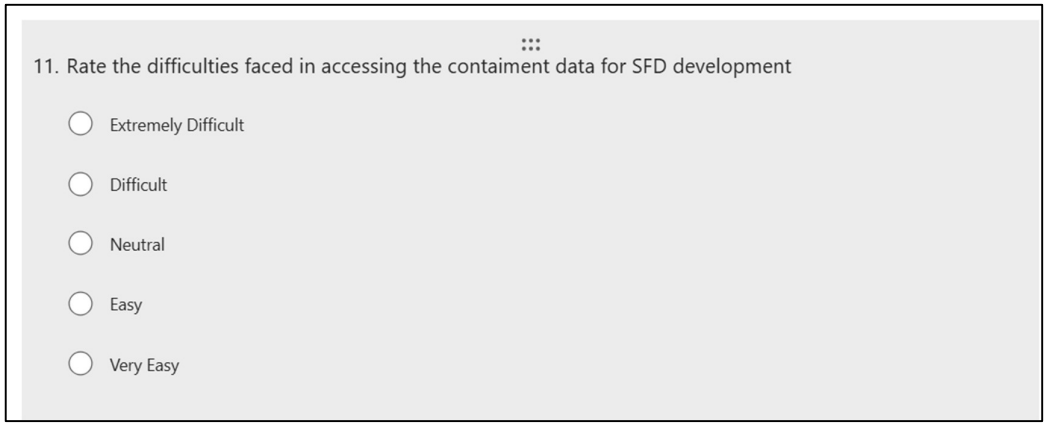


Figure 19 shows an example of multiple-choice questions used in the questionnaire for the study.

4.2.3.1 Data collection procedures

The questionnaires for this study were distributed using email, where respondents received the link to the questionnaire. This approach allowed respondents to complete the questionnaire at their convenience, ensuring they could take the necessary time to consider their responses thoughtfully, without feeling rushed or pressured. As a result, this method led to more accurate and reflective responses. The following steps were undertaken in the data collection process:

4.2.3.1.1 Preparation of questionnaires

The questionnaires were developed based on the analysis of data collected through Methodology 1, ensuring that they addressed the key aspects of the study across the defined data categories. That involved the following:

1. The level of data availability: Questions were designed to assess the extent to which data was accessible for various categories.

2. Methods used for data collection: The questionnaire aimed to explore the different techniques and approaches employed by participants in gathering data, whether through surveys, reports, site visits, or other methods.

3. The difficulty or ease of accessing the data: Participants were asked to reflect on their experiences with data accessibility, including challenges or barriers encountered in retrieving accurate and timely data.

4.2.3.1.2 Participant invitation

Potential participants were contacted through email, which included an introduction explaining the study's purpose, expected commitment, and relevant details. See the participation information sheet Appendix C2.

4.2.3.1.3 Consent and participation confirmation

Informed consent was obtained from participants after clearly outlining the expectations, responsibilities, and timelines associated with their involvement in the study. Participants were provided with detailed information about the study's objectives, the data collection process, and their rights as participants. Once these details were understood, their willingness to participate was confirmed. A copy of the consent form can be found in Appendix C3.

4.2.3.1.4 Distribution of questionnaires

The questionnaires were distributed to the selected participants using an email. A unique link to the online survey was provided, allowing participants to access and complete the questionnaire at their convenience. The link sent to the participants was: https://forms.office.com/r/BGN4ryqvMQ

4.2.3.1.5 Response tabulation

Once the questionnaires were completed, the responses were systematically collected and organised for further analysis. Each response was carefully reviewed and entered into a database to ensure accurate categorisation and facilitate a structured analysis. This process allowed for the identification of key themes .

4.2.3.2 Sampling Method

Participants Criteria: These are individuals who were previously involved in the development of SFDs in South Africa, either through academia, researchers, government stakeholders or NGOs.

Identified population of experts

The expert population from which the sample was drawn comprised professionals with significant experience and knowledge of the SFD. This included individuals from various sectors, such as academia, industry, and organisations directly related to sanitation management. The identified expert pool included

- ✓ One participant from academia
- ✓ One participant from industry

These responses are not considered primary data but serve as secondary data for comparison purposes. The limited sample size is justified, as the study's objective is to reflect on whether the challenges and data gaps identified in the current analysis align with those previously encountered during the development of SFDs. Although the small sample restricts the scope of generalisability, it provides valuable qualitative insights from experts with relevant and direct experience in the field.

4.3 Data analysis

The data analysis process encompassed two primary sources; data obtained through Methodology 1, which involved publicly available sources, and data gathered through Methodology 2, utilising administered questionnaires. The analysis sought to integrate findings from these two methodologies, enabling a comprehensive evaluation of the data's alignment with the study's objectives.

4.3.1 Data analysis: Methodology 1

Microsoft Excel was utilised as the primary tool for analysing and interpreting the data collected through Methodology 1. The software’s versatile features, such as conditional formatting, ranges, tables, and data models, facilitated a structured and in-depth evaluation of the data.

4.3.1.1 *Conditional Formatting for Data overview*

Conditional formatting played a critical role in visualising the patterns within the dataset. By applying predefined criteria, cells and fonts were dynamically coloured, and symbols were strategically positioned next to cell values to represent specific conditions. This feature provided a quick snapshot of data patterns, making it easier to identify trends and outliers as shown in Appendix 8.1.

4.3.1.2 Data Visualisation Formulas

1. Quantifying Data Status

The quantification of data status across thematic categories involved the systematic calculation of occurrences for specific color-coded categories. This process utilised formulas to identify and count the frequency of each colour within the dataset, thereby providing an objective measure of data distribution. For each dataset, the total occurrences of a specific colour were calculated using the formula:

Y = COUNTIF (X,"Colour")

Where:

- X represents the data range or selected cells being analysed.
- "Colour" specifies the particular category or colour being assessed (e.g., "Green," "Red").
- Y is the resulting count of occurrences of the specified colour within the selected data range.

Table 8: Shows an example of the quantified data from the IDP.

Source	Data	Green	Yellow	Light brow	Dark brown	Red	Purple
IDP	Descriptive data	6	0	4	0	2	0
	Sanitation systems used	1	0	0	5	0	0
	Containments	1	0	0	0	12	0
	Emptying and Transportation	0	1	2	0	10	0
	Treatment	0	0	3	0	6	0

2. Calculating availability, completeness and compliance with SFD in percentage

To quantify availability, completeness, and compliance with the SFD in percentage terms, the analysis involved converting the count of occurrences into relative proportions. Once the occurrences for each colour category were determined, the percentage of data status was calculated using the formula:

$$Data\ status\ (\%) = (\frac{Y}{X}) * 100$$

$$X = Y_{Green}+Y_{Yellow}+Y_{Light\ brown}+Y_{Dark\ brown}+Y_{Red}+Y_{Purple}$$

Where:

- X is the resulting count of occurrences of all colours within the selected data range.
- Y is the resulting count of occurrences of the specified colour within the selected data range.

Table 9: Shows an example of the quantified data in percentages.

Source	Data	Green	Yellow	Light brown	Dark brown	Red	Purple
IDP	Descriptive data	50%	0%	33%	0%	17%	0%
	Sanitation systems used	17%	0%	0%	83%	0%	0%
	Containments	8%	0%	0%	0%	92%	0%
	Emptying and Transportation	0%	8%	15%	0%	77%	0%
	Treatment	0%	0%	50%	0%	50%	0%

4.3.2 Data analysis: Methodology 2

This survey, which was conducted to understand the relationship between data reporting for water and sanitation authorities in South Africa and alignment with the SFD, had two participants. Given the limited number of respondents, the analysis focused on descriptive statistics and qualitative feedback provided.

The survey was structured into categories similar to those used in Methodology 1 to ensure ease of comparison and consistency in the analysis. The first section of the questionnaire focused on understanding participants' prior involvement in developing SFDs in South Africa, aiming to gauge their level of experience and contextual understanding of the process. Subsequent sections focused more into critical dimensions of the SFD data collection processes, including data availability, challenges in data access, methods of data collection, and compliance with SFD requirements. The analysis process is as follows:

1. Tabulating Responses

The first step involved organising the survey data into an Excel spreadsheet, where each response was categorised based on predefined sections. Tabulating survey responses was a crucial step in the data analysis process as it helped organise and structure raw data in a clear and systematic format. This process allowed the researcher to categorise responses based on predefined themes, making it easier to access, review, and identify patterns. Tabulation also facilitated the quantification of data, enabling researcher to count the frequency of specific responses and calculate percentages.

Table 10: Shows tabulated responses from the administered questionnaire.

Category	**Participant 1**	**Participant 2**
Level of Involvement	High	Very high
Efficiency of Data Collection	Somewhat Efficient	Neutral
Difficulties in Accessing Data	Neutral	Easy
Containments		
Method	Desktop data collection and one-on-one interactions to confirm data accuracy	Interviews with municipal members
Difficulty	Easy	Easy
Availability	50% readily available	50% readily available
Monitoring	Slightly Monitored	Moderately Monitored
Compliance	Slightly compliant	Moderately compliant
Emptying & Transportation		
Method	One-on-one interactions with Municipality and truck drivers	Interviews with septic tank emptiers and union leaders
Difficulty	Difficult	Difficult
Availability	50% readily available	75% readily available
Monitoring	Slightly Monitored	Very Well Monitored
Compliance	Slightly compliant	Moderately compliant
Treatment		
Method	Same as emptying and transportation method	Interviews with municipal department
Difficulty	Very Easy	Easy
Availability	100% readily available	75% readily available
Monitoring	Very Well Monitored	Very Well Monitored
Compliance	Very Well compliant	Moderately compliant
Reuse/Disposal		
Method	Same as treatment	Interviews with municipal department
Difficulty	Easy	Easy
Availability	50% readily available	50% readily available
Monitoring	Slightly Monitored	Moderately Monitored
Compliance	Slightly compliant	Moderately compliant

2. Quantifying Responses

Once the responses were tabulated, descriptive statistics were calculated to summarise the data. Due to the small sample size of two participants, the focus was on basic measures like frequency counts and percentages. For example, if both participants indicated a "High" level of involvement, this was recorded as 100% for both. This quantification provided a numerical overview of the responses, showing how each participant's answers were distributed across the different categories. By converting qualitative responses into quantitative terms, this process provided an overview of how each participant's answers were distributed across different categories, such as data access, availability, monitoring, and compliance.

The table below illustrates the quantified responses for various aspects of data management, including access, availability, monitoring, and compliance, across different categories. This quantification helps in understanding the extent of alignment between the participants' experiences and the challenges they faced in accessing and managing sanitation data.

Table 11: Shows the quantified responses for data access, availability, monitoring and compliance.

	Category	**Participant 1**	**Participant 2**
Overall	Level of Involvement	75%	100%
	Efficiency of Data Collection	75%	50%
	Difficulties in Accessing Data	50%	75%
Containments	Access	75%	75%
	Availability	50%	50%
	Monitoring	25%	50%
	Compliance	25%	50%
Emptying & Transportation	Access	25%	25%
	Availability	50%	75%
	Monitoring	25%	75%
	Compliance	25%	50%
Treatment	Access	100%	75%
	Availability	100%	75%
	Monitoring	75%	75%
	Compliance	75%	50%
Reuse/Disposal	Access	75%	75%
	Availability	50%	50%
	Monitoring	25%	50%
	Compliance	25%	50%

3. Visualising the Data

To enhance the interpretability of the data, visualisations such as bar charts were created. These charts provided a graphical representation of the responses, allowing for a quick comparison of the participants' answers across various categories

4.4 Framework development

Based on the findings from the data analysis and feedback from respondents, a framework was developed to make the available sanitation data complete and compatible with the requirements of the SFD. This framework was designed to address the identified gaps and improve the overall data quality.

4.4.1 Identified the Municipality for framework development

The first step was to identify the municipality for which the framework would be developed. In this case, the focus was on Ekurhuleni, a major metropolitan municipality in Gauteng. This involved understanding the geographical scope, key stakeholders, and the sanitation systems in place within the municipality.

The selection was narrowed to CoTMM and CoEMM, as both municipalities demonstrated comparatively better data availability within their libraries and greater consistency in the publication of annual reports. In contrast, for most other municipalities, data was not easily accessible, and in several cases, publicly available libraries did not exist. Ekurhuleni was ultimately chosen for framework development because, among the metropolitan municipalities, it exhibited the highest proportion of available sanitation data. This accessibility facilitated more reliable processes of data collection, verification, and analysis. Additionally, Ekurhuleni's status as a major metropolitan municipality with a diverse sanitation profile, encompassing both sewered and non-sewered systems, offered an appropriate context for testing integrated monitoring approaches. The framework was therefore designed with the intention of using Ekurhuleni as a reference point: first, to promote consistency in data collection and reporting across other municipalities, and subsequently, to enhance both the quantity and quality of sanitation data collected and published.

4.4.2 Identified data gaps in Ekurhuleni

Once the municipality was identified, the next step was to identify data gaps in Ekurhuleni. This step involved analysing the available sanitation data in Ekurhuleni, comparing it against the SFD requirements, and identifying areas where the data was incomplete, inaccurate, or non-compliant. The gaps related to aspects such as containment, emptying, transportation, treatment, and reuse/disposal.

4.4.3 Refined data collection methods

Following the identification of data gaps in Ekurhuleni, the study focused on refining the methods used for sanitation data collection. The refinement process prioritised the standardisation of reporting formats to ensure consistency and comparability across various categories, including containment, emptying, transportation, treatment, and reuse/disposal. Clear guidelines were set to standardise the level of detail, format, and frequency of data reporting.

4.4.4 Designed Data collaboration protocols

Protocols were established to enhance collaboration and ensure consistency in data reporting across municipalities in Gauteng, with a specific focus on aligning with the SFD requirements. These protocols included the creation of a centralised platform for sharing sanitation data, enabling municipalities to exchange information and adopt best practices. Standardised reporting templates were introduced to ensure uniformity in the format and content of data submissions, reducing inconsistencies and facilitating comparative analysis.

4.4.5 Strengthened data monitoring mechanisms

To enhance the reliability and accuracy of sanitation data, a robust monitoring system was implemented. This system tracked the progress of data collection efforts, ensuring adherence to reporting requirements and compliance with the SFD guidelines. Advanced real-time monitoring tools were developed and deployed to detect discrepancies or irregularities in data reporting promptly.

These tools allowed for immediate identification of gaps or inconsistencies, facilitating timely corrective actions. Additionally, regular audits and performance reviews were introduced to evaluate the effectiveness of data monitoring practices and ensure continuous improvement. This strengthened monitoring framework aimed to maintain the integrity of the data while supporting sustainable sanitation management practices.

5 RESULTS AND DISCUSSION

5.1 The level of data availability in relation to the Shit Flow Diagram requirements

The analysis of data availability in relation to SFD requirements was conducted using publicly accessible datasets, including annual reports, Integrated Development Plans (IDPs), and the Green Drop Report. The evaluation focused on three key aspects: the completeness of the data, its compliance with SFD requirements, and whether the data is actively monitored. The findings are represented using a color-coded system to provide a visual representation of the level of compliance and monitoring across the various data sources.

5.1.1 The level of data availability in relation to Shit Flow Diagram requirements for the City of Johannesburg Metro Municipality.

The analysis of data availability in relation to SFD requirements was conducted using publicly accessible datasets, including annual reports, Integrated Development Plans (IDPs), and the Green Drop Report (City of Johannesburg, 2020/2021; City of Johannesburg, 2020/2021; Department of Water and Sanitation, 2023). The evaluation focused on three key aspects: the completeness of the data, its compliance with SFD requirements, and whether the data is actively monitored shown in Figure 19 - 22.

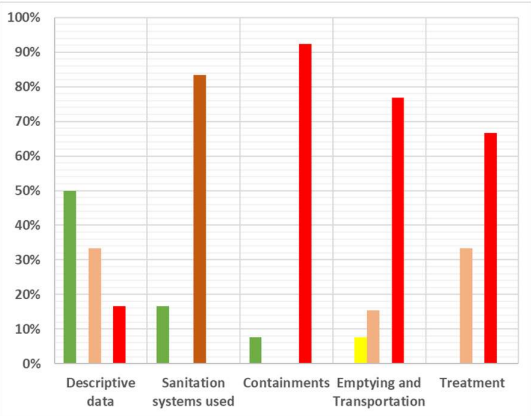


Figure 20: Shows the level of data availability extracted from Integrated Development Plan.

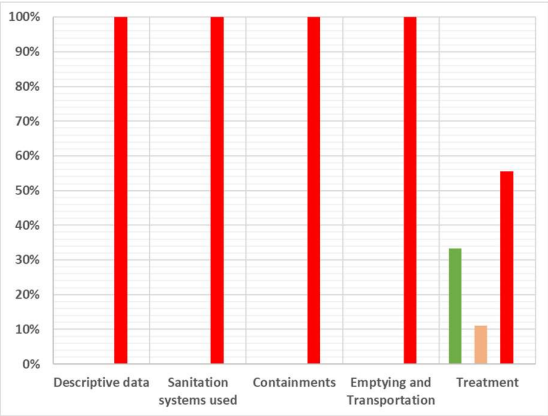


Figure 21: Shows the level of data availability extracted from Green Drop Report.

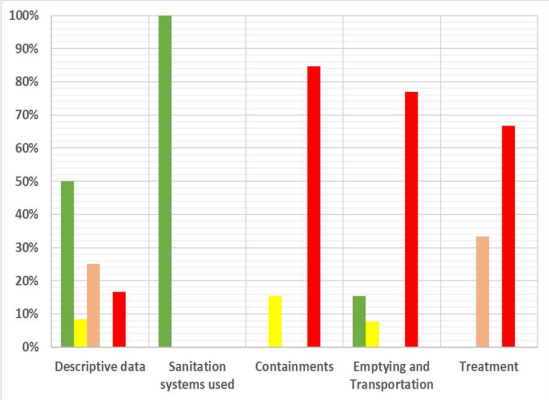


Figure 22: Shows the level of data availability extracted from Annual Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 23: Shows the legend used in the graphs.

The terminology used in various data sources is critical for accurate alignment and integration. However, inconsistencies between the Integrated Development Plan (IDP), the Annual Report, and the SFD created challenges in this study. For instance, the SFD categorises certain areas as "slum settlements," while the IDP and Annual Report refer to the same areas as "informal settlements." (City of Johannesburg, 2020/2021; City of Johannesburg, 2020/2021). This discrepancy complicates the process of aligning the CoJMM data with the SFD framework, as it introduces ambiguity in classification. This challenge highlights the broader issue of terminology standardisation in multi-source datasets. Patel and Thompson (2020) similarly observed that inconsistent language across reports can lead to significant difficulties in data interpretation and integration. As a result, adopting a standardised lexicon for such terms is crucial to ensure compliance and avoid misalignment when analysing data using tools like the SFD.

The terminology used for “open defecation” data in the IDP and the annual reports was unclear. The term "non-sanitation facility" was used without explicitly indicating whether this referred to the community using public facilities, neighbours’ facilities, or actual open defecation practices. This lack of specificity was a critical issue, as it hinders the ability to accurately assess the prevalence and nature of open defecation in the municipality. These similar challenges are well documented in this study, where Smith *et al*. (2019) who highlighted the importance of clear and consistent terminology for effective data collection and reporting in sanitation studies.

The analysis of the IDP and annual report showed that approximately 50% of the ‘Descriptive data’ are compliant, actively monitored and complete, while Green Drop Report is 0% as

required by the SFD. This finding is consistent with broader literature, which indicates that large urban municipalities often struggle with data completeness (Smith *et al*., 2019). The significant gaps in the data observed in the IDP, particularly in 'sanitation system data', where only 17% of the data are compliant, actively monitored and complete and 83% are not actively monitored, highlight the findings of Jones and Brown (2020), who emphasised the difficulties in documenting comprehensive sanitation infrastructure in rapidly urbanising areas. The annual report indicated 100% of the data are compliant, actively monitored and complete, while Green Drop Report is 0%. These gaps suggest a shortfall in reporting practices, which are attributed to inadequate data management systems or a lack of prioritisation in data collection efforts.

The literature stresses the need for detailed and complete data for effective sanitation planning and management (Taylor & Harris, 2021). In Johannesburg, the limited availability of key data such as the number of households connected to various sanitation facilities, indicates a significant gap in comprehensive reporting (City of Johannesburg, 2020/2021). This shortfall stems from resource constraints, insufficient monitoring systems, or a lack of coordination between different municipal departments (Kalonda *et al*., 2021).

The 'Containment' data are particularly concerning, with approximately 8%, 15% and 0% of the available data in the IDP, annual report and Green Drop report respectively. This challenge is outlined by Smith *et al*. (2019), who noted the difficulty in maintaining up-to-date records of sanitation facilities in densely populated municipalities. The literature suggests that such gaps in data can severely impede efforts to monitor and improve public health outcomes (Patel & Thompson, 2020). The observed deficiencies in Containment data may be due to inadequate infrastructure, insufficient funding for data collection, or challenges in accessing informal settlements where such facilities are often lacking (Nkere *et al*., 2025).

The data availability in the area of 'Emptying and Transportation' is alarmingly low, with no compliant, actively monitored and complete data reported in the IDP and Green drop report. Taylor and Harris (2021) highlighted that the absence of reliable data on waste transportation is a widespread issue, which often results in inefficiencies in the management and treatment of wastewater. The annual report shows approximately 15% which is below average. This is due to the logistical challenges of tracking faecal sludge transportation in urban environments, particularly in informal settlements where such services may be irregular or undocumented.

The ‘Treatment’ of wastewater data is also shown to be a significant challenge, with 0%, 0% and 34% of the compliant, actively monitored and complete data, in the IDP, annual report and the green drop report respectively. This finding is consistent with earlier research by Graham and Reed (2018), which highlighted the difficulties that municipalities face in ensuring that all aspects of wastewater treatment are adequately monitored and reported. The lack of data in this area may be attributed to outdated infrastructure, insufficient investment in wastewater treatment facilities, or challenges in interdepartmental coordination, which are commonly cited barriers in the literature.

5.1.2 The level of data availability in relation to Shit Flow Diagram requirements for the City of Tshwane Metro Municipality.

The analysis of data availability for the CoTMM, based on the 2020–21 Integrated Development Plan (IDP), the 2020–21 Annual Report, and the 2023 Green Drop Report, is summarised in Figures 23–25, with the legend provided in Figure 26. These sources reveal significant disparities in data compliance, monitoring and completeness with SFD requirements (City of Tshwane Metro Municipality, 2020/2021; City of Tshwane Metro Municipality, 2020/2021; Department of Water and Sanitation, 2023).

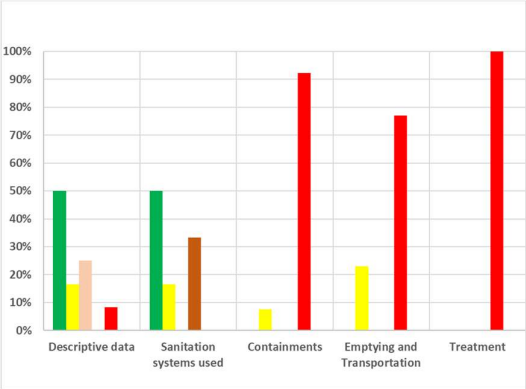


Figure 24: Shows the level of data availability extracted from the Integrated Development Plan.

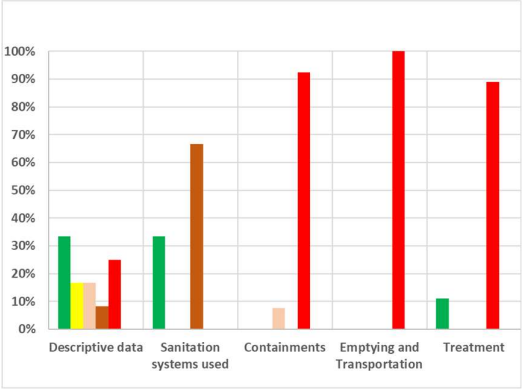


Figure 25: Shows the level of data availability extracted from the Annual Report.

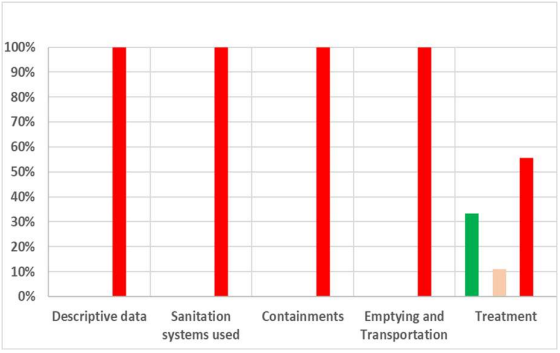


Figure 26: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 26: Shows the legend used in the graphs.

As shown in Figure 23, 'Descriptive data' in the IDP show 50% compliance with SFD requirements, reflecting moderate availability and active monitoring. The Annual Report (Figure 24) presents a low level of data compliance, monitoring and completeness, with approximately 33% of "Descriptive Data" meeting SFD requirements compliance, active monitoring and complete and 25% missing. The Green Drop Report (Figure 25) does not include "Descriptive Data", indicating a gap in this area. These findings suggest that the IDP is the most comprehensive source for "Descriptive Data", but the lack of uniformity across documents highlights a critical challenge in achieving consistency in municipal reporting.

Data on 'Sanitation systems' used vary significantly across the three documents. The IDP (Figure 23) shows 50% compliant, actively monitored and complete while the Annual Report (Figure 24) records only 33%, with 67% of data either incomplete or not monitored. The Green Drop Report (Figure 25) provides no data on sanitation systems, reflecting a limitation in its scope. These discrepancies point to gaps in monitoring practices and resource allocation, as also observed in Johannesburg and noted by Taylor and Harris (2021).

Containment data are particularly concerning across all three reports. As illustrated in Figure 23, the IDP categorises 92% of containment data as no data available, not integrated into the report. The Annual Report (Figure 24) shows similar results, with 92% of data missing. The Green Drop Report (Figure 25) offers no data on containment, reinforcing the critical gaps identified. These findings are consistent with Jones and Brown's, 2020, observations that densely populated municipalities struggle with the collection and integration of containment data due to resource constraints and urban expansion.

Data on "emptying and transportation" reveal alarmingly low availability across the three documents. The IDP (Figure 23) shows 77% of data as missing, while the Annual Report (Figure

24) records 100% of data as "not integrated into the system." The Green Drop Report (Figure 25) does not provide any data in this category. These results align with Graham and Reed's (2018) findings, which attribute such deficiencies to logistical and infrastructural challenges in urban municipalities.

The “Treatment data”, shown in Figures 23–25, present a critical gap. The IDP reports 100% of treatment data as missing and not integrated into the system, while the Annual Report records 89% missing data. The Green Drop Report also indicates significant gaps, with 56% of treatment data unavailable or incomplete (Figure 25). This lack of comprehensive data undermines public health and environmental management efforts, as emphasised by Patel and Thompson (2020).

5.1.3 The level of data availability in relation to Shit Flow Diagram requirements for the City of Ekurhuleni Metro Municipality.

The CoEMM encountered significant obstacles during the data collection process, largely stemming from the draft status of the available Integrated Development Plans, which hindered access to complete, finalised reports. These challenges were exacerbated by gaps identified in the Annual Reports, particularly concerning water supply coverage. For instance, the 2021/2022 Annual Report included a table on water service delivery with empty fields under the water supply category. It was unclear whether these blank spaces signified missing data or represented portions of the population without access to water services. This ambiguity in reporting underscores a major challenge in data interpretation and emphasises the urgent need for more transparent, detailed, and comprehensive documentation practices within the Municipality (City of Ekurhuleni Metro Municipality, 2020/2021; City of Ekurhuleni Metro Municipality, 2020/2021)

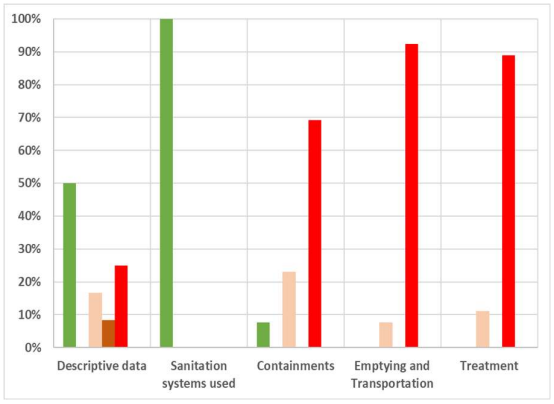


Figure 27: Shows the level of data availability extracted from Integrated Development Plan.

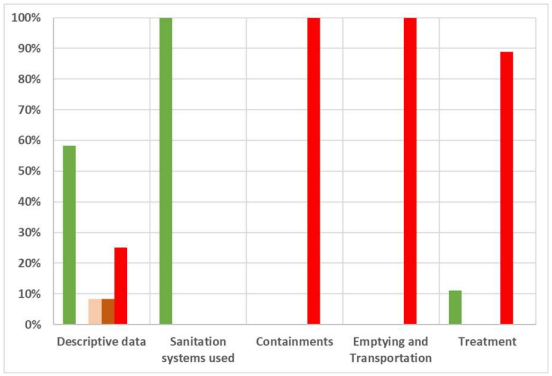


Figure 28: Shows the level of data availability extracted from Annual Report.

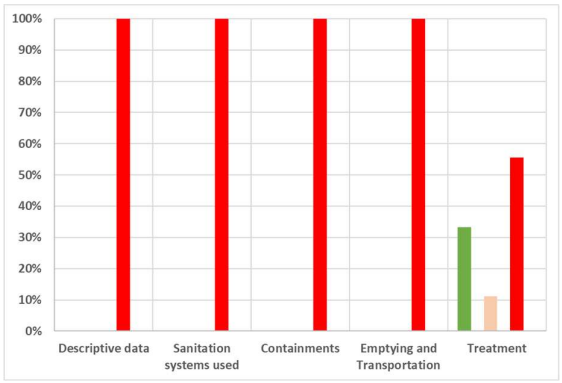


Figure 29: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 26: Shows the legend used in the graphs.

The three reports; IDP, Annual Report, and Green Drop Report, reveal varied strengths and weaknesses in data compliance with SFD requirements, monitoring, and completeness for the CoEMM. In terms of "Descriptive data", the IDP demonstrates moderate compliance, with 50% of the data fully available and complete. However, critical environmental parameters, such as groundwater levels and aquifer vulnerability, are either missing or insufficiently documented. The Annual Report shows slightly higher compliance at 58%, reflecting a more detailed and accurate depiction of the Municipality's general parameters. Despite this improvement, gaps in environmental data persist, limiting the Municipality's ability to plan effectively for water and sanitation services. The Green Drop Report, on the other hand, fails to provide any "Descriptive Data" in compliance with SFD requirements, highlighting a significant shortfall in this area.

When analysing "Sanitation systems used", both the IDP and Annual Report demonstrate full compliance, with 100% of the data meeting SFD requirements. This indicates robust documentation of sanitation infrastructure, such as latrines, sewerage connections, septic

tanks, and public toilets. However, the Green Drop Report lacks any information about “Sanitation systems used”, reflecting a critical gap in its scope. In contrast, “Containment data” reveal significant deficiencies across all three reports. The IDP shows only 8% compliance, suggesting limited monitoring and reporting of containment practices. The Annual Report fares even worse, with no data meeting SFD requirements for containment, while the Green Drop Report similarly provides no compliance, reinforcing systemic weaknesses in this critical area of sanitation.

The “Emptying and transportation data” are equally problematic. The IDP shows minimal compliance, with data availability ranging from 0% to 8%. This gap highlights substantial challenges in tracking and reporting on wastewater logistics. The Annual Report mirrors these findings, offering no compliance in this category. The Green Drop Report also fails to include any relevant data, underscoring persistent shortcomings in monitoring and managing these essential services. The “treatment” category reflects some improvement in the Green Drop Report, with 33% compliance compared to the IDP and Annual Report, which each achieve only 11%. While the Green Drop Report provides slightly better insights into treatment-related data, such as sewage treatment plant capacity, gaps in data on capacity utilisation persist across all three reports, undermining the Municipality's ability to optimise its wastewater treatment facilities effectively.

5.1.4 The level of data availability in relation to Shit Flow Diagram requirements for Sedibeng District Municipality.

Sedibeng District Municipality employs a unique approach to data collection and terminology, recording households as "units," which distinguishes it from other municipalities. This district consists of three local municipalities: Midvaal Local, Lesedi Local, and Emfuleni Local. Functioning primarily as an administrative entity, the Sedibeng District Municipality oversees these local municipalities and ensures coordinated governance across the region. While the district Municipality aggregates and reports data on a broader scale, the local municipalities benefit from their smaller administrative scope, enabling them to implement more detailed and specific data collection mechanisms.

5.1.4.1 Midvaal Local Municipality

The data compliance, monitoring and completeness for Midvaal Local Municipality across the Annual Report, Integrated Development Plan (IDP), and Green Drop Report reveals significant discrepancies as shown in Figure 29-31 (Midvaal Local Municipality, 2020/2021; Midvaal Municipality, 2020/2021, Department of Water and Sanitation, 2023). The Annual Report demonstrates critical data gaps in areas such as “containment, emptying and transportation, and treatment”, where no data are available. This lack of monitoring reflects limited attention to key sanitation practices, including the management of septic tanks, their emptying schedules, and transportation methods. Furthermore, no records exist on treatment plant capacity, wastewater volumes treated, or the efficiency of treatment processes. However, the Annual Report does provide partial compliance in “descriptive data”, with 33% availability covering the area, population, population growth rate, and water supply. Notably, only 17% of sanitation system data, specifically related to the number of households and populations with access to latrine facilities, is monitored and reported.

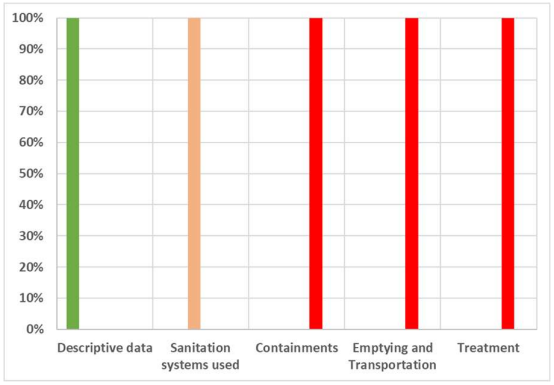


Figure 30: Shows the level of data availability extracted from Integrated Development Plan.

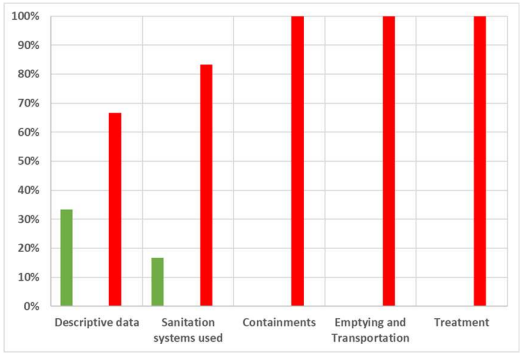


Figure 31: Shows the level of data availability extracted from Annual Report.

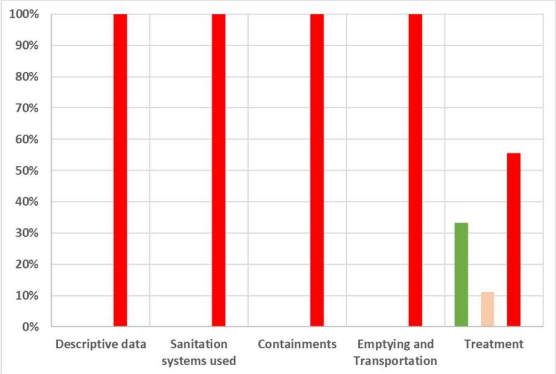


Figure 32: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 26: Shows the legend used in the graphs.

In contrast, the IDP provides a more comprehensive view of the Municipality's data landscape. "Descriptive data" are fully compliant with SFD requirements, offering detailed insights into demographic and geographic factors such as population growth rates, topography, climate, groundwater levels, and aquifer vulnerability. This suggests robust data collection mechanisms in these areas. However, significant gaps persist in sanitation-specific categories. For instance, data on households and populations connected to latrines, sewerage systems, and septic tanks are incomplete. The IDP and annual report has no data for "containment, emptying and transportation, and treatment". This reflects systemic challenges in monitoring and reporting on these critical aspects of sanitation, despite the Municipality's apparent focus on "Descriptive Data".

The Green Drop Report, however, focuses primarily on wastewater treatment but provides limited data coverage for Midvaal Municipality. While the report highlights some treatment-related data, such as compliance indicators for wastewater facilities, significant gaps remain in treatment capacity utilisation and efficiency metrics. The report does not provide any meaningful data on descriptive aspects, sanitation systems, or containment practices, emphasising its narrow scope.

5.1.4.2 Lesedi Local Municipality

The comparison of the Annual Report, Integrated Development Plan (IDP), and Green Drop Report for Lesedi Local Municipality shows gaps in data compliance, actively monitoring and completeness as shown in Figure 32-34 (Lesedi Local Municipality, 2020/2021; Lesedi Municipality, 2020/2021, Department of Water and Sanitation, 2023).

The Annual Report provides relatively comprehensive “descriptive data”, covering critical indicators such as the area, population, and water supply, which support effective monitoring and planning. However, a key deficiency is the absence of climate-related data, reflecting a gap in capturing essential environmental information. For sanitation systems, the Annual Report demonstrates strong compliance, actively monitoring and completeness, with detailed reporting on infrastructure such as latrine facilities, sewerage connections, and septic tanks. Despite this strength, the containment data show significant deficiencies, with missing information on sewage system types, containment conditions, and effluent discharge practices. Similarly, the emptying and transportation data are incomplete, indicating inadequate monitoring of wastewater transportation methods, desludging services, and sewer line conditions. Wastewater treatment data in the Annual Report yield mixed results, with complete coverage of parameters such as treatment plant capacity but missing information on treatment capacity utilisation and efficiency.

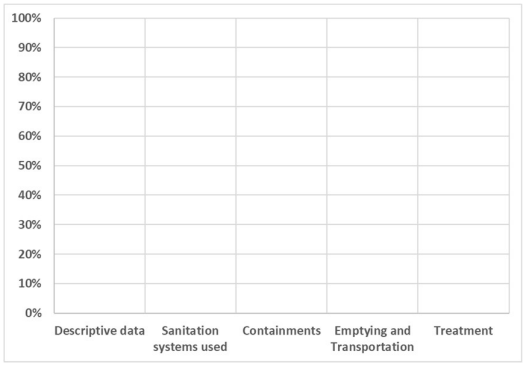


Figure 33: Shows the level of data availability extracted from Integrated Development Plan.

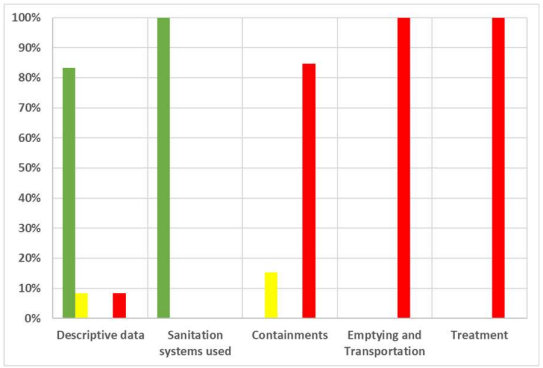


Figure 34: Shows the level of data availability extracted from Annual Report.

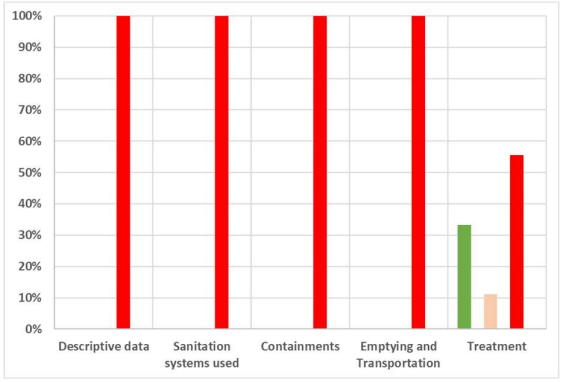


Figure 35: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 26: Shows the legend used in the graphs

The IDP, however, was missing for Lesedi Local Municipality, resulting in significant data gaps across all categories. This absence severely limited the ability to assess the Municipality’s

compliance with SFD data requirements. The Green Drop Report offered a limited focus on wastewater treatment, providing data into treatment capacity and compliance with national wastewater standards. However, it lacks data on other critical areas, such as “Descriptive Data”, sanitation systems, containment measures, and emptying and transportation practices.

5.1.4.3 Emfuleni Local Municipality

The comparison of the Annual Report, Integrated Development Plan (IDP), and Green Drop Report for Emfuleni Local Municipality highlights significant discrepancies in data compliance, active monitoring, and completeness, as shown in Figures 35–37 (Emfuleni Local Municipality, 2020/2021; Emfuleni Municipality, 2020/2021, Department of Water and Sanitation, 2023).
The Annual Report shows high data compliance, actively monitoring and completeness in “descriptive data”. Similarly, the report demonstrates strong compliance with SFD requirements in sanitation systems, including data on households and populations with access to latrines and the prevalence of open defecation. However, substantial gaps are evident in the “containment” section, with limited information on sewage system types, containment conditions, and septic tank discharge methods. Furthermore, data on sewerage and septic tank connections are incomplete, and the total number of public and community toilets is only partially documented.

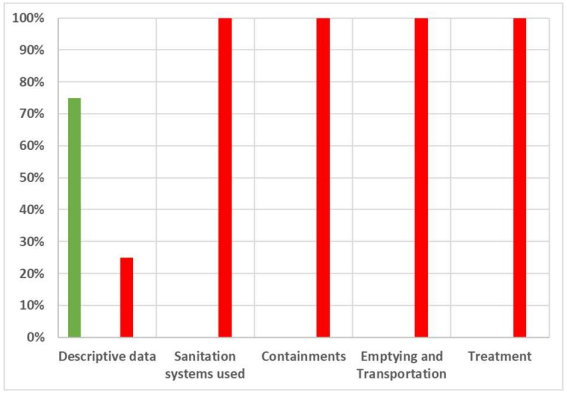


Figure 36: Shows the level of data availability extracted from Integrated Development Plan.

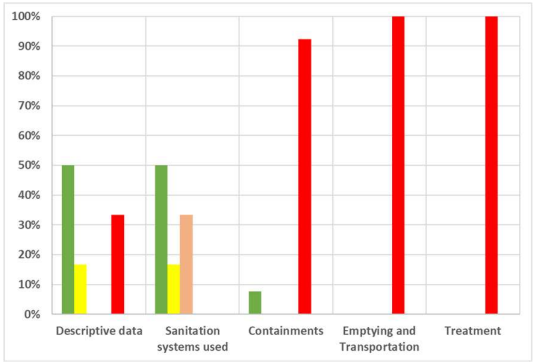


Figure 37: Shows the level of data availability extracted from Annual Report.

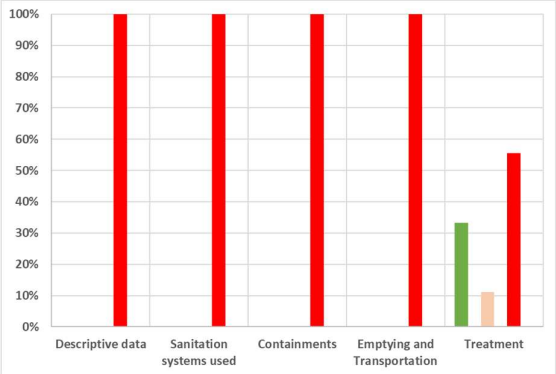


Figure 38: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 39: Shows the legend used in the graphs

The IDP provides strong compliance in “descriptive data”, including detailed demographic and geographic indicators such as city area, population size, growth rate, and water-related parameters like water supply per capita and coverage. Despite this, the IDP reveals relatively limited data availability in “sanitation systems, containment, and treatment”. Minimal data exist on the distribution of sanitation facilities (latrines, sewerage systems, and septic tanks) among households, as well as on the prevalence of open defecation. Containment data, including sewage system types and “emptying and transportation” practices, are missing, as are details on treatment facilities, highlighting critical gaps in monitoring and reporting.

The Green Drop Report provides limited insights, focusing almost exclusively on wastewater treatment. While it offers some information on treatment capacity and compliance with national standards, it lacks data on descriptive parameters, sanitation systems, containment measures, and emptying and transportation practices.

5.1.5 The level of data availability in relation to Shit Flow Diagram requirements for West Rand District Municipality.

The analysis of data availability across the different local municipalities within the West Rand District provides valuable understanding of each Municipality's strengths and weaknesses in data compliance, monitoring and completeness, as shown in Figures 38–49 (West Rand District Municipality, 2021/2022; West Rand Municipality, 2021/2022, Department of Water and Sanitation, 2023).

Mogale Local Municipality appears to rely heavily on the IDP and Annual Reports of Merafong Local Municipality, potentially adopting these reports as their own. This reliance raises concerns about the Municipality's ability to independently collect and report accurate, municipality-specific data. Meanwhile, the IDP report for Rand West Local Municipality contains significant errors in reporting units, such as the use of "ml" (millilitres) instead of the correct unit, "ML" (megalitres). These errors complicate the interpretation of water-related data and highlight gaps in data validation and quality control.

5.1.5.1 Rand west Local Municipality

The three reports; IDP, Annual Report, and Green Drop Report, reveal varied strengths and weaknesses in data compliance, monitoring, and completeness with SFD requirements for Rand West Local Municipality. In terms of “Descriptive data,” the IDP demonstrates strong compliance, actively monitored and complete of 67%. This includes indicators such as the city area, population, population growth rate, water supply coverage, and the number of slum settlements. The Annual Report performs similarly, with 58% of “Descriptive data” compliance, actively monitored and complete, covering essential demographic and geographic parameters. However, gaps remain in areas such as topography, climate, and groundwater levels. The Green Drop Report does not provide any” Descriptive Data”.

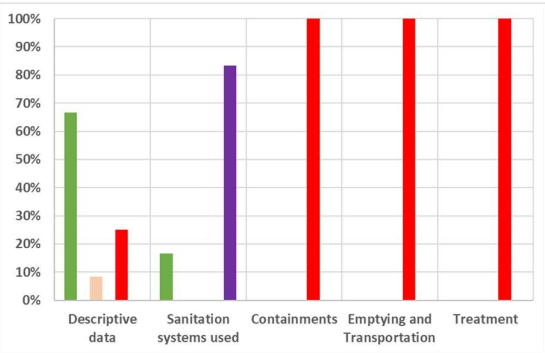


Figure 40: Shows the level of data availability extracted from Integrated Development Plan.

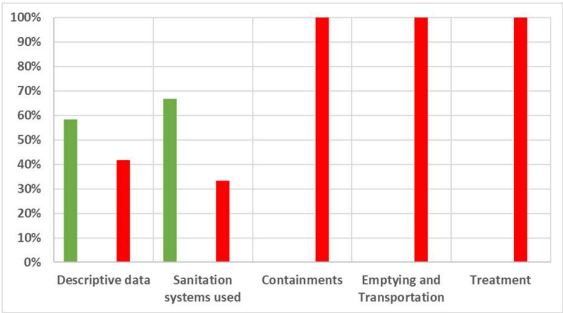


Figure 41: Shows the level of data availability extracted from Annual Report.

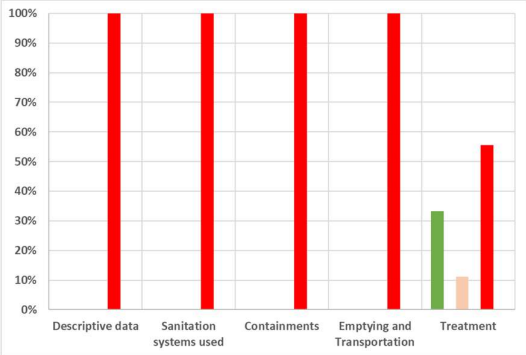


Figure 42: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 43: Shows the legend used in the graph

When analysing "Sanitation systems used," both the IDP and Annual Report reveal significant deficiencies. None of the data in the IDP meet SFD requirements, with missing information on households and populations connected to latrine facilities, sewerage systems, or septic tanks, as well as the prevalence of open defecation. The Annual Report shows slightly better performance, with partial data availability for households connected to various sanitation systems, but gaps persist in community or public toilet usage. The Green Drop Report does not provide any data on sanitation systems.

The "Containment data" reveal systemic weaknesses across all three reports. They show missing data, with no data available on sewage system types, containment conditions, or effluent discharge practices. This lack of data poses significant challenges to understanding and addressing sanitation infrastructure needs. For "Emptying and transportation data," all three reports show a complete absence of compliance. Neither the IDP nor the Annual Report provides data on wastewater logistics, such as desludging services or sewer line conditions. The Green Drop Report similarly excludes these categories, reflecting significant gaps in tracking and managing waste transportation processes.

The "Treatment" category shows mixed performance across the reports. The IDP and Annual Report do not provide any treatment data, such as capacity utilisation or efficiency metrics. The Green Drop Report demonstrates limited compliance, with 33% of treatment-related data available.

5.1.5.2 Mogale Local Municipality

Mogale Local Municipality encountered significant challenges in its data collection and reporting processes, primarily due to the absence of a publicly available annual report, which

limited the Municipality's ability to present a comprehensive overview of its sanitation and wastewater management efforts. The IDP report reveals both strengths and weaknesses, but the lack of supporting documentation exacerbates existing gaps, particularly in sanitation-specific categories. This is shown in Figure 43-45 (Mogale Local Municipality, 2020/2021).

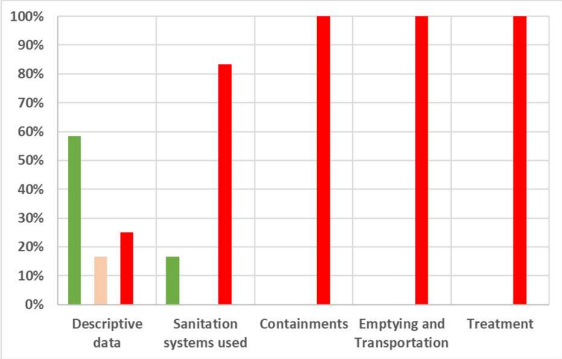


Figure 44: Shows the level of data availability extracted from Integrated Development Plan.

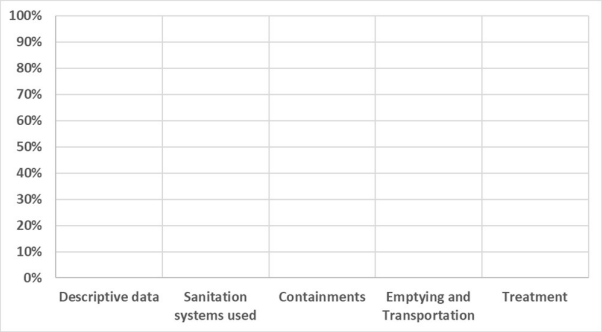


Figure 45: Shows the level of data availability extracted from Annual Report.

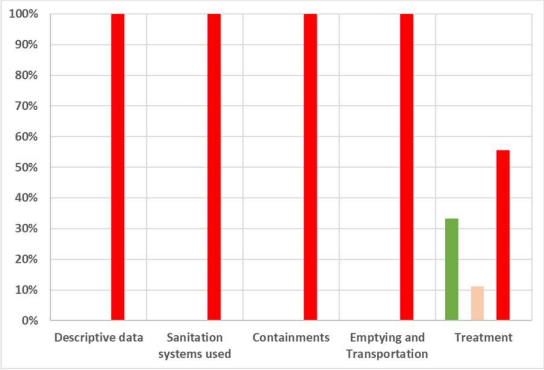


Figure 46: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	√	√	100% Complete
Yellow	√	√	75% Complete
Light brown	√	√	50% Complete
Dark brown	√	X	25% Complete
Red	X	X	0% Complete
Purple	X	√	-

Figure 47: Shows the legend used in the graphs

The three reports; IDP, Annual Report, and Green Drop Report, reveal varied strengths and weaknesses in data compliance with SFD requirements, monitoring, and completeness for Mogale Local Municipality. In terms of "Descriptive data", the IDP demonstrates moderate compliance, with 58% of the data fully available and complete. This includes key parameters such as city area, population, population growth rate, topography, climate, groundwater levels, aquifer vulnerability, water supply sources, water supply per capita, water supply coverage, the number of slum settlements, and the number of households within the municipal boundary. However, the absence of the Annual Report and the lack of relevant data in the Green Drop Report mean that no further insights are available in this category, leaving significant gaps in critical environmental and demographic data.

When analysing “Sanitation systems used”, the IDP demonstrates low compliance, with only 17% of the required data being available. Data on households and populations connected to sanitation facilities, such as latrines, sewerage systems, and septic tanks, is either incomplete or entirely absent. This deficiency is compounded by the lack of sanitation systems data in both the Annual Report and the Green Drop Report.

The “Containment data” reveal systemic weaknesses across all three reports. The IDP, Annual Report, and Green Drop Report all show no compliance, with a complete absence of data on sewage system types, containment conditions, and effluent discharge practices. This lack of data poses significant challenges to understanding and addressing sanitation infrastructure needs within the Municipality. For “Emptying and transportation data”, all three reports demonstrate a 100% absence of compliance. Neither the IDP nor the Green Drop Report provides any relevant data on wastewater logistics, such as desludging services or sewer line conditions, leaving this critical area of sanitation management entirely unaddressed.

In terms of “Treatment”, the Municipality performs poorly across all three reports. The IDP and Annual Report provide no data on treatment capacity utilisation, and the Green Drop Report having 33% of compliant, actively monitored and complete treatment-related data for Mogale Local Municipality

5.1.5.3 Merafong Local Municipality

The analysis of the IDP, Annual Report, and Green Drop Report for Merafong Local Municipality reveals notable strengths in “Descriptive Data” collection but significant gaps in sanitation systems, containment, emptying, transportation, and treatment data. The absence of a cohesive approach across the three reports as shown in Figure 47- 49 indicates the need for improved data monitoring and reporting practices to comply with SFD requirements and to support effective sanitation management (Merafong Local Municipality, 2020/2021; Merafong Municipality, 2020/2021; Department of Water and Sanitation, 2023).

The three reports; IDP, Annual Report, and Green Drop Report, demonstrate varied compliance with SFD requirements. In terms of “Descriptive data”, the IDP shows strong compliance, with 92% of the compliant, actively monitored and complete data. This includes

detailed reporting on parameters such as city area, population, population growth rate, groundwater levels, aquifer vulnerability, and water supply coverage. However, gaps in climate-related data persist, which limits a comprehensive understanding of environmental factors. The Annual Report supports this performance with strong “Descriptive Data”, though gaps are noted in reporting on groundwater levels and water supply per capita. The Green Drop Report, in contrast, provides no “Descriptive Data”.

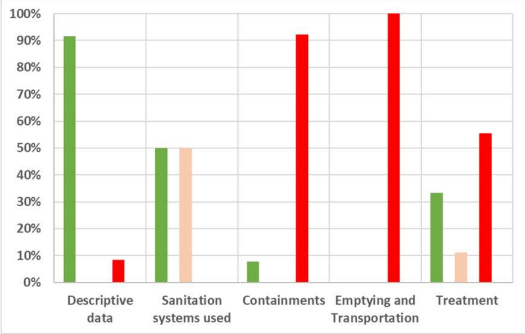


Figure 48: Shows the level of data availability extracted from Integrated Development Plan.

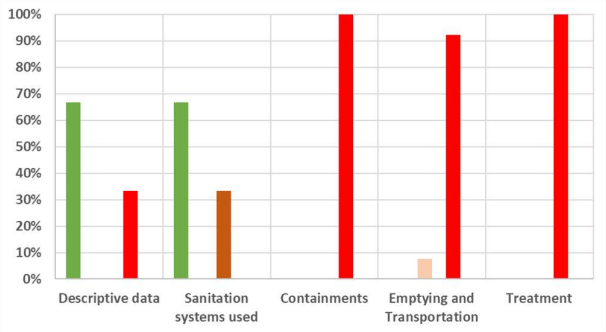


Figure 49: Shows the level of data availability extracted from Annual Report.

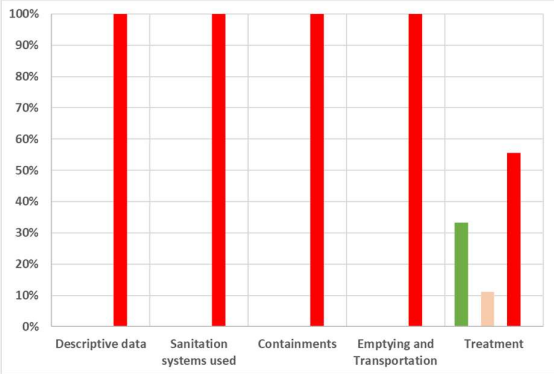


Figure 50: Shows the level of data availability extracted from Green Drop Report.

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 51: Shows the legend used in the graphs

The three reports; IDP, Annual Report, and Green Drop Report, demonstrate varied compliance with SFD requirements. In terms of “Descriptive data”, the IDP shows strong compliance, with 92% of the compliant, actively monitored and complete data. This includes detailed reporting on parameters such as city area, population, population growth rate, groundwater levels, aquifer vulnerability, and water supply coverage. However, gaps in climate-related data persist, which limits a comprehensive understanding of environmental factors. The Annual Report supports this performance with strong “Descriptive Data”, though gaps are noted in reporting on groundwater levels and water supply per capita. The Green Drop Report, in contrast, provides no “Descriptive Data”.

When analysing “Sanitation systems used”, the IDP shows moderate compliance, with 50% of the data meeting SFD requirements. The report demonstrates robust documentation of households connected to sewerage systems but lacks information on households using septic tanks or relying on community or public toilets. Similarly, the Annual Report highlights strong reporting on sewerage connections but identifies gaps in reporting on public toilet facilities. The Green Drop Report fails to include any sanitation systems data.

For “Containment data”, the reports collectively reveal significant deficiencies. The IDP achieves only 8% compliance, with limited information on septic tank types and no data on the functional status of the sewage network or containment conditions. The Annual Report mirrors these findings, providing no additional insights into containment practices. The Green Drop Report also provides no containment data. The “Emptying and transportation data” are entirely absent across all three reports. The IDP and Annual Report fail to provide any data on wastewater logistics, such as desludging frequency or the capacity of emptying trucks. Similarly, the Green Drop Report does not address emptying and transportation, leaving this category completely unaddressed.

In terms of “Treatment”, the IDP demonstrates minimal compliance, with only 33% of the required data available. The report includes basic data on treatment plant capacity but lacks critical details on treatment capacity utilisation and the efficiency of wastewater treatment processes. The Annual Report mirrors this low compliance, adding no further insights into treatment practices. The Green Drop Report, while providing 33% on compliant, actively monitored and complete data, fails to address broader treatment issues, such as efficiency and capacity utilisation.

5.2 Data compliance, monitoring and completeness with the SFD requirements

The effective implementation of the SFD relies heavily on the availability, accuracy, and completeness of sanitation data. Municipalities must meet specific requirements for data compliance and active monitoring to ensure their reporting systems align with SFD standards. This section evaluates the level of data compliance, monitoring practices, and completeness across the Integrated Development Plans (IDPs), Annual Reports, and Green Drop Reports of

selected municipalities. The analysis focuses on key sanitation categories, including Descriptive Data, Sanitation systems used, Containment measures, Emptying and Transportation, and Treatment.

The municipalities assessed include the CoJMM, CoTMM, CoEMM, Sedibeng District Municipality (Midvaal Local Municipality, Lesedi Local Municipality, and Emfuleni Local Municipality), and West Rand District Municipality (Rand West Local Municipality, Mogale Local Municipality, and Merafong Local Municipality) as shown in Table 12 -14.

1. Annual Report

Table 12: Comparison of the level of data compliance, monitoring and completeness with the SFD using the annual report.

Municipality	Level of data availability (%)					
	1	2	3	4	5	6
a. City of Johannesburg Metropolitan Municipality	33%	6%	12%	0%	49%	0%
b. City of Tshwane Metropolitan Municipality	16%	3%	5%	15%	61%	0%
c. Ekurhuleni Metropolitan Municipality	34%	0%	2%	2%	63%	0%
d. Sedibeng District Municipality	6%	0%	0%	0%	94%	0%
i. Midvaal Local Municipality	10%	0%	0%	0%	90%	0%
ii. Lesedi Local Municipality	37%	5%	0%	0%	59%	0%
iii. Emfuleni Local Municipality	22%	7%	7%	0%	65%	0%
e. West Rand District Municipality	6%	0%	6%	29%	58%	0%
i. Rand West Local Municipality	25%	0%	0%	0%	75%	0%
ii. Mogale Local Municipality	-	-	-	-	-	-
iii. Merafong Local Municipality	27%	0%	2%	7%	65%	0%

[1] *Data is compliant with SFD requirements, actively monitored, and fully complete with detailed figures or descriptions.*
[2] *Data is compliant and monitored but only partially complete, with significant gaps in detail.*
[3] *Data is compliant and monitored but moderately complete, with substantial missing descriptions.*
[4] *Data is compliant but unmonitored and minimally complete, providing very limited information.*
[5] *Data required for SFD is entirely unavailable or unreported.*
[6] *Data does not meet SFD compliance requirements but is actively monitored.*

2. Integrated Development Plan

Table 13: Comparison of the level of data acompliance, monitoring and completeness with the SFD using the IDP.

Municipality						
a. City of Johannesburg Metropolitan Municipality	15%	2%	16%	17%	51%	0%
b. City of Tshwane Metropolitan Municipality	20%	13%	5%	7%	56%	0%
c. Ekurhuleni Metropolitan Municipality	32%	0%	12%	2%	55%	0%
d. Sedibeng District Municipality	43%	4%	4%	2%	46%	0%
i. Midvaal Local Municipality	20%	0%	20%	0%	60%	0%
ii. Lesedi Local Municipality	-	-	-	-	-	-
iii. Emfuleni Local Municipality	15%	0%	0%	0%	85%	0%
e. West Rand District Municipality	10%	0%	8%	0%	54%	27%
i. Rand West Local Municipality	17%	0%	2%	0%	65%	17%
ii. Mogale Local Municipality	15%	0%	3%	0%	82%	0%
iii. Merafong Local Municipality	37%	0%	12%	0%	51%	0%

3. Green Drop Report

Table 14: Comparison of the level of data compliance, monitoring and completeness with the SFD using the Green Drop Report.

Municipality						
a. City of Johannesburg Metropolitan Municipality	7%	0%	2%	0%	91%	0%
b. City of Tshwane Metropolitan Municipality	7%	0%	2%	0%	91%	0%
c. Ekurhuleni Metropolitan Municipality	7%	0%	2%	0%	91%	0%
d. Sedibeng District Municipality	7%	0%	2%	0%	91%	0%
i. Midvaal Local Municipality	7%	0%	2%	0%	91%	0%
ii. Lesedi Local Municipality	7%	0%	2%	0%	91%	0%
iii. Emfuleni Local Municipality	7%	0%	2%	0%	91%	0%
e. West Rand District Municipality	7%	0%	2%	0%	91%	0%
i. Rand West Local Municipality	7%	0%	2%	0%	91%	0%
ii. Mogale Local Municipality	7%	0%	2%	0%	91%	0%
iii. Merafong Local Municipality	7%	0%	2%	0%	91%	0%

Tables 12–14 present the level of data availability across municipalities in Gauteng, assessing compliance, monitoring, and completeness based on the SFD checklist requirements. The data is represented using a colour-coded system described previously, with percentages calculated from the checklist parameters. Green indicates data that is compliant, actively monitored, and

either complete or fully described. For example, data on the area of the city and population is both readily available and supported by detailed figures and descriptions in municipal reports. Yellow represents data that is compliant and monitored but 75% incomplete or lacking sufficient detail. An example is records on groundwater levels, where monitoring exists, but the data lacks temporal variations or specific measurement details. Light brown denotes data that is compliant and monitored but only 50% complete or inadequately described. For instance, a municipality may report that septic tanks are used but fail to specify the population relying on them or the number of tanks installed. Dark brown reflects data that is compliant but unmonitored, with only 25% completeness or minimal descriptions. For example, data on faecal sludge containment might note its use but omit essential details such as whether the sludge is safely stored or treated. Red signifies data that is entirely unavailable, such as when no information is provided on the percentage of faecal sludge safely closed when full and relocated. Purple, which was rarely observed, indicates data that is non-compliant with SFD requirements but actively monitored. An example is sanitation systems used in informal settlement such as chemical toilets. These tables capture the overall status of required data within three reports from different municipalities.

Table 12 illustrates the level of sanitation data collected from annual reports availability across Gauteng municipalities. The results reveal considerable variation, with metropolitan municipalities generally performing better than district municipalities. Ekurhuleni (34%) and Johannesburg (33%) record the highest proportions of complete data, while Sedibeng and West Rand districts have the lowest (both at 6%), indicating severe data scarcity in these areas. Within the districts, performance is inconsistent. In Sedibeng, Lesedi stands out with 37% complete data, compared to Midvaal's 10% and Emfuleni's 22%, while West Rand shows a similar disparity, with Rand West (25%) and Merafong (27%) outperforming the district average. The City of Tshwane shows moderate completeness (16%) but has the highest proportion of incomplete data (15%), suggesting reporting is more advanced but not yet comprehensive. Overall, missing data remains the most significant challenge, exceeding 49% in all municipalities, and reaching as high as 94% in Sedibeng.

Table 13 shows the proportion of sanitation data collected from IDPs classified as complete, incomplete, missing, or non-compliant with SFD requirements for Gauteng municipalities.

Across all municipalities, missing data is the dominant issue, ranging from just over 50% to more than 80% of the required dataset. Among the metropolitan municipalities, Sedibeng District Municipality records the highest proportion of complete data (43%), while Tshwane has the most incomplete data (13%). In Sedibeng District, performance varies widely, with Midvaal achieving 20% completeness, Emfuleni only 15%, and Lesedi lacking any available data. West Rand District records the lowest completeness (10%) and the highest non-compliance (27%), with Mogale having the greatest proportion of missing data (82%).

According to the Green Drop Report, there is consistency in data publishing and reporting across municipalities, as shown in Table 14. This consistency arises because the Department of Water and Sanitation applies a uniform methodology for data collection across all municipalities. As a result, the data checklist and recording of available, missing, and incomplete information are standard. Within Gauteng municipalities, 7% of the required data is complete and available for developing SFDs, 91% is missing, and the remainder is incomplete or non-compliant with SFD requirements.

5.2.1 Data compliance with SFD

The available data largely comply with the SFD data requirements, particularly in terms of terminology and definitions. Most of the data are presented in a format that can be readily converted into percentages, aligning with the majority of SFD data requirements. However, certain aspects do not meet compliance standards, particularly concerning the classification of sanitation systems in use. For instance, ambiguous terminology such as "none toilet" lacks a clear definition, making it unclear whether it refers to open defecation, shared facilities, or other alternative sanitation methods.

Non-compliant data are predominantly identified in figures using the legend, such as Figure 50, where data represented in red and purple indicate non-compliance. This section, therefore, focuses on analysing these results. Missing data is inherently non-compliant with SFD requirements, as compliance necessitates a comprehensive representation of key components, including containment, emptying, transport, treatment, and disposal. The absence of any of these elements results in an incomplete assessment of the sanitation system.

Furthermore, compliance requires that data be verifiable through reliable sources such as monitoring reports, field surveys, and municipal records. Missing data, particularly when unsupported by documentation, cannot be validated, further contributing to non-compliance. Additionally, the SFD framework emphasises periodic monitoring and reporting, and the absence of updated data signifies a failure to meet these standards. Datasets that do not align with the data elements specified in the SuSanA checklist or other SFD frameworks are classified under lower compliance categories, reflecting their inability to fulfil minimum reporting standards. Table 12 indicates that over 50% of the data from annual reports are missing, and the available data largely do not comply with SFD requirements. An exception is the City of Johannesburg Metropolitan Municipality (CoJMM), which has 49% missing data. In contrast, Sedibeng District Municipality records the highest percentage of missing data at 94%. A similar pattern is observed in Table 13, which presents data from IDPs, where Sedibeng District Municipality has the lowest percentage of missing data at 46%.

The majority of municipal data aligns with SFD terminology and reporting standards, rare but critical deviations highlight systemic inconsistencies in adherence to compliance protocols. A notable example is the classification of “chemical toilets” in informal settlements, which is coded purple in Tables 12–14 to denote non-compliant but actively monitored data. The term “chemical toilet” contravenes SFD guidelines, which mandate the use of standardised terminology such as “container-based sanitation” or “dry sanitation systems” to describe decentralised sanitation solutions. This deviation reflects a lack of alignment with SFD’s goal of universalising terminology to enable cross-regional benchmarking and policy coherence. The persistence of non-compliant terminology risks misinterpretation by stakeholders, as “chemical toilets” may conflate temporary emergency solutions with permanent infrastructure. Table 13 indicates that 27% of the data available from Integrated Development Plans (IDPs) in West Rand District Municipality do not comply with SFD definitions and terminology.

5.2.2 Data monitoring

Data monitoring within the scope of this study refers to the ongoing process of systematically tracking and evaluating sanitation data across municipalities in Gauteng, with a particular focus on its alignment with the SFD requirements. The primary objective is to assess the

current status of data collection, identify existing gaps, and enhance the overall reliability of the data to foster more effective sanitation management.

To identify the level of data monitoring, an analysis was conducted on the available sources of data, including annual reports, Integrated Development Plans (IDPs), and the timelines associated with the data. The key data sources identified for this study were Statistics South Africa (StatsSA), HIS Markit, GIS data, and the Municipal Demarcation Board. The data from these sources spanned a period from 2011 to 2020, as indicated in Table 22 in the appendix.

This assessment allowed for the identification of trends, the recognition of data gaps, and the evaluation of the consistency and reliability of data across different municipalities. Ultimately, it became clear that while some municipalities have more robust data monitoring systems in place, others still face challenges in ensuring the monitoring of the data, especially in areas like transportation and treatment.

A recurring issue in the data reported by municipalities is the limited monitoring and verification mechanisms in place. Without active and continuous monitoring, there is a significant risk of data becoming outdated or inaccurate, which in turn affects the reliability of the SFDs. The absence of robust verification processes further compounds this issue, as it allows for the perpetuation of errors and inconsistencies in the reported data. The timelines of data presented by different municipalities highlight the challenge of outdated data. For example, the West Rand District and Ekurhuleni have data that date back to 2011 and 2017, which raises concerns about the relevance and accuracy of the information when it is applied to current sanitation challenges.

5.2.3 Data completeness

The fragmentation of data is another significant issue, with many municipalities reporting only partial data that fails to provide a comprehensive picture of the sanitation landscape. This fragmentation is attributed to a variety of factors, including resource limitations, lack of proper data management systems, and inadequate training of personnel involved in data collection. Consequently, critical data points necessary for the accurate generation of SFDs, such as details on wastewater treatment processes, are often missing or inadequately documented. For example, while Rand West and Merafong provide some Descriptive Data and information on sanitation systems, they lack data on the complete sanitation chain, particularly in the

areas of containment and treatment. Similarly, municipalities such as Emfuleni and Lesedi have significant data gaps, with some categories being entirely unreported.

5.2.4 Data Recording

One of the primary challenges identified is the lack of uniformity in the publication of reports across different municipalities. For example, Mogale Local Municipality does not publish an annual report (AR), and Lesedi Local Municipality does not publish an Integrated Development Plan (IDP). This inconsistency extends to the terminology used, variations in municipal reports, categorisation, and even the units of measurement across different datasets. Such discrepancies complicate the data analysis process and can lead to potential misinterpretations when applied to SFDs. It is important to note that with the Green Drop Report, there is consistency in data publishing and reporting across municipalities. The inconsistency is also reflected in the sources of data for the reports. The data used in IDPs and ARs across several municipalities in Gauteng come from different sources, as indicated in the reports; refer to Appendix (7.1.6). For example:

- Rand West Local Municipality, Mogale Local Municipality, and Emfuleni Local Municipality primarily sourced their data for both IDPs and annual reports from Stats SA, with timelines for 2021 and earlier.
- The Moran local Municipality used Stats SA data from 2016 for their IDP, whereas the West Rand District Municipality utilised data from both Stats SA and IHS Markit, covering various years. Midvaal Local Municipality provided IDP data through GIS for 2022, with annual report data sourced from Stats SA for 2011.
- The Lesedi Local Municipality sourced annual reports data from Quantek in 2020.
- The Sedibeng District Municipality obtained IDP data from the Municipal Demarcation Board and IHS Markit for 2023, whereas the annual report data came from the IHS Markit for 2020.
- In major cities such as Johannesburg, Tshwane, and Ekurhuleni, data for both IDPs and annual reports were sourced from Stats SA and other sources, covering different years depending on the Municipality.

5.2.5 Data Accessibility

The absence of a centralised data repository or clear protocols for data sharing significantly hampers efforts to compile and analyse data effectively. This issue is particularly evident in municipalities lacking library platforms or accessible websites for publishing reports. For example, during the data collection phase of this study, the West Rand District Municipality website was inaccessible; however, this issue appears to have been resolved.

5.3 Data Compliance, Monitoring, and Completeness Based on Questionnaire Responses

The surveys conducted provided an understanding of the experiences and challenges faced by professionals involved in the development of Shift Flow Diagrams (SFDs) in South Africa. The feedback from the participants shown in Table 15, who have worked in various provinces and municipalities, highlights both the strengths and areas for improvement in the SFD development process. Both respondents are experienced professionals, with one being a chemical engineering technician (Participant 1) and the other being a sanitation specialist (Participant 2). Their involvement in the development of SFDs spans different regions, including the Eastern Cape, KwaZulu-Natal, and eThekwini. Their extensive involvement, particularly in the years 2016 and 2018, suggests a high level of expertise and familiarity with the SFD process.

The primary methods employed for data collection varied among the respondents, reflecting the diverse challenges and environments in which they operated. Participant 1 emphasised the importance of one-on-one interactions with municipal officials and on-the-ground data collection. This approach was deemed necessary to resolve discrepancies between published data and actual conditions. Additionally, the necessity of site visits to verify the accuracy of the data provided by municipalities is highlighted. Conversely, participant 2 relied more on interviews with municipal members and key stakeholders, such as septic tank emptiers and union leaders. This method was chosen because of the inadequacy of data in annual reports and the difficulty in accessing transportation data. Participant 2's approach

highlights the importance of engaging with stakeholders directly involved in sanitation operations, as these individuals possess critical information not captured in official reports.

Table 15: Shows the comparison of Data Compliance, Monitoring, and Completeness from questionnaire respondents

Category	Data Aspect	Participant 1	Participant 2
Descriptive Data	Completeness	75%	50%
	Monitoring	50%	50%
	Compliance	50%	50%
Sanitation Systems Used	Completeness	50%	50%
	Monitoring	25%	50%
	Compliance	25%	50%
Containments	Completeness	50%	50%
	Monitoring	25%	50%
	Compliance	25%	50%
Emptying & Transportation	Completeness	50%	75%
	Monitoring	25%	75%
	Compliance	25%	50%
Treatment	Completeness	100%	75%
	Monitoring	75%	75%
	Compliance	75%	50%

Compliance with SFD standards varied significantly across sanitation categories, reflecting inconsistencies in how municipalities align their reporting practices with formal guidelines. For instance, Treatment data exhibited the highest compliance (Participant 1: 75%; Participant 2: 50%), likely due to centralised oversight of wastewater facilities, which mandates adherence to national regulatory frameworks. In contrast, Sanitation Systems Used and Containment categories showed lower compliance (Participant 1: 25–50%; Participant 2: 25–50%), attributed to ambiguous terminology such as “safe containment” or “improved sanitation,” which lack standardised definitions across municipalities. Participant 2 specifically criticised vague containment classifications, noting that terms like “safe storage” were inconsistently applied, leading to mismatches between reported data and SFD requirements. Similarly, Emptying & Transportation compliance scores diverged sharply (Participant 1: 25%; Participant 2: 50%), underscoring challenges in documenting informal sector activities, such as unlicensed sludge transporters, which often operate outside formal reporting frameworks.

These discrepancies highlight systemic issues in institutional alignment with SFD protocols, where compliance is hindered by both technical ambiguities and operational complexities.

Monitoring mechanisms were unevenly applied, with significant gaps in verifying data accuracy and timeliness. Treatment data received the highest monitoring scores (both participants: 75%), reflecting routine regulatory inspections at wastewater plants. However, weaker oversight was evident in Sanitation Systems Used (Participant 1: 25%; Participant 2: 50%) and Containment (Participant 1: 25%; Participant 2: 50%), where municipalities often rely on static infrastructure inventories rather than dynamic assessments of functionality or safety. For example, Participant 1 noted that while containment structures (e.g., pit latrines) were catalogued, their maintenance status or leakage risks were rarely tracked. Emptying & Transportation monitoring scores were similarly polarised (Participant 1: 25%; Participant 2: 75%), suggesting regional disparities in capacity. Participant 2 highlighted efforts to audit licensed transporters but acknowledged that informal operators—responsible for a significant share of sludge removal—were rarely included in datasets. This lack of holistic monitoring perpetuates data silos, limiting the SFD's ability to reflect on-ground realities, particularly in informal settlements where unregulated practices dominate.

Completeness gaps were most pronounced in categories requiring granular, context-specific metrics. While Descriptive Data (e.g., population statistics) scored moderately (Participant 1: 75%; Participant 2: 50%), Participant 2 emphasised that even available data often lacked temporal or spatial specificity, such as outdated population figures or aggregated service coverage rates that masked intra-municipal inequities. Emptying & Transportation exhibited stark contrasts: Participant 2 reported 75% completeness but stressed that critical details—such as transporter routes, costs, or sludge disposal sites—were missing in 25% of cases, undermining SFD accuracy. Treatment data were notably complete (Participant 1: 100%; Participant 2: 75%), though Participant 2 flagged omissions in effluent quality metrics or sludge reuse protocols. Conversely, Containment and Sanitation Systems Used suffered from partial reporting (both participants: 50–75%), with municipalities prioritising quantitative metrics (e.g., latrine counts) over qualitative details (e.g., user accessibility or safety). These gaps reflect institutional prioritisation of easily measurable indicators, often at the expense of nuanced data essential for SFD-driven decision-making.

5.3.1 Data accessibility

The feedback on the efficiency of the data collection process reveals mixed experiences. Participant 1 rated the process as "somewhat efficient," noting that the challenges were related mainly to the need for assumptions and the discrepancies between published data and on-the-ground realities. Participant 2, however, rated the process as "neutral," indicating that while some aspects of data collection, such as toilet types and wastewater treatment figures, were straightforward, other aspects, particularly transportation data, were challenging due to a lack of monitoring.

The general difficulties in accessing data also vary. Participant 1 found accessing data relatively easy, especially for containment and reuse/disposal data. However, participant 2 faced significant challenges, particularly with transportation data, which were described as difficult to obtain due to the lack of monitoring and detailed reporting.

6 FRAMEWORK

The effective management of sanitation systems and wastewater requires reliable, consistent, and actionable data. The SFD provides a valuable framework for visualising and assessing sanitation service delivery. However, the tool's efficacy is contingent on the quality and compliance of the data provided by municipalities. Data must not only be complete but also actively monitored and aligned with SFD requirements to ensure its utility for informed decision-making, planning, and monitoring.

This section outlines the development of a framework to address the challenges of compliance, and monitoring and completeness sanitation data. By analysing the gaps identified in current municipal reporting, such as inconsistencies in terminology, limited monitoring of sanitation systems, and insufficient documentation of key processes like containment, transportation, and treatment, the framework aims to bridge the disconnect between available data and SFD standards.

The framework emphasises enhancing data compliance through standardised reporting practices, promoting active monitoring mechanisms to improve data reliability, and ensuring data completeness across all sanitation categories. It is designed to support municipalities in aligning their sanitation data with SFD requirements.

6.1 The purpose of the Framework

The proposed framework emerged from a critical need to address systemic deficiencies in sanitation data practices across Gauteng municipalities, as evidenced by the analysis of Annual Reports, IDPs, and Green Drop Reports (Tables 12–14). These documents revealed pervasive challenges, including fragmented data systems (e.g., Sedibeng District’s 94% data unavailability in Annual Reports), inconsistent compliance with SFD terminology (e.g., ambiguous classifications like “none toilets”), and stagnant monitoring mechanisms (e.g., reliance on decade-old population figures in West Rand). The framework is designed to bridge these gaps by aligning municipal reporting with the SFD requirements, ensuring data is not only available but also complete, compliant, and actionable for equitable sanitation planning.

Central to the framework are five core principles. First, data availability mandates the systematic collection of SFD-critical categories (e.g., containment, treatment) across all municipalities, prioritising historically marginalised districts like Sedibeng, where gaps are most acute. Second, data completeness expands beyond superficial metrics (e.g., latrine counts) to capture granular details such as containment leakage rates or informal sludge transporter routes—parameters often omitted in reports like Emfuleni's IDP (85% unavailability). Third, data compliance resolves terminological ambiguities (e.g., Participant 2's critique of "safe containment") by standardising definitions to align with SFD requirements, ensuring cross-municipal comparability. Fourth, active monitoring introduces real-time tracking mechanisms, such as digital dashboards, to update dynamic metrics (e.g., effluent quality) and mitigate reliance on outdated datasets, as seen in Ekurhuleni's 2017 wastewater records. Finally, standardisation and integration unify disparate reporting systems into a centralised provincial database, reducing inconsistencies between documents like IDPs and Annual Reports (e.g., Sedibeng's compliance rising from 6% to 43% across reports).

The framework directly responds to practitioner-identified challenges (Table 15), such as the exclusion of informal sector activities and poor interoperability between datasets. By integrating mandatory fields for contextual parameters (e.g., temporal population trends) and adopting georeferenced surveys for informal settlements, it ensures SFDs reflect on-ground realities. This approach not only addresses urban-rural disparities (e.g., Midvaal's 90% data gaps) but also empowers municipalities to prioritise interventions in high-risk areas, advancing progress toward SDG 6. Through its structured yet adaptive design, the framework transforms fragmented data into a cohesive foundation for evidence-based sanitation governance.

6.2 Generic framework for Ensuring Data compliance, Active Monitoring, and Completeness

The framework provides a systematic approach to improving data management in sanitation and wastewater services, ensuring that data are compatible with international tools, actively

monitored, and complete across all necessary categories. This generic framework is adaptable to various contexts and aims to address the common challenges faced by municipalities and organisations involved in sanitation planning and management as shown in Figure 52.

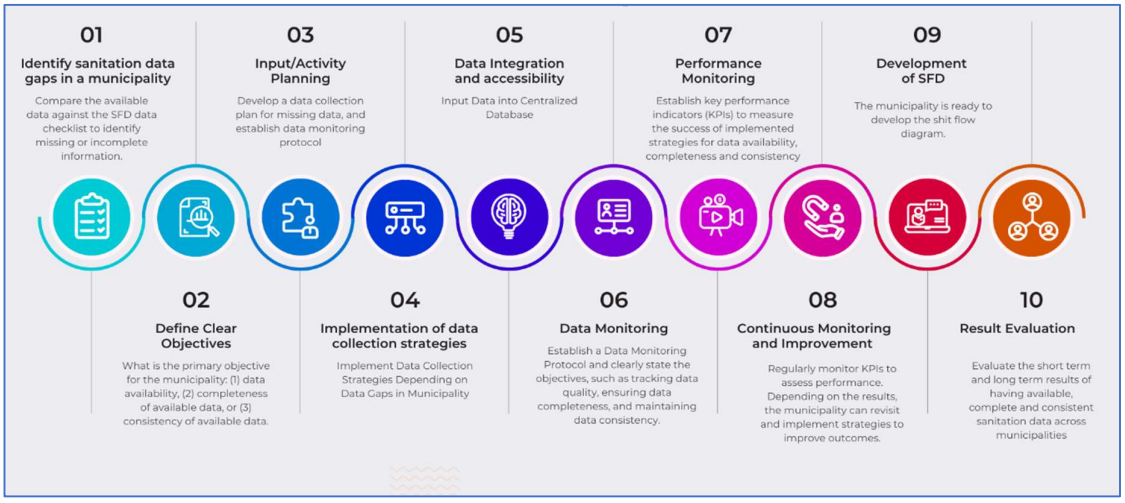


Figure 52: The general framework for Ensuring Data compliance, Active Monitoring, and Completeness

6.3 Application of the Framework to The City of Ekurhuleni Metropolitan Municipality

To develop a framework aimed at improving data in Ekurhuleni to align with SFD development requirements, we must focus on addressing areas where data availability is lacking or incomplete. This framework will guide the enhancement of data monitoring, reporting, and completeness in alignment with SFD criteria, ultimately making the data suitable for SFD development.

1. Identified Gaps in Ekurhuleni Municipality

   Descriptive Data: High priority should be given to enhancing data on groundwater levels, aquifer vulnerability, and topography, which currently have low scores and require better monitoring and data collection.

Sanitation Systems Used: Although data availability is generally better in this area, specific attention is needed for latrine facilities and septic tank connections to ensure that all relevant data are actively monitored and available.

Containment: Significant gaps exist in faecal sludge containment and sewage network status. There is a need to improve the monitoring and completeness of containment data.

Emptying and Transportation: This area has some of the lowest data availability scores. A consistent and monitored data collection process for wastewater (WW) transportation, leakage states, and emptying cycles should be prioritised.

Treatment: Data on wastewater treatment and faecal sludge treatment are critical. Efforts should be made to improve the completeness and monitoring of data regarding treatment capacity and efficiency.

2. Defining Objectives in Ekurhuleni Municipality

The framework's objectives are to ensure that data are sufficiently available, complete, and consistent across all necessary categories. The first step involves increasing data availability, which is crucial for making subsequent efforts to improve completeness and consistency effectively. Addressing the gaps in ”Descriptive Data”, “containment”, and “emptying and transportation” will form the foundation for further enhancements. Once data availability is improved, the focus shifts to ensuring completeness, ensuring that the data are comprehensive and cover all required aspects of sanitation management. The final objective is to standardise the data collection and reporting processes, ensuring that the data are consistent across various sources and systems.

3. Develop a Data Collection Plan for Missing Data

This plan categorises missing data into key sections, such as ”Descriptive Data”, sanitation systems used, attainment, emptying and transportation, and treatment. The data sources will include municipal records, government databases, community surveys, and field inspections. Responsibilities for data collection will be assigned to relevant departments, such as city planning, water and sanitation, and environmental management, ensuring that all necessary data points are managed and monitored effectively.

4. Data collection methodologies

Standardised tools such as surveys, questionnaires, and checklists will be developed to ensure consistency and accuracy in data collection. Data collection teams receive training to familiarise them with these tools and the importance of accurate data capture. Field visits and

community engagements will be conducted where necessary to gather first-hand data, particularly for areas such as containment, emptying and transportation.

5. Data Integration

Municipalities in Gauteng, including Ekurhuleni, have made significant progress in data integration by implementing a centralised database system that leverages an online library approach. This system will be used to consolidate data collected from various departments and ensure that it is accessible for SFD development.

6. Data Monitoring

Ekurhuleni Municipality has a sanitation data monitoring protocol that involves both internal management and coordination, with outsourced private companies responsible for various aspects of sanitation services. The key objectives of this protocol are to track data quality, ensure data completeness, and maintain data consistency. Despite the protocol in place, improvements can be made by strengthening oversight, implementing real-time data collection tools, and ensuring stricter accountability for outsourced companies.

7. Performance monitoring

To enhance sanitation data monitoring, the Green Drop report can be leveraged as a critical tool for driving performance improvements. By integrating Green Drop findings into regular evaluations, Ekurhuleni can ensure that data collection is accurate, consistent, and directly linked to accountability measures. This approach will help identify gaps in current practices, highlight areas requiring attention, and facilitate continuous improvement in sanitation management. The systematic use of the Green Drop report will enable the Municipality to translate standards outlined on paper into effective practices on the ground.

8. The Municipality's Readiness for SFD Development:

With the framework in place, Ekurhuleni is well positioned to develop SFDs that are accurate and reflective of the current sanitation landscape. By addressing identified gaps and ensuring that data are available, complete, and consistent, the Municipality will be able to produce reliable SFDs that contribute to improved sanitation management and planning.

7 CONCLUSION

As the Water Research Commission (WRC) has advanced its efforts to collaborate with water service authorities (WSAs) across South Africa, aiming to utilise SFDs as tools to achieve universal sanitation access by 2030 (SDG 6), this study reveals that many SFDs initially depend on internal knowledge and rough calculations. While this does not preclude the development of SFDs across all WSAs, it underscores the significant challenges that municipalities face in compiling accurate and comprehensive reports. The primary benefit of the SFD lies in its ability to provide a foundational starting point for identifying issues within the sanitation service chain, even when initial data are imprecise. This study highlights specific areas that Gauteng municipalities must address to develop a clearer understanding of the sanitation systems they manage. By acknowledging these challenges and areas for improvement, municipalities can better prepare for the effective implementation of SFDs, ultimately working towards a more accurate and comprehensive picture of their sanitation systems.

The analysis of sanitation data in Gauteng municipalities revealed significant inconsistencies in data availability and compliance with SFD requirements.

7.1 Summary

For Objective 1, which focused on conducting a literature review on sanitation terminology, systems, management tools, and challenges, the key highlights include:

1. Terminology and conceptual clarity:
    - Sanitation terminology varies across different sources, leading to inconsistencies in data interpretation and reporting.
    - The study identified the need for standardised definitions to enhance uniformity in data collection and analysis.
2. Sanitation systems and their complexity:
    - Various sanitation systems exist, including centralised sewer networks, decentralised on-site sanitation, and hybrid models.

- The efficiency of these systems depends on infrastructure, governance, and financial investment, which vary significantly across municipalities.

3. Management tools and their application:
    - Tools such as the SFD provide a structured approach to visualising sanitation data, but their effectiveness relies on data quality and availability.
    - The study reviewed global best practices in sanitation data management, highlighting their applicability to South Africa's context.
4. Challenges in sanitation data management:
    - Key challenges include data fragmentation, lack of real-time monitoring, and inconsistencies in municipal reporting.
    - Limited integration between different sanitation management systems hinders comprehensive analysis and decision-making.
    - The study also identified gaps in how municipalities document sanitation-related activities, affecting the completeness of datasets needed for SFD development.

Objective 2: To collect publicly available sanitation data across municipalities. The key highlights are as follow,

- Annual Reports: In the CoJMM, 33% of the data are complete, compliant, and available, followed by Ekurhuleni at 34%. In contrast, Sedibeng District and West Rand District have the lowest percentages at 6% and 25%, respectively.
- Integrated development plans (IDPs): Sedibeng District has the highest available, complete, and compliant data at 43%, whereas Rand West Local and West Rand Districts have the lowest data at 17% and 10%, respectively.
- Green Drop Report (GDR): All municipalities have consistent 7% data available, complete and compliant.

Objective 3 to filter, collate and compare the data across selection of Gauteng municipalities, the key findings are as follow:

- Inconsistencies in data formatting and structure: Municipalities report sanitation data using different formats and terminologies, making direct comparisons challenging.

Some municipalities provide detailed figures on wastewater flows, while others present narrative descriptions with minimal quantitative data.

- Variability in data completeness: While some municipalities had relatively complete datasets for containment and treatment, others lacked information on emptying, transportation, and reuse/disposal processes. This inconsistency hinders the ability to track sanitation service coverage comprehensively.
- Differences in reporting frequency: The frequency of data updates varied, with some municipalities maintaining annual reports, while others had irregular or outdated records. The lack of real-time monitoring further exacerbates discrepancies in sanitation performance assessments.
- Challenges in cross-municipal comparisons: Due to non-uniform reporting methods, direct comparisons between municipalities were often incomplete or unreliable. The study found that even when similar data categories were present, the definitions and classification criteria differed, limiting cross-municipal benchmarking.
- Limited Integration with SFD Requirements: Most municipal reports did not align directly with SFD data criteria, particularly in tracking informal sanitation services, sludge management, and service reliability. This misalignment affects the accuracy of SFD representations and decision-making based on the tool.

Objective 4: To develop and administer questionnaires to selected respondents to assess if the gaps identified in the data are congruent with those experienced by those who have developed SFDs in South Africa. The key findings are as follow:

Variability in Data Collection Methods:

- Respondents employed different approaches to data gathering—Participant 1 relied on site visits and direct engagement with municipal officials, while Participant 2 used stakeholder interviews due to the inaccessibility of transportation data in official reports.
- This highlights the critical role of primary data verification in ensuring accuracy, as published records often failed to reflect ground realities.

Inconsistencies in Compliance with SFD Standards:

- Treatment data had the highest compliance (Participant 1: 75%; Participant 2: 50%), likely due to regulatory oversight of wastewater plants.

- Sanitation systems and containment had lower compliance rates (25–50%), attributed to ambiguous definitions and inconsistent classification across municipalities.
- Emptying & transportation compliance (25–50%) was notably weak, reflecting gaps in tracking informal service providers who operate outside formal reporting frameworks.

Gaps in Monitoring Practices:

- Treatment data was most actively monitored (75%), supported by routine inspections at wastewater plants.
- Sanitation systems, containment, and emptying processes had significantly weaker monitoring (25–50%), as municipalities often relied on static inventories rather than dynamic tracking of infrastructure functionality or safety.
- Unregulated sludge transporters were largely absent from official datasets, further limiting the accuracy of SFD assessments.

Challenges in Data Completeness:

- Descriptive data (population statistics) scored moderately (75–50%), though concerns were raised about outdated or aggregated figures that masked intra-municipal inequalities.
- Emptying & transportation completeness varied (Participant 1: 50%; Participant 2: 75%), with missing details on transporter routes, disposal sites, and costs, affecting data reliability.
- Containment and sanitation system completeness remained partial (50–75%), as reports prioritised infrastructure counts over qualitative aspects like accessibility and safety.

Data Accessibility Constraints:

- Mixed efficiency ratings for data collection—Participant 1 found it "somewhat efficient", while Participant 2 rated it "neutral", citing major difficulties in accessing transportation data due to poor monitoring.
- Containment and reuse/disposal data were relatively accessible, whereas transportation data remained the most difficult to obtain, reinforcing a key challenge in achieving a complete SFD representation.

Objective 5 is to develop a framework to make the available data complete and compatible with the SFD requirements. The key findings are as follow:

The development of a comprehensive framework to enhance municipal sanitation data marks a significant advancement toward SFD compatibility and improved service delivery monitoring. This evidence-based approach directly addresses the critical gaps identified in current reporting practices across Gauteng municipalities.

The framework is built upon five core principles: data availability, completeness, compliance, active monitoring, and standardisation. By mandating the systematic collection of SFD-critical parameters, expanding beyond superficial metrics to capture granular operational details, standardising terminology, implementing real-time tracking mechanisms, and unifying disparate reporting systems, the framework creates a foundation for meaningful sanitation governance.

Application of this framework to Ekurhuleni Metropolitan Municipality demonstrated its practical utility in addressing specific municipal challenges. The targeted approach identified priority areas requiring immediate attention—including descriptive environmental data, containment systems, and emptying and transportation processes—while establishing clear pathways for progressive improvement. The implementation strategy leverages existing municipal structures while introducing enhanced protocols for data collection, integration, and monitoring.

The framework's integration with established performance monitoring mechanisms, particularly the Green Drop certification program, creates powerful accountability measures that strengthen data quality and reporting consistency. This alignment between data frameworks and performance evaluation systems ensures that improvements in reporting translate directly to enhanced service delivery.

Preliminary assessment indicates that with this framework in place, municipalities like Ekurhuleni are well-positioned to develop accurate, comprehensive SFDs that reflect current sanitation realities. This represents a critical step toward evidence-based decision-making, equitable resource allocation, and ultimately, improved sanitation outcomes for all communities—particularly those in historically underserved areas where data gaps have been most pronounced.

7.2 Limitations

The most significant limitation of this study is the extremely small sample size of only two participants, which affects several aspects of the study. This limitation affected the study's generalisability, as the findings cannot be extrapolated to a broader population of professionals involved in the SFD development. The limited sample size also restricted the depth of statistical analysis, allowing for only basic descriptive insights rather than robust inferential conclusions. The reliance on such a small number of participants also increased the potential for bias, as their responses may not capture the full diversity of experiences and perspectives within the field. A study by Hennink *et al.* (2022) suggests that thematic saturation can often be achieved with the minimum of 9–17 interviews, indicating that a sample size within this range is typically sufficient for qualitative studies.

7.3 Future research

The future research should focus on the following areas to advance the understanding and implementation of data compliance, monitoring, and completeness in alignment with SFD requirements:

1. Expand the research to include multiple municipalities within a region, allowing for comparisons and identifying common challenges and best practices in sanitation data collection and management.
2. Explore the development and implementation of standardised reporting templates and terminology to address inconsistencies across municipal data sources and improve alignment with SFD requirements.
3. Examine the feasibility and impact of incorporating real-time data collection and monitoring tools to enhance the accuracy, timeliness, and reliability of sanitation data.
4. Conduct targeted research on addressing specific gaps identified in containment, emptying and transportation, and wastewater treatment, focusing on the challenges of data collection and monitoring in these areas.
5. Investigate the role of municipal policies, interdepartmental coordination, and governance structures in influencing data quality, monitoring practices, and compliance with SFD requirements.

6. Explore the role of community participation in improving the accuracy and completeness of sanitation data, particularly in informal settlements and underserved areas.

8 REFERENCES

1. África, D. 1996. *Constitution of the Republic of South Africa*. Bill of Rights, Paragraph 27. https://www.gov.za/documents/constitution/chapter-2-bill-rights
2. África, D. 1997. *Water Services Act. Act No. 108 of 1997*. Government Printer. https://www.gov.za/sites/default/files/gcis_document/201409/a108-97.pdf
3. African Region. 2022. *Data Collection Survey on Urban Sanitation, Sewerage and Faecal Sludge Management in Africa: Final Report*. https://openjicareport.jica.go.jp/pdf/1000047017.pdf
4. Alliance, N.F.S.S.M. & Aayog, N.I.T.I. 2021. *Faecal sludge and septage management in urban areas: Service and business models*. https://www.niti.gov.in/sites/default/files/2021-08/NITI-NFSSM-Alliance-Report-for-digital.pdf
5. Babbie, E.R. 2020. *The practice of social research*. Cengage Au. https://thuvienso.hoasen.edu.vn/bitstream/handle/123456789/13352/Contents.pdf
6. Bailey, K.D. 2018. *Methods of Social Research*. 6th edn. New York, NY: The Free Press.
7. Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T. & Bartram, J. 2014. 'Faecal contamination of drinking-water in low-and middle-income countries: a systematic review and meta-analysis', *PloS Medicine*, 11(5):e1001644. https://doi.org/10.1371/journal.pmed.1001644
8. Bartram, J., Brocklehurst, C., Fisher, M.B., Luyendijk, R., Hossain, R., Wardlaw, T. & Gordon, B. 2014. 'Global monitoring of water supply and sanitation: history, methods and future challenges', *International Journal of Environmental Research and Public Health*, 11(8):8137–8165. https://www.mdpi.com/1660-4601/11/8/8137
9. Bayu, T., Kim, H. & Oki, T. 2020. 'Water governance contribution to water and sanitation access equality in developing countries', *Water Resources Research*, 56(4):e2019WR025330. https://doi.org/10.1029/2019WR025330
10. Beail-Farkas, L. 2012. 'The human right to water and sanitation: context, contours, and enforcement prospects', *Wisconsin International Law Journal*, 30:761. https://wilj.law.wisc.edu/wp-content/uploads/sites/1270/2014/04/Beail-Farkas_print.pdf
11. Bell, E., Bryman, A. & Harley, B. 2022. *Business research methods*. Oxford University Press. https://www.academia.edu/download/53452857/researchproposal_final.pdf
12. Bidassey-Manilal, S., Wright, C.Y., Kapwata, T. & Shirinde, J. 2020. 'A study protocol to determine heat-related health impacts among primary schoolchildren in South Africa', *International Journal of Environmental Research and Public Health*, 17(15):5531. https://doi.org/10.3390/ijerph17155531
13. Bisung, E., Elliott, S.J., Schuster-Wallace, C.J., Karanja, D.M. & Bernard, A. 2014. 'Social capital, collective action and access to water in rural Kenya', *Social Science & Medicine*, 119:147–154. https://doi.org/10.1016/j.socscimed.2014.07.060
14. Biswas, R., Arya, K., Fernandes, V. & Shah, T. 2021. 'Find A Loo: an app for sanitation governance', *Information, Communication & Society*, 24(11):1586–1602. https://doi.org/10.1080/1369118X.2020.1716038

15. Blackett, I., Hawkins, P. & Heymans, C. 2014. *The missing link in sanitation service delivery: A review of faecal sludge management in 12 cities*. Water and Sanitation Programme (WSP), International Bank for Reconstruction and Development/The World Bank. https://www.susana.org/_resources/documents/default/2-2037-wsp-fecal-sludge-12-city-review-research-brief.pdf
16. Bond, P. 2003. 'The degeneration of urban policy after apartheid', in *Confronting fragmentation: Housing and urban development in a democratising society*, pp.40–56. https://ccs.ukzn.ac.za/files/Bond%20Urban%20Policy%20Critique.pdf
17. Bryman, A. 2016. *Social research methods*. Oxford University Press. https://lib.mdpu.org.ua/wp-content/uploads/2024/03/Alan-Bryman-Social-Research-Methods2016.pdf
18. City of Johannesburg Metropolitan Municipality. 2013. *By-law on Waste Management*. City of Johannesburg Metropolitan Municipality. https://openbylaws.org.za/akn/za-jhb/act/by-law/2013/waste-management/eng@2013-07-30
19. Coffey, D., Gupta, A., Hathi, P., Khurana, N., Spears, D., Srivastav, N. and Vyas, S., 2014. Revealed preference for open defecation. Economic & Political Weekly, 49(38), p.43.
20. Council for Scientific and Industrial Research (CSIR). 2000. *Guidelines for human settlement planning and design: Volume 2 (Chapter 10: Sanitation)*. CSIR. https://www.dhs.gov.za/sites/default/files/documents/publications/HS_Volume_2_A.pdf
21. Creswell, J.W. & Clark, V.L.P. 2017. *Designing and conducting mixed methods research*. Sage Publications. https://toc.library.ethz.ch/objects/pdf/z01_978-1-4129-7517-9_01.pdf
22. Creswell, J.W. & Creswell, J.D. 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications. https://cumming.ucalgary.ca/sites/default/files/teams/82/communications/Creswell%202003%20-%20Research%20Design%20-%20Qualitative%2C%20Quantitative%20and%20Mixed%20Methods.pdf
23. Crocker, J., Saywell, D., Shields, K.F., Kolsky, P. & Bartram, J. 2017. 'The true costs of participatory sanitation: Evidence from community-led total sanitation studies in Ghana and Ethiopia', *Science of the Total Environment*, 601:1075–1083. https://doi.org/10.1016/j.scitotenv.2017.05.279
24. Cronk, R. & Bartram, J. 2018. 'Environmental conditions in health care facilities in low-and middle-income countries: coverage and inequalities', *International Journal of Hygiene and Environmental Health*, 221(3):409–422. https://doi.org/10.1016/j.ijheh.2018.01.004
25. Cross, X. & Buckley, C. 2016. *SFD Promotion Initiative, SFD Report Durban*. Durban, South Africa: SuSanA. https://www.susana.org/knowledge-hub/resources?id=2540&directdownload=1
26. CSE. 2022. *Managing Septage in Cities of Uttar Pradesh*. Water Programme, Centre for Science and Environment (CSE). Volume 2. https://www.susana.org/_resources/documents/default/3-3453-7-1552907030.pdf
27. De Bruijne, G., Geurts, M. & Appleton, B. 2007. *Sanitation for all?*. Delft, The Netherlands: IRC International Water and Sanitation Centre. https://fr.ircwash.org/sites/default/files/Bruijne-2007-Sanitation.pdf

28. Denscombe, M. 2017. *The good research guide: For small-scale social research projects*. McGraw-Hill Education (UK).
29. Department of Cooperative Governance and Traditional Affairs (CoGTA). 2020. *Annual Report 2019/2020*. Department of Cooperative Governance and Traditional Affairs. https://www.cogta.gov.za/cgta_2016/wp-content/uploads/2020/08/CoGTA-AR-2019-2020-19-Nov-FINAL.pdf
30. Department of Performance Monitoring and Evaluation (DPME) & Department of Human Settlement (DHS). 2012. *Sanitation Services–Quality of Sanitation in South Africa: Report on the Status of Sanitation Services in South Africa*. https://www.dpme.gov.za/publications/Reports%20and%20Other%20Information%20Products/Sanitation%20Report.pdf
31. Department of Water Affairs and Forestry (DWAF). 1994. *Water Supply and Sanitation Policy-White Paper Water-an indivisible national asset*. Cape Town. https://www.dws.gov.za/Documents/Policies/nwpwp.pdf
32. Department of Water Affairs and Forestry (DWAF). 2001. *White paper on basic household sanitation*. Pretoria, South Africa. https://www.dws.gov.za/Documents/Policies/SanitationReviewPolicy.pdf
33. Department of Water and Sanitation. 2001. *White Paper on Basic Household Sanitation*. Department of Water Affairs and Forestry. https://www.dws.gov.za/Documents/Policies/SanitationReviewPolicy.pdf
34. Department of Water and Sanitation. 2016. *National Sanitation Policy*. Department of Water and Sanitation. https://www.gov.za/sites/default/files/gcis_document/201706/national-sanitation-policy.pdf
35. Department of Water and Sanitation. 2019. *National Water and Sanitation Master Plan: Volume 1*. Pretoria: Government of South Africa. https://www.gov.za/sites/default/files/gcis_document/201911/national-water-and-sanitation-master-plandf.pdf
36. Department of Water and Sanitation. 2023. *Green Drop Report*. Pretoria: DWS. https://ws.dws.gov.za/iris/releases/GDWR.pdf
37. Devaraj, R., Raman, R.K., Wankhade, K., Narayan, D., Ramasamy, N. & Malladi, T. 2021. 'Planning fecal sludge management systems: challenges observed in a small town in southern India', *Journal of Environmental Management*, 281:111811. https://doi.org/10.1016/j.jenvman.2020.111811
38. Emanti Management. 2021. *SFD Report Ulundi Local Municipality Zululand District Municipality KwaZulu Natal, South Africa*. Emanti Management. https://www.susana.org/_resources/documents/default/3-4396-7-1631275473.pdf
39. Emanti Management. 2022. *SFD Lite Report Amathole District Municipality*. Eastern Cape, South Africa. https://www.susana.org/_resources/documents/default/3-4986-7-1654002832.pdf
40. Emanti Management. 2022. *SFD Lite Report Dalton/Coolair, uMshwati Local Municipality, uMgungundlovu District Municipality*. Kwazulu Natal, South Africa. https://www.susana.org/knowledge-hub/resources?id=4984
41. Endris, S., Kebede, A., Assefa, E., Ali, A. & Desale, T. 2024. 'Excreta flow mapping along the sanitation service chain, a case of Kombolcha town, Ethiopia', *Scientific Reports*, 14(1):3690. https://doi.org/10.1038/s41598-024-53724-7

42. Foxon, K., Buckley, C., Brouckaert, C., & Bakare, B. 2011. *What happens when the pit is full? Developments in on-site faecal sludge management (FSM)*. Durban, South Africa: Water Research Commission. Gastner, M., & Newman, M. 2006. "The spatial structure of networks," *European Physical Journal B-Condensed Matter and Complex Systems*, 49(2), 247-252.
43. Furlong, C. 2016. *Shit Flow Diagram Report for Santa Cruz*. https://ihedelftrepository.contentdm.oclc.org/digital/api/collection/masters2/id/116736/download
44. Getahun, A., Kassie, G.G., & Bunare, T.S. 2022. "Latrine access and factors associated with it among people with physical disability in Kombolcha Town, Northeast Ethiopia: A mixed cross-sectional study," *PloS one*, 17(6), e0270395. https://doi.org/10.1371/journal.pone.0270395
45. Ghauri, P., Grønhaug, K., & Strange, R. 2020. *Research methods in business studies*. Cambridge University Press. https://assets.cambridge.org/97811084/86743/frontmatter/9781108486743_frontmatter.pdf
46. Gill, J., & Johnson, P. 2010. *Research methods for managers*. https://www.torrossa.com/gs/resourceProxy?an=4913082&publisher=FZ7200
47. Graham, J.P., & Polizzotto, M.L. 2013. "Pit latrines and their impacts on groundwater quality: A systematic review," *Environmental Health Perspectives*, 121(5), 521-530. https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1206028
48. Guterres, A. 2020. *The sustainable development goals report 2020*. United Nations: Department of Economic and Social Affairs. https://unstats.un.org/sdgs/report/2021/The-Sustainable-Development-Goals-Report-2021.pdf
100. Harada, H., Strande, L. and Fujii, S., 2016. Challenges and opportunities of faecal sludge management for global sanitation. Towards future earth: challenges and progress of global environmental studies. Kaisei Publishing, Tokyo, pp.81-100.
49. Hartman, R.M., Cohen, A.L., Antoni, S., Mwenda, J., Weldegebriel, G., Biey, J., Shaba, K., De Oliveira, L., Rey, G., Ortiz, C., & Tereza, M. 2023. "Risk factors for mortality among children younger than age 5 years with severe diarrhea in low-and middle-income countries: Findings from the World Health Organization-coordinated global rotavirus and pediatric diarrhea surveillance networks," *Clinical Infectious Diseases*, 76(3), e1047-e1053. https://doi.org/10.1093/cid/ciac561
50. Hennink, M. and Kaiser, B.N., 2022. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Social science & medicine, 292, p.114523.
51. Hidenori, H., Strande, L., & Fujii, S. 2016. "Challenges and Opportunities of Faecal Sludge Management for Global Sanitation," in *Towards Future Earth: Challenges and Progress of Global Environmental Studies*, ed. Takeshi Katsumi & Shizuka Hashimoto, pp. 81-100. Kaisei Publishing, Tokyo. ISBN: 978-4-87603-500-7.
52. Hoossein, S., Tandlich, R., Whittington-Jones, K., Laubscher, R., Madikizela, P., & Zuma, B.M. 2016. "International Perspectives: Disaster Management Policy Options to Address the Sanitation Challenges in South Africa," *Journal of Environmental Health*, 78(7), E1-E7. https://www.jstor.org/stable/26330432 https://doi.org/10.1016/j.socscimed.2021.114523

53. Hutton, G., & Chase, C. 2016. "The knowledge base for achieving the sustainable development goal targets on water supply, sanitation and hygiene," *International Journal of Environmental Research and Public Health*, 13(6), 536. https://doi.org/10.3390/ijerph13060536
54. Ingallinella, A.M., Sanguinetti, G., Koottatep, T., Montangero, A., & Strauss, M. 2002. "The challenge of faecal sludge management in urban areas-strategies, regulations and treatment options," *Water Science and Technology*, 46(10), 285-294. https://doi.org/10.2166/wst.2002.0355
55. Isaacs, L. 2018. "Child (3) dies after falling into pit toilet in Limpopo," Eyewitness News. July 5. https://ewn.co.za/2018/07/05/child-3-dies-after-falling-into-pit-toilet-in-limpopo
56. Johannesburg Water. 2023. *Annual Performance Report*. City of Johannesburg. https://www.joburg.org.za/documents_/Pages/202223-Annual-Report.aspx
57. Kalonda, J.K., & Govender, K. 2021. "Factors affecting municipal service delivery: A case study of Katima Mulilo Town Council, Namibia," *African Journal of Public Affairs*, 12(2), 1-26. https://hdl.handle.net/10520/ejc-ajpa_v12_n2_a2
58. Kappauf, L., Heyer, A., Makuwa, T., & Titova, Y. 2018. *SFD Report Lusaka Zambia Final Report*. https://www.susana.org/_resources/documents/default/3-3468-7-1541604933.pdf
59. Kayembe, J.M., Thevenon, F., Laffite, A., Sivalingam, P., Ngelinkoto, P., Mulaji, C.K., Otamonga, J.P., Mubedi, J.I., & Poté, J. 2018. "High levels of faecal contamination in drinking groundwater and recreational water due to poor sanitation in the sub-rural neighborhoods of Kinshasa, Democratic Republic of the Congo," *International Journal of Hygiene and Environmental Health*, 221(3), 400-408. https://doi.org/10.1016/j.ijheh.2018.01.003
101. Kirsten K., 2023. A strategy for sanitation success. Infrastructure News. https://infrastructurenews.co.za
60. Krenz, A., & Strulik, H. 2019. *Menstruation hygiene management and work attendance in a developing country*. CEGE Discussion Papers, Number 386. https://ssrn.com/abstract=3312788
61. Kumar, G.S., Kar, S.S., & Jain, A. 2011. "Health and environmental sanitation in India: Issues for prioritizing control strategies," *Indian Journal of Occupational and Environmental Medicine*, 15(3), 93. https://doi.org/10.4103/0019-5278.93196
62. Landau, L., & Gindrey, V. 2008. *Migration and population trends in Gauteng province 1996–2055*. Migration Studies Working Paper Series, 42. https://www.academia.edu/download/30470575/42_landaugindrey.pdf
63. Local Government in Gauteng Province. 2018. *South Africa Gateway*. https://southafrica-info.com/land/infographic-local-government-municipalities-gauteng-province/
64. Majikijela, M. 2007. *Service delivery and service payment at Emfuleni local Municipality* (Doctoral dissertation, North–West University). https://repository.nwu.ac.za/bitstream/handle/10394/2532/majikijela_mziwoxolo.pdf;sequence=1
65. Mamera, M., van Tol, J. J., Aghoghovwia, M. P., & Mapetere, G. T., 2020. Community Faecal Management Strategies and Perceptions on Sludge Use in Agriculture. International Journal of Environmental Research and Public Health, 17(11), 4128. https://doi.org/10.3390/ijerph17114128

66. Maqbool, N., Shahid, M.A., & Khan, S.J. 2022. "Situational assessment for faecal sludge management in major cities of Pakistan," *Environmental Science and Pollution Research*, 1-12. https://journals.e-palli.com/home/index.php/ari/article/download/1526/741/9357
67. Mara, D. 2013. *Domestic wastewater treatment in developing countries*. Routledge. https://doi.org/10.4324/9781849771023
68. Martínez, L.F. 2016. *Using the Shit/Excreta Flow Diagrams–SFDs-for modelling future scenarios in Kumasi, Ghana* (Doctoral dissertation, Loughborough University). https://www.susana.org/_resources/documents/default/3-2688-7-1480666154.pdf
69. Mbelengwa, S. 2016. *Community participation in the Integrated Development Plan of the City of Johannesburg municipality* (Master's thesis, University of Pretoria). https://search.proquest.com/openview/bc39438d04fd639501eaf2905df9f28d/1?pq-origsite=gscholar&cbl=2026366&diss=y
70. Mjoli, N. 2010. *Review of sanitation policy and practice in South Africa from 2001-2008*. Water Research Commission, Pretoria. ISBN 978-1-77005-899-6. https://es.ircwash.org/sites/default/files/Mjoli-2010-Review.pdf
71. Mjoli, N. 2012. *A framework for sanitation governance in South African Municipalities*. Water Research Commission. https://www.wrc.org.za/wp-content/uploads/mdocs/TT%20629-15.pdf
72. Mjoli, S. 2010. "Sanitation Service Delivery in South Africa: A Review of Policy and Practice," *South African Journal of Public Administration*, 45(3), 523-541. ISBN 978-1-77005-899-6. https://www.ircwash.org/sites/default/files/Mjoli-2010-Review.pdf
73. Moorgas, S. 2020. *Country-wide Shit-Flow Diagram: Establishing National Excreta Flows in South Africa*. https://policycommons.net/artifacts/2233582/country-wide-shit-flow-diagram/2991515/
74. Mukuka, M.N., & Kennedy-Walker, R. 2021. "Lessons Learned OnsiteOn-site Sanitation and Faecal Sludge Management from the Lusaka Sanitation Project: Moving the Service Provision Agenda at Scale for Low-Income Communities in Zambia." *World Bank Blogs*. https://blogs.worldbank.org/en/nasikiliza/lessons-from-zambia-improving-sanitation-through-planning-awareness-building-collaboration-afe-0824
75. Municipal Systems Act 32 of 2000. 2000. *Integrated Development Plans and Waste Management*. Government Printer. https://www.gov.za/sites/default/files/gcis_document/201409/a32-000.pdf
76. Murthy, S.L. 2013. "The Human Right(s) to Water and Sanitation: History, Meaning, and the Controversy Over Privatization." *Berkeley Journal of International Law*, 31, 89. https://papers.ssrn.com/sol3/Delivery.cfm?abstractid=2195071
77. Nkere, G., Mahachi, J., Onatu, G., & Mphambukeli, T.N. 2025. "Sanitation Infrastructure Challenges in Informal Settlements in Johannesburg: The Need for Resident's Education and Empowerment." In *Development and Investment in Infrastructure in Developing Countries: A 10-Year Reflection*, 478-486. CRC Press. DOI: 10.1201/9781003483519
78. Nunbogu, A.M., & Elliott, S.J. 2022. "Characterizing Gender-Based Violence in the Context of Water, Sanitation, and Hygiene: A Scoping Review of Evidence in Low- and Middle-Income Countries." *Water Security*, 100113. https://doi.org/10.1016/j.wasec.2022.100113

79. Paladh, R., Graham, N., and Kaplan, J. 2018. "A Review of the Challenges and Constraints Associated with the Provision of Sanitation Services in Urban Informal Settlements." https://www.wrc.org.za/wp-content/uploads/mdocs/2486_Finalreport.pdf
80. Panesar, A., Walther, D., Kauter-Eby, T., Bieker, S., Rohilla, S., Dube, R., Augustin, K., & Schertenleib, R. 2022. "The SuSanA Platform and the Shit Flow Diagram: Tools to Achieve More Sustainable Sanitation for All." *A Better World*, 2018(3), 40. http://cdn.cseindia.org/attachments/0.71887700_1521624726_shit-flow-diagram.pdf
81. Peal, A., Evans, B., Ahilan, S., Ban, R., Blackett, I., Hawkins, P., Schoebitz, L., Scott, R., Sleigh, A., Strande, L., & Veses, O. 2020. "Estimating Safely Managed Sanitation in Urban Areas: Lessons Learned from a Global Implementation of Excreta-Flow Diagrams." *Frontiers in Environmental Science*, 8, 1. https://doi.org/10.3389/fenvs.2020.00001
82. Peal, A., Evans, B., Blackett, I., Hawkins, P., and Heymans, C. 2014. "Fecal Sludge Management (FSM): Analytical Tools for Assessing FSM in Cities." *Journal of Water, Sanitation and Hygiene for Development*, 4(3), pp.371-383. https://doi.org/10.2166/washdev.2014.139
83. Pearson, J., and McPhedran, K. 2008. "A Literature Review of the Non-Health Impacts of Sanitation." *Waterlines*, pp.48-61. https://www.jstor.org/stable/24684955
84. Plessis, A. 2023. "Cholera in South Africa: A Symptom of Two Decades of Continued Sewage Pollution and Neglect." *The Conversation*. https://theconversation.com/cholera-in-south-africa-a-symptom-of-two-decades-of-continued-sewage-pollution-and-neglect-206141
85. Purkayastha, D., and Raheja, G. 2022. "Interpreting Inclusion for Sanitation Perspectives from India: A Contextual Approach to Universal Design." *Transforming Our World through Universal Design for Human Development*, pp.315-322. https://ebooks.iospress.nl/pdf/doi/10.3233/SHTI220855
86. Revilla, M.L., Qu, F., Seetha Ram, K.E., and Rao, B. 2021. "Sanitation in the Top Development Journals: A Review." *ADBI Working Paper*, 1253. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3912364#
87. Richards, R., O'Leary, B., and Mutsonziwa, K. 2007. "Measuring Quality of Life in Informal Settlements in South Africa." *Social Indicators Research*, 81, pp.375-388. http://dx.doi.org/10.1007/s11205-006-9014-1
88. Ritchie, H., and Roser, M. 2021. "Clean Water and Sanitation." *Our World in Data*. https://ourworldindata.org/water-access?ref=ameasuredapproach.blog
89. Robson, C., and McCartan, K. 2016. *Real World Research*. 4th edn. Hokoben. https://www.researchgate.net/publication/321498176_Real_World_Research_4th_Edition
90. Rohilla, S., Luthra, B., Bhatnagar, A., and Gupta, B. 2017. "Shit Flow Diagram Report for Bijnor, India." *SuSanA Knowledge Hub*. https://www.susana.org/_resources/documents/default/3-3651-7-1563974580.pdf
91. Rohilla, S., Luthra, B., Bhatnagar, A., and Gupta, B. 2020. "Shit Flow Diagram Report for Bijnor, India." *SuSanA Knowledge Hub*. https://www.susana.org/_resources/documents/default/3-3991-7-1608132425.pdf

92. Roma, E., Pearce, J., Brown, C., and Islam, S. 2012. "Sanitation Mapper: A Tool for Mapping and Monitoring Sanitation in Low-Income Countries." *Waterlines*, pp.309-313. https://www.jstor.org/stable/24686819
93. Safi, F., Furlong, C., Luthra, B., Rohilla, S.K., and Brdjanovic, D. 2022. "Monitoring Progress in Citywide Sanitation." *Frontiers in Environmental Science*, 9, p.751534. https://doi.org/10.3389/fenvs.2021.751534
94. Sankara Narayan, A. 2022. *Planning Citywide Inclusive Sanitation* (Doctoral dissertation, ETH Zurich). https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/561822/1/Narayan2022DoctoralThesisPlanningCWIS.pdf
95. Sekaran, U. 2016. *Research Methods for Business: A Skill Building Approach*. https://so01.tci-thaijo.org/index.php/bkkthon/article/download/33962/28587
96. SFD-PI (2018a). SFD Manual, Volumes 1 and 2, Version 2.0. Available online at: https://sfd.susana.org/knowledge/the-sfd-manual
97. Shahriar, A.T.M., Mahfuz-ud-Darain, K., and Islam, M.T. 2022. "Towards Environmentally Safe Faecal Sludge Management in Informal Settlements of Bangladesh: A Context-Sensitive Model." *Khulna University Studies*, pp.104-119. https://doi.org/10.53808/KUS.2022.ICSTEM4IR.0059-se
98. Simiyu, S., Chumo, I., and Mberu, B. 2021. "Faecal Sludge Management in Low Income Settlements: Case Study of Nakuru, Kenya." *Frontiers in Public Health*, 9. https://doi.org/10.3389/fpubh.2021.750309
99. Singh, S., Laker, F., Bateganya, N.L., Nkurunziza, A.G., Semiyaga, S., and Brdjanovic, D. 2022. "Evaluation of Business Models for Faecal Sludge Emptying and Transport in Informal Settlements of Kampala, Uganda." *Water*, 14(18), p.2914. https://doi.org/10.3390/w14182914
100. Soboksa, N.E., Gari, S.R., Hailu, A.B., and Alemu, B.M. 2020. "Association Between Microbial Water Quality, Sanitation and Hygiene Practices, and Childhood Diarrhea in Kersa and Omo Nada Districts of Jimma Zone, Ethiopia." *PLOS ONE*, 15(2), p.e0229303. https://doi.org/10.1371/journal.pone.0229303
101. Sommer, M., Hirsch, J.S., Nathanson, C., and Parker, R.G. 2015. "Comfortably, Safely, and Without Shame: Defining Menstrual Hygiene Management as a Public Health Issue." *American Journal of Public Health*, 105(7), pp.1302-1311. https://doi.org/10.2105/AJPH.2014.302525
102. Statistics South Africa. (2021). *General Household Survey 2021*. Statistics South Africa. https://www.statssa.gov.za/publications/P0318/P03182021.pdf
103. Statistics South Africa. (2021). *General Household Survey*. Pretoria: Stats SA. https://www.statssa.gov.za/publications/P0318/P03182021.pdf
104. Stats SA (Statistics South Africa). (2018). *General Household Survey 2018*. Pretoria: Statistics South Africa. http://www.statssa.gov.za/publications/P0318/GHS_2018_presentation.pdf
105. Strande, L. and Brdjanovic, D. eds., 2014. *Faecal Sludge Management: Systems Approach for Implementation and Operation*. IWA Publishing.
106. Susmita, S., Depinder, K., Arne, P., Rahul Sharma, V., Monika, B., Mintje, B., Annkathrin, T., and Sebastian, K. 2022. "A Journey of Urban Sanitation in India." https://www.susana.org/_resources/documents/default/3-4432-7-1654675191.pdf
107. Sustainable Sanitation Alliance. 2018. "Shit Flow Diagram, What is SFD?" https://sfd.susana.org/knowledge/faq/47-1-what-is-an-sfd

108. Sutherland, C., Hordijk, M., Lewis, B., Meyer, C., and Buthelezi, S. 2014. "Water and Sanitation Provision in eThekwini Municipality: A Spatially Differentiated Approach." *Environment and Urbanization*, 26(2), pp.469-488. https://doi.org/10.1177/0956247814544871
109. Swart, M. 2019. "Activists Hail S African Court Ruling Over Boy's Pit Toilet Death, 19 Dec." *Al Jazeera News*. https://www.aljazeera.com/news/2019/12/19/activists-hail-s-african-court-ruling-over-boys-pit-toilet-death
110. The City of Johannesburg Metropolitan Municipality. 2013. *Waste Management By-Laws*. Gauteng. https://joburg.org.za/documents_/Documents/By-Laws/waste%20management%20by-law.pdf
111. Tilley, E., Ulrich, L., Lüthi, C., Reymond, P. and Zurbrügg, C., 2014. Compendium of sanitation systems and technologies. 2nd revised edn. Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).
112. Tissington, K. 2011. *Basic Sanitation in South Africa: A Guide to Legislation, Policy and Practice*. Socio-Economic Rights Institute of South Africa. https://www.researchgate.net/publication/304801901_Basic_Sanitation_in_South_Africa_A_Guide_to_Legislation_Policy_and_Practice
113. UN Water. 2018. *Sustainable Development Goal 6 Synthesis Report on Water and Sanitation*. Published by the United Nations New York, New York, 10017. https://www.unwater.org/publications/sdg-6-synthesis-report-2018-water-and-sanitation
114. UNICEF. 2020. *Water, Sanitation and Hygiene (WASH) in Schools*. New York: UNICEF. https://data.unicef.org/wp-content/uploads/2018/08/JMP-WASH-in-Schools-WEB.pdf
115. UNICEF. 2020. *What Do Safely Managed Sanitation Services Mean for UNICEF Programmes?* https://www.unicef.org/media/59001/file
116. United Nations Children's Fund and World Health Organization. 2024. *Progress on Household Drinking Water, Sanitation and Hygiene 2000-2022: Special Focus on Gender*. World Health Organization.
117. United Nations Environment Programme, International Water Management Institute, Global Wastewater Initiative and GIAR Research Program on Water, Land and Ecosystems, 2020. Faecal Sludge Management in Africa: Socioeconomic Aspects and Human and Environmental Health Implications. https://wedocs.unep.org/20.500.11822/34350
118. United Nations Environment Programme. 2020. *Faecal Sludge Management in Africa: Socioeconomic Aspects and Human and Environmental Health Implications*. https://wedocs.unep.org/20.500.11822/34350
119. United Nations. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. New York: United Nations Department of Economic and Social Affairs, 1, 41. https://sdgs.un.org/2030agenda
120. Valette, H. and Colon, M. 2024. "Institutional Change for the Development of Urban Sanitation in the Global South: A Social Science Review." *Utilities Policy*, 88, p.101755. https://doi.org/10.1016/j.jup.2024.101755
121. Van Minh, H. and Hung, N.V. 2011. "Economic Aspects of Sanitation in Developing Countries." *Environmental Health Insights*, 5, pp.EHI-S8199. https://doi.org/10.4137/EHI.S8199

122. Waste Act 59 of 2008. (2008). *National Waste Management Strategy*. Government Printer. https://www.dffe.gov.za/sites/default/files/legislations/nema_amendment_act59.pdf
123. Water & Sanitation. 2016. *National Sanitation Policy 2016*. Department of Water and Sanitation. https://www.gov.za/sites/default/files/gcis_document/201706/national-sanitation-policy.pdf
124. Water Research Commission (WRC). 2021. "From Excreta Flow Diagrams to Brown Drop?" *The Water Wheel*, March/April 2021. https://wrc.org.za/?mdocs-file=61239
125. WaterAid. 2016. *The True Cost of Poor Sanitation*. https://www.lixil.com/en/impact/sanitation/pdf/white_paper_en_cc_2016.pdf
126. WaterAid. 2020. *Living in a Fragile World: The Impact of Climate Change on the Sanitation Crisis*. https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/living-in-a-fragile-world-the-impact-of-climate-change-on-the-sanitation-crisis_1.pdf
127. Winkler, I.T. 2015. "The Human Right to Sanitation." *U. Pa. J. Int'l L.*, 37, p.1331. https://papers.ssrn.com/sol3/Delivery.cfm?abstractid=2728068
128. Winkler, M.S., Fuhrimann, S., Pham-Duc, P., Cissé, G., Utzinger, J., and Nguyen-Viet, H. 2017. "Assessing Potential Health Impacts of Waste Recovery and Reuse Business Models in Hanoi, Vietnam." *International Journal of Public Health*, 62, pp.7-16. https://link.springer.com/article/10.1007/s00038-016-0877-x#citeas
129. World Health Organization (WHO). 2024. "Diarrhoeal Disease." World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease
130. World Health Organization and United Nations Children's Fund. 2023. *Water, Sanitation, Hygiene, Waste and Electricity Services in Health Care Facilities: Progress on the Fundamentals*. 2023 Global Report. World Health Organization. https://www.sciencedirect.com/science/article/pii/S0301479720317369
131. World Health Organization and United Nations Children's Fund. 2021. *Progress on Household Drinking Water, Sanitation and Hygiene 2000-2020: Five Years into the SDGs*. World Health Organization.
132. World Health Organization, 2019. *Water, Sanitation, Hygiene and Health: A Primer for Health Professionals* (No. WHO/CED/PHE/WSH/19.149). World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/330100/WHO-CED-PHE-WSH-19.149-eng.pdf
133. World Health Organization, 2020. *State of the World's Sanitation: An Urgent Call to Transform Sanitation for Better Health, Environments, Economies and Societies*. https://www.who.int/publications/i/item/9789240014473
134. World Health Organization, 2022. *Progress on Drinking Water, Sanitation and Hygiene in Schools: 2000-2021 Data Update*. World Health Organization.
135. Yongsi, H.B.N., 2021. "How Lack or Insufficient Provision of Water and Sanitation Impacts Women's Health Working in the Informal Sector: Experiences from West and Central Africa." *Urban Health and Wellbeing Programme: Policy Briefs*, Volume 2, pp.45-50. https://link.springer.com/chapter/10.1007/978-981-33-6036-5_8#citeas

136. Zhou, X., Li, Z., Zheng, T., Yan, Y., Li, P., Odey, E.A., Mang, H.P., and Uddin, S.M.N., 2018. "Review of Global Sanitation Development." *Environment International*, 120, pp.246-261. https://doi.org/10.1016/j.envint.2018.07.047

9 APPENDICES

9.1 Data collected from publicly available sources

9.1.1 City of Johannesburg Metropolitan Municipality

Table 16: Data availability, completeness, and compliance for the CoJMM collected from the IDP and annual report

Section	The data checks	Intergrated Development Plan (IDP)	Annual Report (AR)
DESCRIPTIVE DATA	Area of city	3	3
	Population	5	5
	Population growth rate	5	5
	Topography	3	3
	Climate	1	1
	Ground Water level	1	1
	Vulnerability of the aquifer: rock type	3	3
	Source of water supply	3	5
	Water supply per capita	5	5
	water supply coverage	5	4
	No. of slums settlement	5	5
	No. of HH with municipal boundary	5	5
SANITATION SYSTEMS USED	No. of HH and population with latrine facility	2	5
	No. of HH and population connected to sewerage	2	5
	No. of HH and population connected to Septic tank	2	5
	No. of HH and population dependent on community or public toilet	2	5
	Total no. of community and public toilet	2	5
	No. of HHs and population practicing open defecation	5	5
CONTAINMENT	Sewage system used (centralized or decentralized)	1	1
	Once off connection charges	1	1
	Monthly charges	1	1
	Functional status of the sewage network	5	1
	Feacal sludge contained	1	4
	Feacal sludge not contained	1	1
	No. of HHs and population connected to septic tank whose effluent d	1	1
	No. of HH and population connected to septic tank whose effluent di	1	1
	No. of HH and population connected to pit	1	1
	No. of HHs and population with no containment	1	1
	Type of septic tank prevalent in the city	1	1
	Septic tank design over time	1	1
	Containment state	1	4
PTYING AND TRANSPORTATI	WW transported	1	1
	WW not transported	1	1
	sewer lines Leakage- State	4	4
	Desludging services given by government or private	1	5
	The emptying cycle	1	5
	Specify no. of trucks for each	1	1
	The manner how it is emptied	1	1
	Onsite emptying capacity	1	1
	Truck trips per day	1	1
	Trucks emptying capacity	1	1
	The percentage safely closed when full and relocated	1	1
	The Percentage of FS legally dumped	3	1
	The Percentage of FS illegally dumped	3	1
TREATMENT	waste water generated per day in MLD	1	1
	Capacity of Sewage treatment plant	1	1
	Treatment capacity utilized	1	1
	Sewage not treated	3	3
	Sewage treated	3	3
	FS safely closed when full and relocated facility	1	1
	Treatment efficiency	3	3
	FS treated	1	1
	FS not treated	1	1

9.1.2 City of Tshwane Metropolitan Municipality

Table 17: Data availability, completeness, and compliance for the CoTMM collected from the IDP and annual report

Section	The data checks	IDP	Annual repor
DESCRIPTIVE DATA	Area of city	5	5
	Population	5	5
	Population growth rate	5	5
	Topography	3	3
	Climate	1	1
	Ground Water level	3	1
	Vulnerability of the aquifer: rock type	3	1
	Source of water supply	5	5
	Water supply per capita	4	4
	water supply coverage	5	3
	No. of slums settlement	4	4
	No. of HH with municipal boundary	5	2
SANITATION SYSTEMS USED	No. of HH and population with latrine facility	5	5
	No. of HH and population connected to sewerage	5	5
	No. of HH and population connected to Septic tank	5	2
	No. of HH and population dependent on community or public toilet	2	2
	Total no. of community and public toilet	2	2
	No. of HHs and population practicing open defecation	4	2
CONTAINMENT	Sewage system used (centralized or decentralized)	1	1
	Once off connection charges	1	1
	Monthly charges	1	1
	Functional status of the sewage network	4	1
	Feacal sludge contained	1	1
	Feacal sludge not contained	1	1
	No. of HHs and population connected to septic tank whose effluent d	1	3
	No. of HH and population connected to septic tank whose effluent dis	1	1
	No. of HH and population connected to pit	1	1
	No. of HHs and population with no containment	1	1
	Type of septic tank prevalent in the city	1	1
	Septic tank design over time	1	1
	Containment state	1	1
PTYING AND TRANSPORTATI	WW transported	1	1
	WW not transported	1	1
	sewer lines Leakage- State	4	1
	Desludging services given by government or private	1	1
	The emptying cycle	1	1
	Specify no. of trucks for each	1	1
	The manner how it is emptied	1	1
	Onsite emptying capacity	1	1
	Truck trips per day	1	1
	Trucks emptying capacity	1	1
	The percentage safely closed when full and relocated	1	1
	The Percentage of FS legally dumped	4	1
	The Percentage of FS illegally dumped	4	1
TREATMENT	waste water generated per day in MLD	1	1
	Capacity of Sewage treatment plant	1	1
	Treatment capacity utilized	1	5
	Sewage not treated	1	1
	Sewage treated	1	1
	FS safely closed when full and relocated facility	1	1
	Treatment efficiency	1	1
	FS treated	1	1
	FS not treated	1	1

9.1.3 City of Ekurhuleni Metropolitan Municipality

Table 18: Data availability, completeness, and compliance for the CoEMM collected from the IDP and annual report

Section	The data checks	IDP	Annual report
DESCRIPTIVE DATA	Area of city	3	3
	Population	5	5
	Population growth rate	5	5
	Topography	3	2
	Climate	1	1
	Ground Water level	1	1
	Vulnerability of the aquifer: rock type	1	1
	Source of water supply	2	5
	Water supply per capita	5	5
	water supply coverage	5	5
	No. of slums settlement	5	5
	No. of HH with municipal boundary	5	5
SANITATION SYSTEMS USED	No. of HH and population with latrine facility	5	5
	No. of HH and population connected to sewerage	5	5
	No. of HH and population connected to Septic tank	5	5
	No. of HH and population dependent on community or public toilet	5	5
	Total no. of community and public toilet	5	5
	No. of HHs and population practicing open defecation	5	5
CONTAINMENT	Sewage system used (centralized or decentralized)	1	1
	Once off connection charges	3	1
	Monthly charges	5	1
	Functional status of the sewage network	3	1
	Feacal sludge contained	1	1
	Feacal sludge not contained	1	1
	No. of HHs and population connected to septic tank whose effluent d	1	1
	No. of HH and population connected to septic tank whose effluent di	1	1
	No. of HH and population connected to pit	1	1
	No. of HHs and population with no containment	1	1
	Type of septic tank prevalent in the city	1	1
	Septic tank design over time	1	1
	Containment state	3	1
EMPTYING AND TRANSPORTATION	WW transported	1	1
	WW not transported	1	1
	sewer lines Leakage- State	3	1
	Desludging services given by government or private	1	1
	The emptying cycle	1	1
	Specify no. of trucks for each	1	1
	The manner how it is emptied	1	1
	Onsite emptying capacity	1	1
	Truck trips per day	1	1
	Trucks emptying capacity	1	1
	The percentage safely closed when full and relocated	1	1
	The Percentage of FS legally dumped	1	1
	The Percentage of FS illegally dumped	1	1
TREATMENT	waste water generated per day in MLD	1	1
	Capacity of Sewage treatment plant	1	5
	Treatment capacity utilized	3	1
	Sewage not treated	1	1
	Sewage treated	1	1
	FS safely closed when full and relocated facility	1	1
	Treatment efficiency	1	1
	FS treated	1	1
	FS not treated	1	1

9.1.4 West Rand District Municipality

Table 19: Data availability, completeness, and compliance for the West Rand District Municipality and its three local municipalities, as collected from the IDP and annual report.

		Rand West local		Mogale local		Morafong local		West Rand Distrct	
		IDP	Annual report	IDP	Annual report (Replica of Morafong)	IDP	Annual report	IDP	Annual report
Section	The data checks	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria
DESCRIPTIVE DATA	Area of city	5	5	5		5	1	3	3
	Population	5	5	5		5	5	5	5
	Population growth rate	5	5	5		5	5	5	5
	Topography	5	1	5		5	5	3	3
	Climate	3	1	1		1	1	3	3
	Ground Water level	1	1	1		5	1	1	1
	Vulnerability of the aquifer: rock type	1	1	1		5	5	1	1
	Source of water supply	5	5	3		5	5	3	5
	Water supply per capita	1	1	3		5	1	0	2
	water supply coverage	5	5	5		5	5	5	2
	No. of slums settlement	5	5	5		5	5	5	1
	No. of HH with municipal boundary	5	5	5		5	5	5	1
SANITATION SYSTEMS USED	No. of HH and population with latrine facility	0	5	1		5	5	0	2
	No. of HH and population connected to sewerage	0	5	5		5	5	0	2
	No. of HH and population connected to Septic tank	0	5	1		3	5	0	2
	No. of HH and population dependent on community or public toilet	0	1	1		3	2	0	2
	Total no. of community and public toilet	0	1	1		3	2	0	2
	No. of HHs and population practicing open defecation	5	5	1		5	5	0	2
CONTAINMENT	Sewage system used (centralized or decentralized)	1	1	1		1	1	1	1
	Once off connection charges	1	1	1		1	1	1	1
	Monthly charges	1	1	1		1	1	1	1
	Functional status of the sewage network	1	1	1		1	1	1	1
	Feacal sludge contained	1	1	1		1	1	1	1
	Feacal sludge not contained	1	1	1		1	1	1	1
	No. of HHs and population connected to septic tank whose effluent discharge to drain	1	1	1		1	1	1	1
	No. of HH and population connected to septic tank whose effluent discharge to soakpit	1	1	1		1	1	1	1
	No. of HH and population connected to pit	1	1	1		5	1	1	1
	No. of HHs and population with no containment	1	1	1		1	1	1	1
	Type of septic tank prevalent in the city	1	1	1		1	1	1	1
	Septic tank design over time	1	1	1		1	1	1	1
	Containment state	1	1	1		1	1	1	1
EMPTYING AND TRANSPORTATION	WW transported	1	1	1		1	1	1	1
	WW not transported	1	1	1		1	1	1	1
	sewer lines Leakage- State	1	1	1		1	3	1	1
	Desludging services given by government or private	1	1	1		1	1	1	1
	The emptying cycle	1	1	1		1	1	1	1
	Specify no. of trucks for each	1	1	1		1	1	1	1
	The manner how it is emptied	1	1	1		1	1	1	1
	Onsite emptying capacity	1	1	1		1	1	1	1
	Truck trips per day	1	1	1		1	1	1	1
	Trucks emptying capacity	1	1	1		1	1	1	1
	The percentage safely closed when full and relocated	1	1	1		1	1	1	1
	The Percentage of FS legally dumped	1	1	1		1	1	1	1
	The Percentage of FS illegally dumped	1	1	1		1	1	1	1
TREATMENT	waste water generated per day in MLD	1	1	1		1	1	2	1
	Capacity of Sewage treatment plant	1	1	1		5	1	2	1
	Treatment capacity utilized	1	1	1		5	1	2	1
	Sewage not treated	1	1	1		3	1	2	1
	Sewage treated	1	1	1		1	1	2	1
	FS safely closed when full and relocated facility	1	1	1		1	1	2	1
	Treatment efficiency	1	1	1		5	1	2	1
	FS treated	1	1	1		1	1	2	1
	FS not treated	1	1	1		1	1	2	1

9.1.5 Sedibeng District Municipality

Table 20: Data availability, completeness, and compliance for the Sedibeng District Municipality and its three local municipalities, as collected from the IDP and annual report.

		Midvaal local		Lesedi local		Emfuleni local		Sedibeng Distrct	
		IDP	Annual report	IDP	Annual report	IDP	Annual report	IDP	Annual report
Section	The data checks	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria	Availability Criteria
DESCRIPTIVE DATA	Area of city	5	5		5	5	5	5	5
	Population	5	5		5	5	5	5	5
	Population growth rate	5	5		5	5	5	5	5
	Topography	5	1		4	5	1	2	1
	Climate	5	1		1	1	1	5	1
	Ground Water level	5	1		5	1	1	5	1
	Vulnerability of the aquifer: rock type	5	1		5	1	1	5	1
	Source of water supply	5	1		5	5	5	5	1
	Water supply per capita	5	5		5	5	4	1	1
	water supply coverage	5	1		5	5	4	5	1
	No. of slums settlement	5	1		5	5	5	5	1
	No. of HH with municipal boundary	5	1		5	5	5	5	1
SANITATION SYSTEMS USED	No. of HH and population with latrine facility	3	5		5	1	5	5	1
	No. of HH and population connected to sewerage	3	1		5	1	3	5	1
	No. of HH and population connected to Septic tank	3	1		5	1	3	5	1
	No. of HH and population dependent on community or public toilet	3	1		5	1	5	5	1
	Total no. of community and public toilet	3	1		5	1	4	3	1
	No. of HHs and population practicing open defecation	3	1		5	1	5	4	1
CONTAINMENT	Sewage system used (centralized or decentralized)	1	1		1	1	5	1	1
	Once off connection charges	1	1		1	1	1	1	1
	Monthly charges	1	1		1	1	1	1	1
	Functional status of the sewage network	1	1		1	1	1	1	1
	Feacal sludge contained	1	1		1	1	1	1	1
	Feacal sludge not contained	1	1		1	1	1	1	1
	No. of HHs and population connected to septic tank whose effluent discharge to	1	1		1	1	1	1	1
	No. of HH and population connected to septic tank whose effluent discharge to	1	1		1	1	1	1	1
	No. of HH and population connected to pit	1	1		1	1	1	1	1
	No. of HHs and population with no containment	1	1		1	1	1	1	1
	Type of septic tank prevalent in the city	1	1		4	1	1	1	1
	Septic tank design over time	1	1		4	1	1	1	1
	Containment state	1	1		1	1	1	1	1
EMPTYING AND TRANSPORTATIO	WW transported	1	1		1	1	1	5	1
	WW not transported	1	1		1	1	1	5	1
	sewer lines Leakage- State	1	1		1	1	1	5	1
	Desludging services given by government or private	1	1		1	1	1	1	1
	The emptying cycle	1	1		1	1	1	1	1
	Specify no. of trucks for each	1	1		1	1	1	1	1
	The manner how it is emptied	1	1		1	1	1	1	1
	Onsite emptying capacity	1	1		1	1	1	1	1
	Truck trips per day	1	1		1	1	1	1	1
	Trucks emptying capacity	1	1		1	1	1	1	1
	The percentage safely closed when full and relocated	1	1		1	1	1	1	1
	The Percentage of FS legally dumped	1	1		1	1	1	1	1
	The Percentage of FS illegally dumped	1	1		1	1	1	1	1
TREATMENT	waste water generated per day in MLD	1	1		1	1	1	1	1
	Capacity of Sewage treatment plant	1	1		1	1	1	5	1
	Treatment capacity utilized	1	1		1	1	1	5	1
	Sewage not treated	1	1		1	1	1	5	1
	Sewage treated	1	1		1	1	1	5	1
	FS safely closed when full and relocated facility	1	1		1	1	1	5	1
	Treatment efficiency	1	1		1	1	1	5	1
	FS treated	1	1		1	1	1	3	1
	FS not treated	1	1		1	1	1	3	1

Table 21: Data availability, and compliance, and completeness for all municipalities in Gauteng, as collected from the Green Drop Report.

				Sedibeng District		West Rand District	
The data checks	City of Ekurhuleni	City of Joburg	City of Tshwar	EMFULENI LOCAL MUNICIPALITY	MIDVAAL LOCAL MUNICIPALITY	MOGALE CITY LOCAL MUNICIPALITY	RAND WEST CITY LOCAL MUNICIPALITY
Area of city	1	1	1	1	1	1	1
Population	1	1	1	1	1	1	1
Population growth rate	1	1	1	1	1	1	1
Topography	1	1	1	1	1	1	1
Climate	1	1	1	1	1	1	1
Ground Water level	1	1	1	1	1	1	1
Vulnerability of the aquifer: rock type	1	1	1	1	1	1	1
Source of water supply	1	1	1	1	1	1	1
Water supply per capita	1	1	1	1	1	1	1
water supply coverage	1	1	1	1	1	1	1
No. of slums settlement	1	1	1	1	1	1	1
No. of HH with municipal boundary	1	1	1	1	1	1	1
No. of HH and population with latrine facility	1	1	1	1	1	1	1
No. of HH and population connected to sewerage	1	1	1	1	1	1	1
No. of HH and population connected to Septic tank	1	1	1	1	1	1	1
No. of HH and population dependent on community or public	1	1	1	1	1	1	1
Total no. of community and public toilet	1	1	1	1	1	1	1
No. of HHs and population practicing open defecation	1	1	1	1	1	1	1
Sewage system used (centralized or decentralized)	1	1	1	1	1	1	1
Once off connection charges	1	1	1	1	1	1	1
Monthly charges	1	1	1	1	1	1	1
Functional status of the sewage network	1	1	1	1	1	1	1
Feacal sludge contained	1	1	1	1	1	1	1
Feacal sludge not contained	1	1	1	1	1	1	1
No. of HHs and population connected to septic tank whose ef	1	1	1	1	1	1	1
No. of HH and population connected to septic tank whose eff	1	1	1	1	1	1	1
No. of HH and population connected to pit	1	1	1	1	1	1	1
No. of HHs and population with no containment	1	1	1	1	1	1	1
Type of septic tank prevalent in the city	1	1	1	1	1	1	1
Septic tank design over time	1	1	1	1	1	1	1
Containment state	1	1	1	1	1	1	1
WW transported	1	1	1	1	1	1	1
WW not transported	1	1	1	1	1	1	1
sewer lines Leakage- State	1	1	1	1	1	1	1
Desludging services given by government or private	1	1	1	1	1	1	1
The emptying cycle	1	1	1	1	1	1	1
Specify no. of trucks for each	1	1	1	1	1	1	1
The manner how it is emptied	1	1	1	1	1	1	1
Onsite emptying capacity	1	1	1	1	1	1	1
Truck trips per day	1	1	1	1	1	1	1
Trucks emptying capacity	1	1	1	1	1	1	1
The percentage safely closed when full and relocated	1	1	1	1	1	1	1
The Percentage of FS legally dumped	1	1	1	1	1	1	1
The Percentage of FS illegally dumped	1	1	1	1	1	1	1
waste water generated per day in MLD	5	5	5	5	5	5	5
Capacity of Sewage treatment plant	5	5	5	5	5	5	5
Treatment capacity utilized	5	5	5	5	5	5	5
Sewage not treated	1	1	1	1	1	1	1
Sewage treated	1	1	1	1	1	1	1
FS safely closed when full and relocated facility	1	1	1	1	1	1	1
Treatment efficiency	3	3	3	3	3	3	3
FS treated	1	1	1	1	1	1	1
FS not treated	1	1	1	1	1	1	1

Colour	Compliance	Monitored	Complete Figure
Green	✓	✓	100% Complete
Yellow	✓	✓	75% Complete
Light brown	✓	✓	50% Complete
Dark brown	✓	✗	25% Complete
Red	✗	✗	0% Complete
Purple	✗	✓	-

Figure 53: Legend of the data explaining the level of data availability, completeness, and compliancy

9.1.6 Timeline and source of data

Table 22: Sources of data for the IDPs and annual reports of various municipalities in Gauteng.

MUNICIPALITY	Data	Source of data (IDP)	Timeline of data(IDP)	Source of data (AR)	Timeline of data (AR)
Rand West local	Descriptive data	Statssa	2021	Statssa	2021
	Sanitation systems used	Statssa	2021	Statssa	2021
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Mogale local	Descriptive data	Statssa	2021	-	-
	Sanitation systems used	Statssa	2021	-	-
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Morafong local	Descriptive data	Statssa	2016	Statssa	2016
	Sanitation systems used	-	-	-	2022
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
West Rand Distrct	Descriptive data	Statssa, IHS Markit	2018, 2017	-	2020
	Sanitation systems used	IHS Markit	2017	-	-
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Midvaal local	Descriptive data	GIS	2022	Statssa	2011
	Sanitation systems used	Statssa	2016	Statssa	2016
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Lesedi local	Descriptive data	-	-	Quantek	2020
	Sanitation systems used	-	-	Lesedi Municipality	-
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Emfuleni local	Descriptive data	Statssa	-	-	-
	Sanitation systems used	-	-	-	-
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Sedibeng Distrct	Descriptive data	Municipal Demarcation Board, IHS Marki	2023	IHS Markit	2020
	Sanitation systems used	Statssa	2016	-	-
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Joburg	Descriptive data	Statssa	2019	Statssa, IHS Markit	2020, 2021
	Sanitation systems used	IHS Markit	-	-	2020
	Containments	-	-	-	2020
	Emptying and Transportation	-	-	-	2020
	Treatment	-	-	-	2020
Tshwane	Descriptive data	Statssa	2022	Statssa	2022
	Sanitation systems used	Statssa	2022	Statssa	2022
	Containments	-	-	-	2022
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-
Ekurhuleni	Descriptive data	Statssa	2011	Regional Explorer	2020
	Sanitation systems used	Statssa	2020	-	2021
	Containments	-	-	-	-
	Emptying and Transportation	-	-	-	-
	Treatment	-	-	-	-

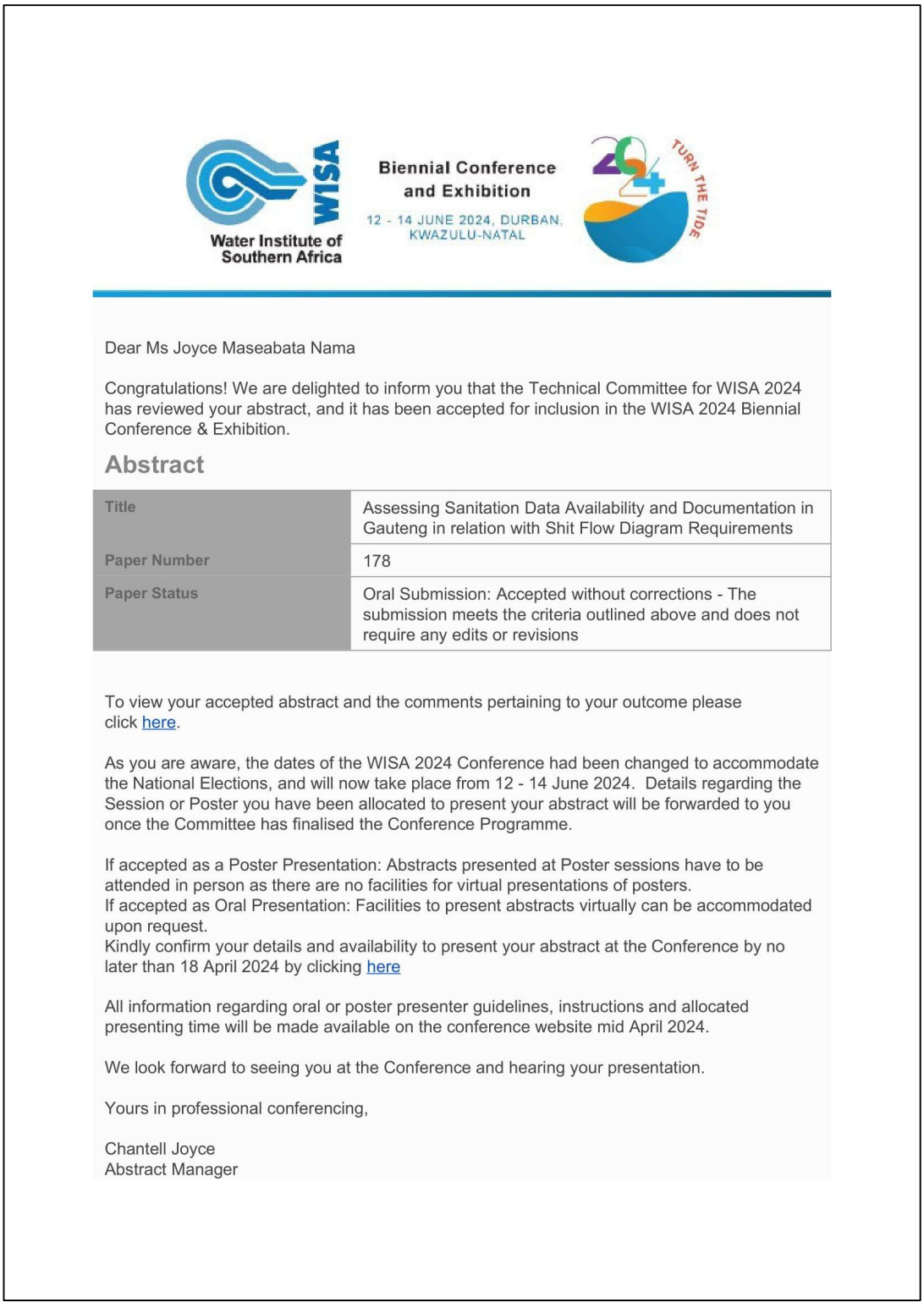
9.2 Data collected from Questionnaires

Table 23: Questionnaires feedback

Category	**Participant 1**	**Participant 2**
Level of Involvement	75% (High)	100% (Very high)
Efficiency of Data Collection	75% (Somewhat Efficient)	50% (Neutral)
Difficulties in Accessing Data	50% (Neutral)	75% (Easy)
Descriptive Data		
Method	Desktop data collection and municipal reports	Desktop data collection and municipal reports
Difficulty	50% (Neutral)	50% (Neutral)
Availability	75% (75% readily available)	50% (50% readily available)
Monitoring	50% (Moderately Monitored)	50% (Moderately Monitored)
Compliance	50% (Moderately compliant)	50% (Moderately compliant)
Sanitation systems used		
Method	Desktop research	Desktop research
Difficulty	75% (Easy)	50% (Neutral)
Availability	50% (50% readily available)	50% (50% readily available)
Monitoring	25% (Slightly Monitored)	50% (Moderately Monitored)
Compliance	25% (Slightly compliant)	50% (Moderately compliant)
Containments		
Method	Desktop data collection and one-on-one interactions to confirm data accuracy	Interviews with municipal members
Difficulty	75% (Easy)	75% (Easy)
Availability	50% (50% readily available)	50% (50% readily available)
Monitoring	25% (Slightly Monitored)	50% (Moderately Monitored)
Compliance	25% (Slightly compliant)	50% (Moderately compliant)
Emptying & Transportation		
Method	One-on-one interactions with the Municipality and truck drivers	Interviews with septic tank emptiers and union leaders
Difficulty	25% (Difficult)	25% (Difficult)
Availability	50% (50% readily available)	75% (75% readily available)
Monitoring	25% (Slightly Monitored)	75% (Very Well Monitored)
Compliance	25% (Slightly compliant)	50% (Moderately compliant)
Treatment		
Method	Same as emptying and transportation method	Interviews with municipal department
Difficulty	100% (Very Easy)	75% (Easy)
Availability	100% (100% readily available)	75% (75% readily available)
Monitoring	75% (Very Well Monitored)	75% (Very Well Monitored)
Compliance	75% (Very Well compliant)	50% (Moderately compliant)
Reuse/Disposal		
Method	Same as treatment	Interviews with municipal department
Difficulty	75% (Easy)	75% (Easy)
Availability	50% (50% readily available)	50% (50% readily available)
Monitoring	25% (Slightly Monitored)	50% (Moderately Monitored)
Compliance	25% (Slightly compliant)	50% (Moderately compliant)

9.3 Conference presentation and Publications

9.3.1 Accepted abstract letter for the WISA2024 biennial conference



Water Institute of Southern Africa

Biennial Conference and Exhibition

12 - 14 JUNE 2024, DURBAN, KWAZULU-NATAL

TURN THE TIDE

Dear Ms Joyce Maseabata Nama

Congratulations! We are delighted to inform you that the Technical Committee for WISA 2024 has reviewed your abstract, and it has been accepted for inclusion in the WISA 2024 Biennial Conference & Exhibition.

Abstract

Title	Assessing Sanitation Data Availability and Documentation in Gauteng in relation with Shit Flow Diagram Requirements
Paper Number	178
Paper Status	Oral Submission: Accepted without corrections - The submission meets the criteria outlined above and does not require any edits or revisions

To view your accepted abstract and the comments pertaining to your outcome please click here.

As you are aware, the dates of the WISA 2024 Conference had been changed to accommodate the National Elections, and will now take place from 12 - 14 June 2024. Details regarding the Session or Poster you have been allocated to present your abstract will be forwarded to you once the Committee has finalised the Conference Programme.

If accepted as a Poster Presentation: Abstracts presented at Poster sessions have to be attended in person as there are no facilities for virtual presentations of posters.
If accepted as Oral Presentation: Facilities to present abstracts virtually can be accommodated upon request.
Kindly confirm your details and availability to present your abstract at the Conference by no later than 18 April 2024 by clicking here

All information regarding oral or poster presenter guidelines, instructions and allocated presenting time will be made available on the conference website mid April 2024.

We look forward to seeing you at the Conference and hearing your presentation.

Yours in professional conferencing,

Chantell Joyce
Abstract Manager

9.3.2 The Oral Presentation Abstract for WISA conference 2024

ASSESSING SANITATION DATA AVAILABILITY AND DOCUMENTATION IN GAUTENG IN RELATION WITH SHIT FLOW DIAGRAM REQUIREMENTS

Ms Joyce Maseabata Nama[1], Mrs Xanthe Roux[2], Professor Adesola Ilemobade[2]

[1]University of the Witwatersrand, Johannesburg, South Africa,

[2]Arumloo, Johannesburg, South Africa,

This abstract addresses the critical relationship between data reporting for water and sanitation authorities (WSAs) and the utilisation of the Shit Flow Diagram (SFD) tool in Gauteng, South Africa, particularly in light of a cholera outbreak in 2023. The SFD, developed by the World Bank, is seen as vital for policy advocacy and sanitation planning, yet data reliability and monitoring are essential for its effective implementation. The study employs a comprehensive methodology, including literature reviews, municipality record examination, and surveys, to assess the availability and accessibility of sanitation data in Gauteng. Significant gaps are identified in data capture, uniformity, and terminology consistency, hindering alignment with SFD guidelines. WSAs exhibit substantial data gaps in containment, emptying, transportation, and treatment, highlighting the need for improved monitoring and reporting mechanisms. Despite challenges, the SFD provides a starting point for identifying sanitation system issues, facilitating progress toward achieving universal access to sanitation by 2030. This study underscores the importance of addressing data inconsistencies and gaps to enhance sanitation planning and decision-making in Gauteng's municipalities.

9.3.3 Paper in the SAICE Magazine paper

Paving the way for reliable sanitation solutions in Gauteng municipalities

Maseabata Joyce Nama
MSc Candidate
School of Civil and Environmental Engineering
University of the Witwatersrand
1475243@students.wits.ac.za

Xanthe Roux
Sanitation Specialist and COO
Arumloo
xanthe@arumloo.com

Shit Flow Diagrams (SFD) are an important tool in addressing the sanitation crisis; but do we have sufficient monitored sanitation data to develop a reliable SFD? A recent study set out to determine whether this is the case in Gauteng municipalities, highlighting where the challenges lie.

In low- and middle-income countries, over a million lives are lost annually due to inadequate water, sanitation, and hygiene practices. In 2023 Gauteng witnessed 15 casualties in the wake of a cholera outbreak, emphasising the immediate consequences of inadequate sanitation facilities.

According to the 2023 Green Drop report, South Africa's wastewater treatment infrastructure is in critical condition. To address these challenges and enhance sanitation service delivery, innovative tools such as the SFD are essential. However, reliable and monitored data must be prioritised to implement effective sanitation solutions.

eThekwini Metropolitan Municipality achieved a significant milestone in 2016 when it became the first municipality to develop an SFD through a collaboration between the University of KwaZulu-Natal's Water Sanitation & Hygiene Research & Development Centre and eThekwini Water and Sanitation.

The SFD is a snapshot of the current general sanitation conditions throughout a municipality, including on-site and off-site sanitation facilities.

This initiative was part of the SFD promotion drive later adopted by the Water Research Commission (WRC) for nationwide implementation. Since then, Emanti Management has played a key role, having developed eight SFDs across South Africa. The most recent SFD, created in 2018 for Ulundi Local Municipality in Zululand District Municipality, KwaZulu-Natal, reflects the continued commitment to this approach. The provinces of KwaZulu-Natal and the Eastern Cape are currently the only regions in South Africa where SFDs have been successfully implemented.

UNDERSTANDING THE SHIT FLOW DIAGRAM

The SFD is a snapshot of the current general sanitation conditions throughout a municipality, including on-site and off-site sanitation facilities. Tracing the transit of faeces across the sanitation chain, which includes containment, emptying, transport, treatment, and reuse and/or disposal, it depicts the proportion of a city's excreta that is treated safely and the locations where faecal contamination occurs. In doing so, it reveals components of the urban sanitation system that have been hidden because it is a system that is largely buried, unmonitored and unmetered. This hidden aspect of sanitation results in issues with management and maintenance (such as leaks or inappropriate containment of unsafe material) going unnoticed and unaddressed.

The illustration and layout of the SFD diagram are simple enough for non-sanitation specialists to interpret. This is essential for establishing a shared understanding and a common vocabulary to discuss a city's sanitation challenges, such as where the primary difficulties lie and what it would take to achieve an inclusive, integrated, citywide sanitation system. The SuSanA website, a global repository of SFDs, currently holds reports for over 150 cities in Africa, Asia, and South America that have developed SFDs since 2014, assisting in the improvement of the planning framework for urban sanitation services for 150 million people.

STUDY DETAILS

Research was conducted utilising the SFD tool data requirements checklist to assess the availability of sanitation data for developing SFDs in Gauteng municipalities. The data collected spanned the entire sanitation service chain (from toilet interface (containment) through to collection, transportation, treatment and disposal/reuse), encompassing:

- Descriptive data, including the city's area, population, growth rate, topography, climate, groundwater level, and water supply details.
- The sanitation system used, including data on facility systems, sewerage, septic tanks, and community or public toilets.
- Containment, namely the data on containment conditions, types of containment, and containment designs.
- Emptying and transportation, including data on the transport of

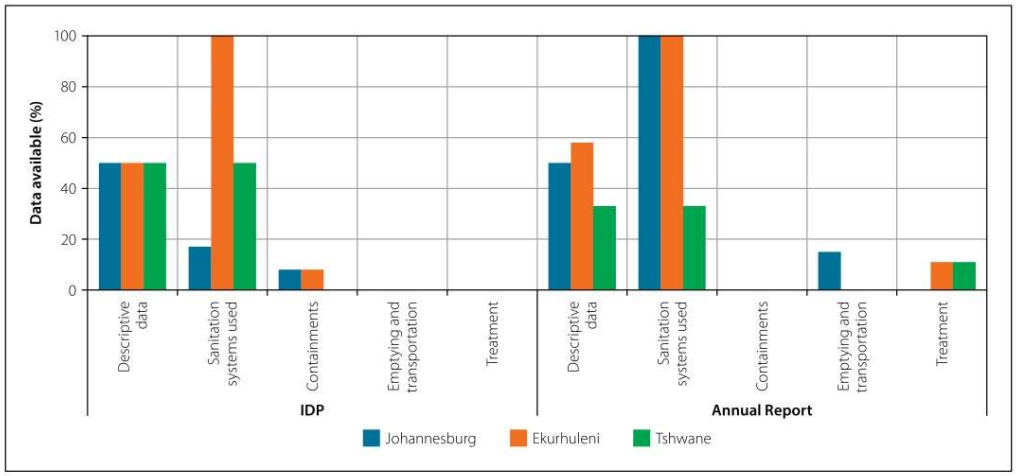


Figure 1 Data availability percentile per metro using IDPs and annual reports

wastewater, leakages, desludging services, and the handling of faecal sludge.

- Treatment, including wastewater generation, sewage treatment plant capacity, efficiency, and the treatment of faecal sludge.

DATA AVAILABILITY

Figure 1 indicates the absence of data in Gauteng municipalities' Integrated Development Plans (IDPs) pertaining to the aspects of emptying, transportation, and treatment of wastewater. Notably, the data reveals that less than 10% of the reports address sanitation facilities' containment, and this data remains largely unmonitored. This observation suggests a notable lack of emphasis on these critical aspects within Gauteng's three metropolitan municipalities (Johannesburg, Ekurhuleni and Tshwane). On the other hand, the annual reports for these municipalities exhibit a reasonably good dedication to monitoring data on the sanitation systems in use.

The Green Drop Report consistently presents data across municipalities, highlighting a uniformity in reported data. Figure 2 emphasises the report's primary focus on wastewater treatment, and how it falls short of providing a comprehensive view of treatment plant efficiency, which

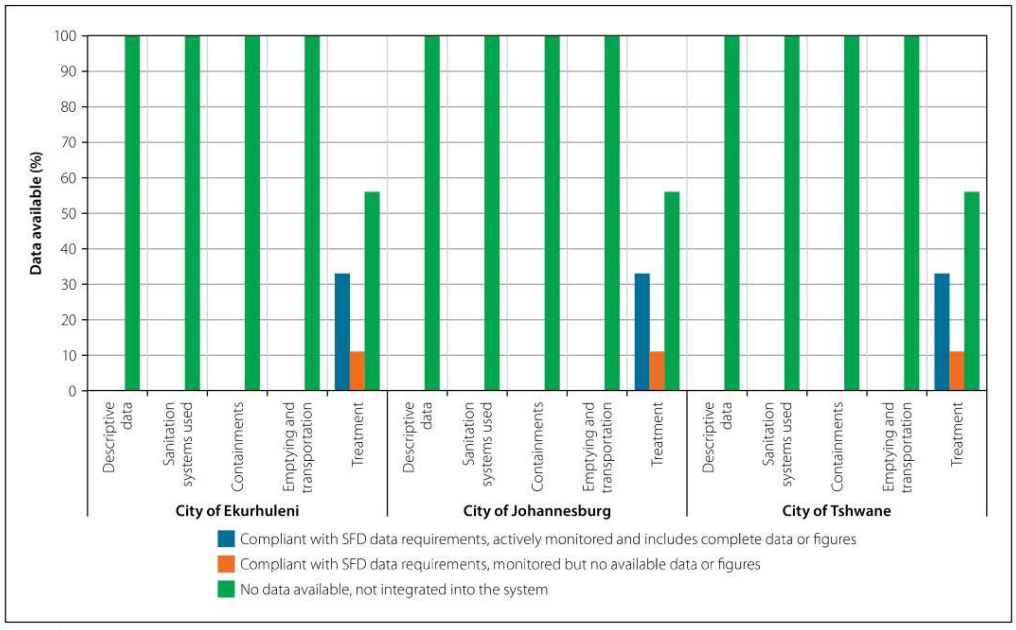


Figure 2 The level and form of data available in Gauteng metros

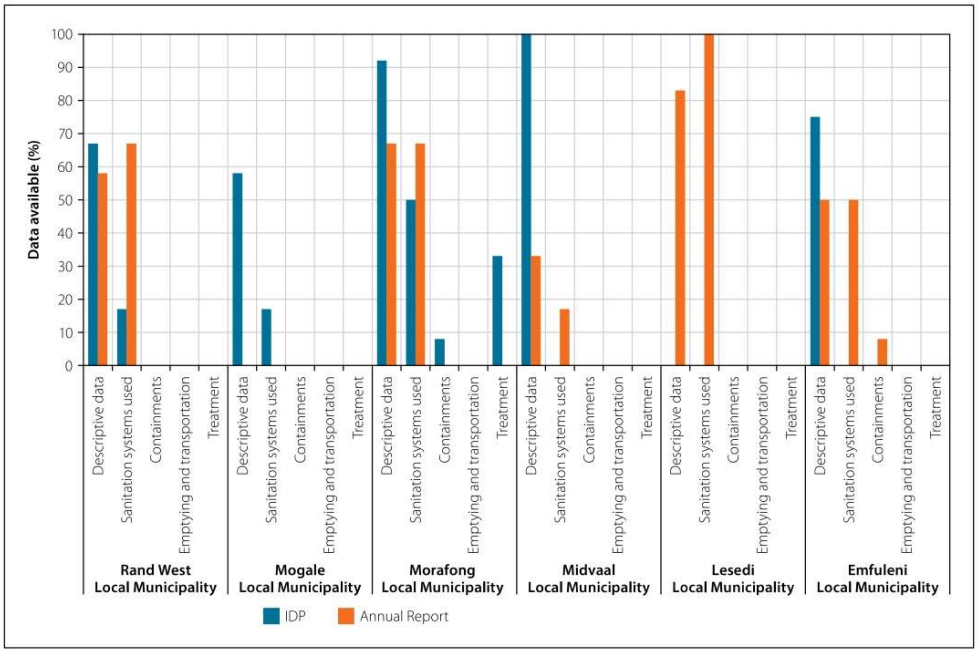


Figure 3 Data availability in Gauteng local municipalities using IDPs and annual reports (AR)

is crucial for understanding the entirety of wastewater management. The report lacks a detailed depiction of the wastewater transportation process, including the proportion left untreated and discharged into the environment.

Figure 3 shows a significant discrepancy in the accessibility of municipal reports to the public. Some municipalities have not made their reports public, and others lack accessible documentation platforms, such as websites or online libraries, limiting public access. This is exemplified by Mogale Local Municipality publishing a replica of Merafong Local Municipality's annual report. Lesedi Local Municipality has not published its IDP, calling into question the reliability and integrity of the available data.

CONCERNS IN DATA DOCUMENTATION IN RELATION TO SFD REQUIREMENTS

The gaps identified from the documentation in relation to SFD requirements highlights a significant challenge regarding terminology consistency and clarity within the reports. Noteworthy discrepancies in naming conventions, such as the interchangeable use of terms like "slum settlements" and "informal settlements," as well as variations like "household" and "units," create difficulties in aligning the data with SFD guidelines. The use of unclear terms like "none sanitation facility" adds complexity to interpretation, lacking specificity about the type of sanitation practices involved and the classification of "other" toilets, with reports omitting clear definitions, hinders precise categorisation.

The water service authorities (WSAs) exhibit significant data gaps, particularly in containment, emptying, transportation, and treatment, as depicted in Figures 1, 2 and 3. The existing sanitation facilities lack monitoring in terms of containment designs and existing conditions. There is no data on the emptying and transportation of faecal sludge and little monitoring of sewer lines. This may be because there is no clear indication of how private entities are supported and monitored to ensure safe transportation and disposal of sludge. The

The water service authorities (WSAs) exhibit significant data gaps, particularly in containment, emptying, transportation, and treatment

IDP and annual reports provide minimal data on treatment plant conditions, and the Green Drop Report concentrates solely on treatment plants, neglecting the crucial aspect of how wastewater is transported.

CONCLUSION

While the WRC moves forward working with WSAs across South Africa to roll out and ensure continual use of SFDs as a tool to help achieve universal access to sanitation by 2030 (SDG 6), this study shows that many of the SFDs will have to base their figures on internal knowledge and rough calculations. This is not to say that it would not be possible for the development of SFDs across all WSAs, but this study provides an indication of the challenge that the municipalities will face in compiling these reports.

One of the key benefits of the SFD tool is that is allows for a starting point in finding where the issues lie in the sanitation service chain, no matter how rough the initial data is. In this same way, this study is an identification of the areas that Gauteng municipalities need to start addressing as they move towards having a clear picture of the sanitation systems that they are mandated to manage. ◻

9.4 The questionnaire documentations

9.4.1 Ethical certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Nama

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H23/04/24**
PROJECT TITLE	The compatibility, reliability, and availability of sanitation data in Gauteng in relation to Excreta (Shit) Flow Diagram requirements
INVESTIGATOR(S)	Miss J Nama
SCHOOL/DEPARTMENT	School of Civil and Environmental Engineering/
DATE CONSIDERED	21 April 2023
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	05 June 2026

DATE 06 June 2023 **CHAIRPERSON** _____
(Professor J Watermeyer)

cc: Supervisor : Professor X Roux

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **A SIGNED COPY** returned to the Secretary electronically. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I/we agree to completion of a regular progress report. For Minimal and Low Risk studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

J Nama
Signature

07 / 06 / 2023
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

9.4.2 Participation Information Sheet

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
Private Bag 3, Wits 2050, South Africa | Tel: +27 11 717 7104 | Fax: +27 11 717 7045
Excel. Together.

Title of research: The availability, compatibility and reliability of sanitation data in Gauteng's municipalities in relation to Excreta (Shit) Flow Diagram requirements.

Dear Sir/Madam

My name is Joyce Maseabata Nama and I am a Masters student at the University of the Witwatersrand, Johannesburg, in the school of Civil and Environmental Engineering, under the supervision of Mrs. Xanthe Roux and Prof. Adeshola Ilemobade. I am conducting research on Excreta (Shit) Flow Diagram. The study title is the compatibility, reliability, and availability of sanitation data in Gauteng in relation to Excreta (Shit) Flow Diagram requirements.

I would like to invite you to participate in a research survey that will last about 5 to 10 minutes online, at a time that works best for you. Your selection as a participant is based on your extensive knowledge, research, and practical experience in the Shit Flow Diagram tool. If you choose to participate, the survey with kept in a password-secured cloud file. Only I, as the researcher, will have access to the data.

During the survey, I will ask for some personal information, including your name. However, the interview will be confidential, and your personal information will not be included in the research study's results or passed on to other researchers.

Participation in this research study is voluntary, and you can withdraw at any time. You do not have to answer any questions if you do not want to. There are no direct benefits or costs to participating in the study. The research study will be written up as a research report and made available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or after the interview or any concerns or complaints about the ethical procedures of this research study, please do not hesitate to contact me or my supervisor, Mrs. Xanthe Roux, using the contact information provided below. If you have concerns about the ethical procedures of this research study, you can also contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email at hrecnon-medical@wits.ac.za.

Thank you for your time and consideration.

Sincerely,
Joyce Maseabata Nama

Researcher:
Joyce Maseabata Nama, 1475243@students.wits.ac.za, +27 (0)734262755

Supervisor:
Mrs. Xanthe Roux, Xanthe.Roux@wits.ac.za, +27 (0)11 717 7112
Prof. Adeshola Ilemobade, Adesola.Ilemobade@wits.ac.za, +27 (0)117177153

9.4.3 Consent Form

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
Private Bag 3, Wits 2050, South Africa | Tel: +27 11 717 7104 | Fax: +27 11 717 7045
Excel. Together.

Title of project: The availability, compatibility and reliability of sanitation data in Gauteng's municipalities in relation to Excreta (Shit) Flow Diagram requirements.

Name of researcher: Joyce Maseabata Nama

As part of the research project, we have arranged a questionnaire for you, which is expected to take 5 to 10 minutes of your time. We want to assure you that your participation carries no anticipated risks, and you have the right to stop with the survey or withdraw from the research at any point if you choose to do so.

I, ... agree to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES	NO
I understand that I can volunteer to take part in the study.	YES	NO
I agree that direct quotations from my questionnaire may be used by the researcher in their research report.	YES	NO
I agree that other researchers may use the information I provide in my questionnaire (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on.	YES	NO

..... (signature)
..... (name of participant)
..... (date)

JNama ..... (signature)
Maseabata Joyce Nama ..... (name of researcher/person seeking consent)
17th April 2024 ..... (date)

CONSENT FORM JM NAMA

9.4.4 Administered questionnaire

Assessing Sanitation Data: Previously developed SFDs in South Africa

Completing this survey, which has five sections, will take approximately 5 to 10 minutes, and your participation would be greatly appreciated. This research aims to investigate the relationship between data reporting for water and sanitation authorities (WSAs) and alignment with the Shit Flow Diagram (SFD), a tool developed by the World Bank and other organizations to aid in policy advocacy and sanitation planning. The survey includes questions related to data monitoring: (1) containments, (2) emptying, (3) transportation, and (4) treatment. It provides an opportunity to understand the data opportunities or challenges encountered during the previously developed SFDs.

The primary goal of this questionnaire is to understand the opportunities and challenges in data collection, specifically focusing on comparison with those faced during the research for the Gauteng municipalities. It aims to uncover whether the issues related to data availability and documentation faced in the past persist as current challenges in sanitation data.

General Information

1. Full name

2. Occupation

3. Have you been involved in the development of Shit Flow Diagrams (SFDs) in South Africa, either in the past or currently?

- ◯ Yes
- ◯ No

4. In which province and municipality did you develop the SFD?

5. What year was the SFD you were involved in developed?

6. Rate your level of involvement in the SFD development

- ◯ Very low
- ◯ Low
- ◯ Moderate
- ◯ High
- ◯ Very high

7. Rate the general efficiency of the data collection process for SFD development in South Africa

- ◯ Inefficient
- ◯ Somewhat Inefficient
- ◯ Neutral
- ◯ Somewhat Efficient
- ◯ Efficient

8. Rate the general difficulties faced in accessing the data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

9. Is there anything you would like to add?

Descriptive data

Refer to data that provide a detailed description of the study area, including various factors such as topography, types of settlements, climate, and soil conditions.

10. Specify the primary method employed for data collection and provide the rationale behind its selection.

11. Rate the difficulties faced in accessing the descriptive data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

12. Rate the data availability of descriptive data

- ◯ 100% readily available
- ◯ 75% readily available
- ◯ 50% readily available
- ◯ 25% readily available
- ◯ 0% readily available

13. Indicate the extent to which areas of data available were monitored during data collection

- ◯ Not Monitored at All
- ◯ Slightly Monitored
- ◯ Moderately Monitored
- ◯ Very Well Monitored
- ◯ Fully Monitored

14. Indicate the extent to which areas of data available were in compliance with SFD tool requirements.

- ◯ Not compliant
- ◯ Slightly compliant
- ◯ Moderately compliant
- ◯ Very Well compliant
- ◯ Fully compliant

15. Is there anything you would like to add?

Sanitation systems used

16. Specify the primary method employed for data collection and provide the rationale behind its selection.

17. Rate the difficulties faced in accessing the sanitation systems data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

18. Rate the data availability of sanitation systems

- ◯ 100% readily available
- ◯ 75% readily available
- ◯ 50% readily available
- ◯ 25% readily available
- ◯ 0% readily available

19. Indicate the extent to which areas of data available were monitored during data collection

- ◯ Not Monitored at All
- ◯ Slightly Monitored
- ◯ Moderately Monitored
- ◯ Very Well Monitored
- ◯ Fully Monitored

20. Indicate the extent to which areas of data available were in compliance with SFD tool requirements.

- ◯ Not compliant
- ◯ Slightly compliant
- ◯ Moderately compliant
- ◯ Very Well compliant
- ◯ Fully compliant

21. Is there anything you would like to add?

Containment

22. Specify the primary method employed for data collection and provide the rationale behind its selection.

23. Rate the difficulties faced in accessing the containment data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

24. Rate the data availability of sanitation facility containments

- ◯ 100% readily available
- ◯ 75% readily available
- ◯ 50% readily available
- ◯ 25% readily available
- ◯ 0% readily available

25. Indicate the extent to which areas of data available were monitored during data collection

- ◯ Not Monitored at All
- ◯ Slightly Monitored
- ◯ Moderately Monitored
- ◯ Very Well Monitored
- ◯ Fully Monitored

26. Indicate the extent to which areas of data available were in compliance with SFD tool requirements.

- ◯ Not compliant
- ◯ Slightly compliant
- ◯ Moderately compliant
- ◯ Very Well compliant
- ◯ Fully compliant

27. Is there anything you would like to add?

Emptying and Transportation

28. Specify the primary method employed for data collection and provide the rationale behind its selection.

29. Rate the difficulties faced in accessing the emptying and transportation data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

30. Rate the data availability of emptying and transportation

- ◯ 100% readily available
- ◯ 75% readily available
- ◯ 50% readily available
- ◯ 25% readily available
- ◯ 0% readily available

31. Indicate the extent to which areas of data available were monitored during data collection

- ◯ Not Monitored at All
- ◯ Slightly Monitored
- ◯ Moderately Monitored
- ◯ Very Well Monitored
- ◯ Fully Monitored

32. Indicate the extent to which areas of data available were in compliance with SFD tool requirements.

- ◯ Not compliant
- ◯ Slightly compliant
- ◯ Moderately compliant
- ◯ Very Well compliant
- ◯ Fully compliant

33. Is there anything you would like to add?

Treatment

34. Specify the primary method employed for data collection and provide the rationale behind its selection.

35. Rate the difficulties faced in accessing the treatment data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

36. Rate the data availability of treatment

- ◯ 100% readily available
- ◯ 75% readily available
- ◯ 50% readily available
- ◯ 25% readily available
- ◯ 0% readily available

37. Indicate the extent to which areas of data available were monitored during data collection

- ◯ Not Monitored at All
- ◯ Slightly Monitored
- ◯ Moderately Monitored
- ◯ Very Well Monitored
- ◯ Fully Monitored

38. Indicate the extent to which areas of data available were in compliance with SFD tool requirements.

- ◯ Not compliant
- ◯ Slightly compliant
- ◯ Moderately compliant
- ◯ Very Well compliant
- ◯ Fully compliant

39. Is there anything you would like to add?

Reuse/Disposal

40. Specify the primary method employed for data collection and provide the rationale behind its selection.

41. Rate the difficulties faced in accessing the reuse/disposal data for SFD development

- ◯ Extremely Difficult
- ◯ Difficult
- ◯ Neutral
- ◯ Easy
- ◯ Very Easy

42. Rate the data availability of reuse/disposal

- ◯ 100% readily available
- ◯ 75% readily available
- ◯ 50% readily available
- ◯ 25% readily available
- ◯ 0% readily available

43. Indicate the extent to which areas of data available were monitored during data collection

- ◯ Not Monitored at All
- ◯ Slightly Monitored
- ◯ Moderately Monitored
- ◯ Very Well Monitored
- ◯ Fully Monitored

44. Indicate the extent to which areas of data available were in compliance with SFD tool requirements.

- ◯ Not compliant
- ◯ Slightly compliant
- ◯ Moderately compliant
- ◯ Very Well compliant
- ◯ Fully compliant

45. Is there anything you would like to add?