Assessment of human consumption of wild and cultivated plants in Kanana, a gold mining town in North West Province

By

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Declaration

This report was supervised by Dr J. Botha and co-supervised by Ms I. M. Weiersbye. I declare that this research report is my own, unaided work; where use has been made of the work of others it has been duly acknowledged in the text. This report is being submitted in partial fulfilment of the requirements for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Jubilee Bubala
07th October 2013.

Abstract

This study evaluated potential health risks associated with the consumption of commonly consumed leafy vegetables, *Amaranthus hybridus* (tepe), *Brassica oleracea* (cabbage) and *Spinacia oleracea* (spinach) in the gold mining town of Kanana in North West Province, where these three plants were the most commonly consumed. Structured interviews were conducted with 40 households to determine their socioeconomic status and the consumption patterns of vegetables (cultivated and wild plants). Along with interviews, plant samples were sampled in home gardens and at various harvesting locations in the wild for chemical analysis. Finally, analysis of mercury content in the sampled three leafy vegetable species was performed to ascertain the contributions of the vegetables to the dietary mercury intake among a predominantly young and poor subpopulation of Kanana, which was found to be largely dependent on state welfare grants and on the cultivation and gathering of wild plants for survival.

The study found that all three leafy vegetable species under analysis had mercury concentrations that exceeded the maximum permitted by the World Health Organisation. The highest mean mercury concentrations were found in *A. hybridus* 0.287µg/g dry mass and the lowest in *S. oleracea* 0.128µg/g dry mass. Equally, mercury ingestion through the three leafy vegetables by adults in the surveyed subgroups of Kanana exceeded thresholds prescribed by the (2007). Based on consumption patterns, dietary mercury intake by adults exceeded the recommended limits by one order of magnitude, with yearly dose exceeding by as much as four and three orders of magnitude. Long term mercury exposure can cause damage to the central nervous system and chronic intoxication. The surveyed subpopulation is therefore exposed to health risks from mercury toxicity. To ensure food safety and to protect the residents from metal toxicity, awareness programmes are recommended to educate communities living in the vicinity

of mines to avoid the areas of highest contamination, such as the artisanal mine dumps and (in this case) the Schoonspruit stream, and to control the artisanal use of mercury. Alternative vegetable gardening methods such as vegetable container gardening using unpolluted soil can also be implemented for the community. In addition, remediation of all the sites where local people cultivate vegetables and gather edible wild plants should be considered where feasible. The insights gained through the study should be used to inform local land use planning and create awareness among personnel from local regulators and development agencies. The insights can also be used to inform environmental management planning processes, risk mitigation and social impact assessment for industries in the region, in particular those involved in mining.

Keywords: consumption patterns, gold mining, human health risk, leafy vegetables, mercury.

Dedication

I dedicate this work to my dad George M. Bubala and my mum Emily H. M. Bubala.

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Acronyms and Abbreviations

ARD	Acid Rock Drainage
FAO	Food and Agriculture Organisation
RfDo	Reference Dose
TSFs	Tailing Storage Facilities (also known as slimes dams or mine dumps)
UNDP	United Nations Development Programme
WHO	World Health Organisation

Chapter 1. Introduction

Worldwide, mining operations contribute to the economies of countries endowed with mineral resources, but also frequently cause negative environmental and health impacts. In the Witwatersrand Basin of South Africa, the natural weathering of surface ore-bodies as a result of the geology of the area and the long history of gold and uranium mining activities have resulted in contamination of soils, surface water and groundwater resources with various metal/loids and naturally occurring radionuclides (Naicker *et al*., 2003; Batakula *et a*l., 2008). Apart from mining, other anthropogenic activities such as agriculture (e.g. irrigating crops with industrial wastewater or application of fertilisers) and industry are also potential sources of metal contaminants in the water, soil and air (WHO, 1996; Al Jassir *et al*., 2005; Mapanda *et al*., 2005; Farooq *et al*., 2008; Singh *et al*., 2011; Avci, 2012; Muchuweti *et al*., 2006; Frost and Ketchum Jr, 2000).

Mining activities alone can significantly increase contamination through varying technological practices, some of which are unsafe, such as the use of mercury in gold extraction, which was historically used by mining companies until 1915 and is still frequently used by artisanal and small-scale miners in many developing countries including South Africa (Lusilao, 2012). There is, therefore, the potential for uptake and bioaccumulation of toxic trace elements of mining origin by plants (Naicker *et al*., 2003; Pollmann *et al*., 2010). In the Witwatersrand Basin, local communities have been observed collecting wild and domesticated leafy vegetables in contaminated areas (Botha and Weiersbye, 2010) and could be cultivating vegetables in contaminated sites. The consumption of such plants, if sufficiently contaminated, could therefore pose potential risks to human health and safety in communities living near gold and uranium mines. A study was thus initiated to determine whether there is a potential risk to human health associated with the consumption of selected leafy vegetables in Kanana, a gold mining town in the North West Province. The contribution of the vegetables to the daily intake of mercury was assessed, comparing the data to international health guidelines. It is known that there is severe mercury contamination in the study area as a consequence of the historical and artisanal use of mercury for gold recovery (Lusilao, PhD, 2012).

For the purpose of this research, the term 'African leafy vegetables' will be used to refer to edible plant species that are neither cultivated nor domesticated but are accessible from their natural habitat and are utilised for food (Beluhan and Ranogajec, 2011; Faber *et al*., 2010). It is important to note that not all African Leafy vegetables, including *A.hybridus*, originate from Africa; many of these plants are exotic but have become naturalised in South Africa where they are extensively used and have names in various vernacular languages. Structured interviews were conducted with 40 households to record their socio-economic status and the consumption patterns of vegetables (cultivated and African leafy vegetables). Leafy vegetables *A.hybridus*, *B. oleracea* and *S. oleracea* were then collected from sites identified by the community, as well as purchased in Orkney (outside the study area) and finally the mercury concentration was analysed in the part consumed (i.e. the leaves of the vegetables).

In developing countries like South Africa, where many people are living in poverty, the gathering of non-timber forest products such as wild edible plants and small-scale crop production are very important livelihood strategies (Paumgarten, 2006; Shackleton *et al*., 2001; Dovie *et al*., 2003; Dovie *et al*., 2002). In the Witwatersrand Basin gold and uranium mining region, wild plant species occurring on mine properties are known to be used for traditional medicine, veterinary applications, food, livestock fodder, building materials, firewood, furniture and/or household implements (Botha and Weiersbye, 2010). Rashed (2010) investigated elemental concentrations of mercury (Hg), cadmium (Cd), lead (Pb), arsenic (As) and associated metal contaminants in soils and wild plants near gold mine tailings in North Africa, and found that they contained potentially toxic concentrations of these metals and thus were not suitable for grazing, livestock fodder, household consumption, or other agricultural activities that involve food production. Subsistence activities, even though they contribute to people's survival, may expose communities living near mining operations to toxic metals. For example, mercury can be particularly toxic even at low concentrations (Zahir *et al*., 2005).

Generally, communities are unaware of the health and safety impacts that may arise from practising such activities on mining and industrial footprints. In South Africa, where an environment not harmful to human health is regarded as a basic human right under the Constitution, contamination presents a serious socio-economic and legal issue for mining companies operating within the communities where residents practise subsistence activities on mine footprints, acid rock drainage sites or other contaminated sites that could cause harm.

1.1 Contaminants of mining origin in South Africa

In South Africa, mining has been contributing significantly to the economy of the country for over a century (Pollmann *et al*., 2010), but it has also unfortunately left the country with a substantial social and environmental legacy, with approximately 6000 derelict and abandoned mines, some of which pose hazards to the communities residing in their vicinities (Coetzee *et al*., 2008). Prior to the promulgation of the Minerals Act (Act 50 of 1991) and the Mineral and Petroleum Resources Development Act (Act 28 of 2002), mining companies in South Africa rarely took adequate responsibility for environmental management, leaving numerous polluted areas un-rehabilitated after completion of the mines' life cycle (Swart, 2003; Weiersbye *et al*., 2006). This is evident from the Witwatersrand region, which has been mined for over a hundred years and covers an extensive area of approximately 1600km^2, making it the world's largest gold and uranium basin (Chevral *et al*., 2008). This has left a legacy of approximately 400 km^2 in surface area covered by tailing storage facilities (TSFs), with the area impacted by pollution being much greater (Weiersbye *et al*., 2006).

1.1.2 Waste generation

Large amounts of waste are generated throughout a mine`s lifecycle. Approximately 315 million tonnes of solid waste per annum were generated in South Africa up to 2003 from mining activities alone (Chamber of Mines of South Africa, 2004). Waste generated from gold mining activities is known to be the largest single source of waste and pollution in South Africa (Department of Water Affairs and Forestry, 2008). The gold and uranium mines in the Witwatersrand Basin alone accounted for 105 million tonnes per annum. Waste is produced at a rate of 200 000 tonnes for every 1000 kg's of gold, and most of this is in the form of tailings (Chamber of Mines of South Africa, 2004), which are stored in unlined (TSFs), also known as slime dams or mine dumps. This type of waste can be detrimental to the environment as it has the capacity to contaminate the environment beyond the waste deposit sites in various forms of ground and surface water pollution (Naicker *et al*., 2003; Van Tonder *et al*., 2008), soil pollution (Rösner and Van Schalkwyk, 2000) and air pollution (Tutu, 2005).The long term impact of this is evident in the goldfields.

1.1.3 Air pollution

Many TSFs in the Witwatersrand Basin are exposed to wind erosion, resulting in the loss of extensive particulate matter (Blight, 2007; Mphephu, 2004), as many are not vegetated or are sparsely vegetated (Weiersbye *et al*., 2006). Agricultural lands or crops including pasture, vegetables and fruit as well as wild edible plants could be contaminated through the deposition of radioactive or metal-enriched dust particles from these facilities. Leafy vegetables grown in contaminated land sites reportedly accumulate higher amounts of metal contaminants through assimilation from direct absorption from the air through leaves and also through their roots (Feng *et al*., 1993; Al Jassir *et al*., 2005; Nabulo *et al*., 2006). It is therefore important to determine dose contributions via ingestion (Anglo Gold Ashanti Ltd, 2009). Apart from air pollution, water pollution is another way in which metals from mining activities contaminate crops and wild edible plants consumed by humans.

1.1.4 Surface and groundwater contamination

Groundwater pollution from mining activities occurs as a result of rainfall seeping through TSFs into the soil and underlying aquifers and the movement of water from mine voids (Van Tonder *et al*., 2008). In the Witwatersrand Basin, some groundwater is contaminated with metals and is acidified due to the oxidation of iron pyrite, a source of acid rock drainage (ARD) (Naicker *et al*., 2003; Mphephu, 2004). ARD occurs when a reactive sulphide mineral-bearing rock (eg. iron pyrite) is exposed to air and water and it oxidizes, releasing sulphuric acid and dissolved ions, which can be escalated in the presence of bacterial activity (Akcil and Kaldas, 2006). Discharges of ARD from closed abandoned underground mines and leaching from residue deposites, such as waste dumps and TSFs, result in increased dissolved constituents such as chromium (Cr), uranium (U), cyanide (CN), mercury (Hg), manganese (Mn),and arsenic (As) (Winde and Sandham, 2004; Tutu *et al*., 2008; Akcil and Kaldas, 2006; Batakula *et al*., 2008; Cukrowska *et al*., 2008). This adversely affects the quality of surface water (due to accidental seepage from TSFs and old underground mine workings, which lack adequate pollution control measures to prevent the contaminated seepage and run-off from entering the local surface water system (Van Tonder *et al*., 2008) and groundwater (Winde and Sandham, 2004; Winde and Van Der Walt, 2004a; Winde and Van Der Walt, 2004b). TSFs have not only affected surface and groundwater, but have also adversely affected the soil quality in gold mining areas (Rösner and Van Schalkwyk, 2000).

1.1.5 Soil contamination

Once introduced to the environment, ARD and other contaminants may enter the soil, resulting in a lowering of soil pH and an increase in bio-available concentrations of toxic metals (Rosner *et al*., 2001; Dube *et al*., 2001). For example, gold and uranium mining activities have contaminated soils in many areas of the Witwatersrand Basin. Contaminants in soil that emanate from gold mining activities include metal cyanide complexes (Batakula *et al*., 2008), a wide range of metals (Sutton and Weiersbye, 2007) and mercury (Hg) (Cukrowska *et al*., 2010). Soils underneath reclaimed TSFs are often highly acidified, with some metal contaminants being potentially bioavailable , such as cobalt (co), nickel (Ni) and zinc (Zn) (Rösner and Van Schalkwyk, 2000). The lower the pH of the soil in an oxidising environment, the more soluble and mobile some metals become and the more readily available they are for uptake by susceptible plants (Dube *et al*., 2001).

1.1.6 Metal contaminants and uptake by plants

Plants are exposed to contaminants and metal/loids via contaminated water, air and soil (Dushenkov *et al*., 1995; Raskin *et al*., 1997; Rahman and Hasegawa, 2011; Islam *et al*., 2013; Abhilash *et al*., 2009; Arora *et al*., 2008; Egwu and Agbenin, 2013; Al Jassir *et al*., 2005). However, the ability of soil constituents to bind with metals makes them a major metal pollutant reservoir (Dube *et al*., 2001). The mobility, bio-availability and bio-accessibility of metals in soils depends on the physical, chemical and biological properties of soils, such as soil acidity (pH) (Camberato, 2001; Aucamp and van Schalkwyk, 2003) and cation exchange capacity (CEC), which is defined by Camberato (2001) as "the amount of negative charges in soil existing on the surface of clay and/or organic matter that gives the soil particles the capacity to bind positively charged ions". Bio-accessibility refers to metals that are available for plant uptake but are temporally constrained in the soil media over time at a given site (Semple *et al*., 2004). Clay content, organic matter content and mineralogical composition all contribute to controlling the bioavailability of potentially soluble metals in soil (Dube *et al*., 2001; Raikwar *et al*., 2008). Bioavailability can be defined as "the proportion of total metals that are readily available for uptake by biota" (David and Leventhal, 1995). As plants uptake essential nutrient elements such as sodium (Na), magnesium (Mg), and calcium (Ca) for plant physiological functions, they can also potentially uptake non-nutrients such as arsenic (As), mercury (Hg), uranium (U), chromium (Cr) cadmium (Cd) and lead (Pb) from their growth media (Salt *et al*., 2002; Ismail *et al*., 2005). Uptake and accumulation of elements by plants is mainly through the soil media via roots and the air media via the leaf surface (Sawidis *et al*., 2001; Al Jassir *et al*., 2005). However, this depends on many factors, including exposure of plants to wind-blown dust containing soluble trace metals, plant growth stages (Sawidis *et al*., 2001), the metal species and mobility and the physiological properties of the plant species (Liu *et al*., 2005).

Some plants grow and thrive in both naturally metalliferous soils and in soils contaminated with metals from anthropogenic activities such as mining; such plants are called 'metallophytes' (Baker, 1981; Rascio and Navari-Izzo, 2011). Those that tolerate metal toxicity but do not bio-accumulate are known as "excluders" or "indicators"; tolerance in these plants results from their capacity to control metal entrance to the root, and uptake or translocation to the shoot. Control mechanisms occur at the root level by excluding the uptake, or retaining and decontaminating much of the heavy metals in the plant root tissues and only allowing a small quantity to be translocated to their leaves, which are much more sensitive to the phytotoxic effects (Baker, 1981). Other plants that can tolerate metal toxicity are able to bioaccumulate the metals and translocate most of them to the leaves, where the plant accumulates the metals to concentrations that could be toxic to consumers (Baker, 1981), such as herbivores and humans. For example, an estimated 25% of the plant species belonging to the family of Brassicaceae (cabbage family), especially those of the genera *Thlaspi* and *Alyssum*, are known to be hyper-accumulators (Brooks, 1989).

Cobb *et al*.(2000) investigated the uptake of heavy metals in different vegetables grown in contaminated soils and found that they accumulated and translocated the elements differently, with some leafy vegetables, such as *Lactuca sativa* (lettuce) and *Raphanus sativus* (radish), significantly accumulating the elements in their leaves, whereas *Solanum lycopersicum* (tomatoes) and *Phaseolus lunatus* (beans) concentrated the elements in their roots. This is because the bioaccumulation factor (more accurately expressed as the ratio of plant metal concentration to the soluble metal concentrations in that of the soil in which it is found growing, but sometimes also expressed in relation to soil total concentrations) differ between plant vegetable groups as well as species (Zayed et al., 1998). For example, while investigating toxic metals ingested via consumption of food crops in the vicinity of Dabaoshan mine, South China, it was found that the average bioaccumulation factor values of leafy vegetables were considerably higher than those of non-leafy vegetables at all four different sampling locations. It is through ingestion of such plants and inhalation of contaminated air among other mechanisms that humans are exposed to metals.

1.2 Exposure of humans to metals

Generally, humans are exposed to metals by ingestion of foodstuffs and water or inhalation of contaminated air, with ingestion reported to be the major pathway of exposure to these elements (Howard, 2002; Al Jassir *et al*., 2005; Islam *et al*., 2007; WHO, 1996; Zhuang *et al*., 2009). Ingestion may be via contaminated soil particles on unwashed foods, or metals within foods (i.e. incorporated via uptake into the plant or animal). Peri-urban lands are usually used for cultivation of vegetables, and are often contaminated with metals such as mercury (Hg), copper (Cu), zinc (Zn), arsenic (As), chromium (Cr), lead (Pb) and nickel (Ni) from industrial discharge, sewage and sludge, use of pesticides in farming and emissions from motor vehicles (Singh and Kumar, 2006). Working on an industrial site or living in close proximity to industries that utilize metal contaminants also increases one's risk of exposure (Martin and Griswold, 1999; Tomicic *et al*., 2011). Bitala (2008) investigated heavy metal pollution in soils and plants and associated impacts on the social environment in a gold mining community in Eastern Africa. He found that the environment was severely contaminated and various human diseases were reported due to inhalation of wind-blown dust from TSFs, domestic utilisation of polluted water and consumption of contaminated food crops. In the Witwatersrand gold fields, mining land that previously supported mine tailings, rock dumps, metallurgical plants and other polluted areas have been redeveloped for other land use activities, such as agriculture and housing in both formal and informal settlements (Sutton and Weiersbye, 2008). Land use activities such as these on mine footprints or other contaminated sites could cause harm such as metal toxicity to people living there, due to potential contaminants remaining in the soils and groundwater (Sutton and Weiersbye, 2008).

Worldwide, metal toxicity is reported to be one of the major current environmental health problems in many countries, placing humans and animals at risk (Kumar *et al*., 2007; Islam *et al*., 2007; Miclean *et al*., 2000). For example, high metal concentrations have also been reported in medicinal plants and/or herbs (Mahmood *et al*., 2013; Hussain *et al*., 2006). In South Africa, an analysis of metal concentrations in such plants demonstrated that only a few had demonstrated higher concentrations of barium (Ba), strontium (Sr), copper (Cu) and arsenic (As), however the doses of these plants that are administered to humans are usually low and unlikely to pose a health risk (Steenkamp *et al*., 2006). However, another study, an assessment of metal concentrations in plants and urine of patients treated with medicinal plants, indicated a risk that metal toxicity could be present in some of the plants, as there is no quality control in terms of harvesting and the methods used in preparing the herbal remedies (Steenkamp *et al*., 2000).

1.2.1 Toxic effects of metals on human health

This study focuses on analysing the risk of human ingestion of mercury in vegetables. A synopsis of the other contaminants from gold mining are beyond the scope of this study, however hereafter follows a brief analysis of the effects of other metals. Metal/loids such as uranium (U), arsenic (As), cadmium (Cd) and chromium (Cr) are classified as environmental contaminants due to their ability to cause toxicity in plants, humans and animals (Singh *et al*., 2011; WHO, 1996; Howard, 2002). Elements such as phosphorus (P), calcium (Ca), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), Cobalt (Co), molybdenum (Mo), selenium(Se), vanadium(V), and iron (Fe) are vital to human health, for example in the functioning of enzyme systems, but are also toxic in excess (Howard, 2002; Singh *et al*., 2011). For example, zinc (Zn) and copper (Cu) cause nausea, gastric irritation, hepatitis, vomiting, diarrhoea, fever, cirrhosis, liver damage, jaundice and even comas and death when accumulated in excessive concentrations (WHO, 1996). The non-nutrient metals such as mercury (the metal under analysis in this study) play no role in human physiology and when ingested can be highly toxic, even at relatively low concentrations of exposure, as it tends to concentrate in human body tissues causing neurotoxic effects (Zahir *et al*., 2005; WHO, 1996; Howard, 2002).

1.2.2 Human exposure to mercury and toxicity

Mercury is a naturally occurring metal that is widespread in biophysical environments such as air, water, and soil and in flora and fauna (Saltman *et al*., 2003). During the past century, anthropogenic activities have significantly contributed to the increased concentrations of mercury in the atmosphere, terrestrial and aquatic ecosystems as compared to natural sources (Fitzgerald *et al.*, 1998). Approximately one tenth of mercury emissions generated worldwide from anthropogenic activities are from artisanal and small-scale mining activities (Telmer and Veiga, (2009) and there are also mercury residues in many tailings dams from historical use by large-scale formal mining companies (Cukrowska *et al*., 2010). Globally, humans are exposed to the three forms of mercury (organic, elemental and inorganic) through various pathways. Which among others include exposures during gold amalgamation (a technique of using mercury to extract gold from ores) mainly used by small-scale and artisanal miners (Díez, 2009) and exposures from consumption (Benefice *et al*., 2008b). Methyl mercury (MeHg), a form of organomercury, in water and foodstuffs is known to be the most bioavailable, and therefore chronic exposure to it is common. MeHg is extremely toxic, with the nervous system in human beings being the primary target (Li *et al*., 2010; Aschner and Aschner, 1990) and globally it is known to cause the greatest risk to human health from dietary exposure. The primary route of exposure to this organic mercury is well documented to be through the consumption of contaminated fish (Saltman *et al*., 2003; Boischio *et al*., 1995; Agusa *et al*., 2005; WHO, 1990; Benefice *et al*., 2008a). Other studies have shown that edible plants grown in contaminated vicinities of industries where mercury is still being utilised for processing, for example in mining areas, are another potential pathway by which humans can be exposed to and contaminated by MeHg through consumption (Horvat *et al*., 2003; Feng *et al*., 2008; Zhang *et al*., 2010). Chronic exposure to minute quantities of mercury have been observed to cause acute and chronic intoxication (Bose-O'Reilly *et al*., 2010b), a condition in which an individual's ability to act or reason is impaired. The main threats to human health arise from the effects of mercury on the central nervous system and the brain (which are especially detrimental to foetuses if pregnant women are exposed) (Díez, 2009; WHO, 1996; Castoldi *et al*., 2001).

Susceptibility to metal toxicity and the effects thereof also depend on many factors, such as the amount consumed, the physiology of the consumer (Liu et al., 2005), the age of the consumer, the dietary status of the consumer (Howard, 2002), the body weight of the consumer and the gender of the consumer, with pregnant women being much more at risk (WHO, 1996; Howard, 2002) and children generally being more vulnerable than adults, given the same duration of exposure (Castoldi *et al*., 2001).

(Kasperson et al.) (1995, as cited in (Sutton, 2012), defined vulnerability as “the propensity of social or ecological systems to suffer harm from external stresses and perturbations”. Subsistence lifestyles can also present higher risks of exposure and health-related impacts because of hunting and gathering activities such as the collection of African leafy vegetables. Normally this is a concern only if plants are collected from contaminated sites, such as artisanal mining locations or TSF footprints, where there is a risk of exposure to harmful concentrations of metals such as mercury. African leafy vegetables are vital to food security for many poor households in South Africa.

1.3 Contribution of African leafy vegetables to food security of the poor

In South Africa a large proportion of the population lives in poverty, which is defined as “ the inability of individuals, households or entire communities to command sufficient resources to satisfy a socially acceptable minimum standard of living” (May, 1999). Many depend on plants that have been gathered from the wild for food and income, among other uses (Shackleton *et al*., 2007). People living in poverty adopt various livelihood strategies, including the gathering and selling of wild plants, informal sector work (Paumgarten, 2006), rearing of livestock (Dovie *et al*., 2006) and subsistence crop production (Dovie *et al*., 2003). Indigenous plants and forest resources are a source of social security for many people as they provide building materials, fuel, food, medicine, and a source of income to the poorest in society throughout the world (Dovie *et al*., 2004; Shackleton *et al*., 1995; Sunderlin *et al*., 2005; Shackleton *et al*., 2007). A study in Thorndale (Bushbuckridge district, Limpopo) has shown that the majority of households consumed wild edible herbs gathered from uncultivated areas of farms and rangelands, averaging 15.4 kg dried weight per household annually, with an estimated value of US$167 per household (Dovie *et al*., 2007). In Kwazulu-Natal, the plants were also largely utilised with rural households collecting the African leafy vegetables themselves, whereas urban households usually accessed the plants from urban markets (Faber *et al*., 2010). African leafy vegetables are vital to nutrition and, in some households, supplement incomes (Dovie *et al*., 2007). Therefore, when faced with food insecurity and limited choices many people depend heavily on the gathering of African leafy vegetables (Dovie *et al*., 2002), which can be a source of exposure to heavy metals, if these plants grow in areas that have naturally high concentrations of metals (metal-rich soil) or mine footprints. It is therefore the responsibility of mining companies to take environmental and social responsibility for their daily operations to ensure that they are operating according to the principles of sustainable development, and for government agencies to identify sites which may be contaminated by historical or artisanal mining, and assess safety for subsequent land-users.

1.4 Environmental and social responsibility in mining

Corporate social responsibility and sustainable business practice require that organisations take full responsibility for the impacts that their operations have on society and the biophysical environment (Amato *et al*., 2009). The strict application of the principles of sustainable development in their operations is needed, as required by the National Environmental Management Act (Act No. 107 of 1998), which envisages "the integration of social, economic and environmental factors into planning, implementation and decision making frameworks, so as to ensure that development serves the present and future generations". For example, native plants of economic value to local communities (Mulizane *et al*., 2005), other than those utilised for food, can be used for land rehabilitation purposes, taking into consideration the needs of various stakeholders in order to attain the principles of sustainable development (Hoadley and Limpitlaw, 2008; Ross and Bond, 2008). However, this has proven to be one of the biggest challenges that the mining industry is facing today (Haagner *et al*., 2008). If done incorrectly, the resulting negative legacy may cause significant liabilities and not satisfy the principles of sustainable development (Mban, 2008). Mine closure has been observed to cause severe distress for surrounding communities because of the threat of economic and social collapse (Hoadley and Limpitlaw, 2008; Limpitlaw and Smithen, 2003; Ross and Bond, 2008; Van Tonder *et al*., 2008), leaving communities jobless, which can in turn trigger an increase in subsistence activities on contaminated land sites. As a result of past experience with mine closures, best mining practice today places responsibility on mining companies to create benefits for the communities in which they have operated (Hoadley and Limpitlaw, 2008).

In South Africa, the Constitution of 1996 Act (Act No. 108 of 1996) stipulates that people have the right to an environment that is not harmful to human health, and the negative environmental impacts of mining and other industries on the poor can therefore no longer be overlooked (Sutton and Weiersbye, 2007; Botha and Weiersbye, 2010). The legislation overseeing the environment is stringent in terms of the need to protect the environment, and where damage does occur, it is incumbent upon the polluter to rehabilitate the land back to its original state or a state that conforms to the principles of sustainable development. Similarly, the Minerals and Petroleum Resources Development Act (MPRDA) (Act No. 28 of 2002), requires mining companies to pursue “sustainable development”, striving to strike a balance between their economic purpose and their social and environmental responsibilities. Global mining companies that are members of the International Council on Mining and Metals (ICMM), such as AngloGold Ashanti Ltd, require continuous assessment and consultation on social, health, safety, environmental and economic impacts throughout the life cycle of a mine (Sutton *et al*., 2008). Their policy states that the company will leave communities better off for having been there

(Anglo Gold Ashanti ltd, 2004; Anglo Gold Ashanti Ltd, 2009). In order to contribute to sustainable rehabilitation and safe land use post-mining, various research studies have been initiated by AngloGold Ashanti South Africa Region and the University of the Witwatersrand (Restoration and Conservation Biology Research Group); for example, in 1995 a study was done to (1) determine the contamination status of soils in the vicinity of Anglo American Gold Division's mine operations and (2) determine what plant species were common on polluted soils and mine tailings and may thus be useful for rehabilitation purposes (Weiersbye *et al*., 2006; Weiersbye and Witkowski, 2007; Weiersbye and Witkowski, 2003; Wiersbye and Witkowski, 2002).

1.5 Rationale

Following on from this previous research, the present study was initiated by AngloGold Ashanti and the University of the Witwatersrand as a pilot survey which will contribute to a larger dataset. It has been established that numerous wild plants grow naturally in polluted soils on the Witwatersrand Basin gold mines (Weiersbye *et al.,* (2006) and that some of these are edible or medicinal species (Botha and Weiersbye, 2010). Kanana is a town in the North West Province of South Africa, located downstream of the industrial area of the town of Klerksdorp, and adjacent to both historical and current gold and uranium mining operations, as well as artisanal gold mining activities. People have been observed harvesting wild African leafy vegetables in contaminated areas in Kanana and other contaminated sites on the Witwatersrand (Botha and Weiersbye, 2010) and could also be cultivating vegetables in contaminated areas, with a possibility of exposing themselves to health hazards such as mercury toxicity. Mercury is of concern because of its high toxic effects even at relatively low concentrations of exposure (Zahir et al., 2005; Bose-O'Reilly et al., 2010b)). It was historically used by large-scale and small-scale mines in gold processing and is still illegally being used in the area by small scale and artisanal miners in gold amalgamation (Lusilao, 2012; Cukrowska *et al*., 2010).

Household interviews were thus conducted to determine the socio-economic and demographic data of residents, their use of cultivated and African leafy vegetables and consumption patterns of all vegetable species utilised for food, with a subset of three leafy vegetable species identified for sampling from residents' harvesting sites and markets outside the study area. Analysis for mercury concentration (calculated using dry mass) in the edible portions of these were then conducted on the sampled leafy vegetables *B. oleracea* (cabbage), *S. oleracea* (spinach) and the African leafy vegetable *A. hybridus* (tepe) because of their capacities to bioaccumulate potentially toxic metals in their leaves than other vegetable types, as indicated by previous research (Al Jassir *et al*., 2005; Zhuang *et al*., 2009; Shaheen *et al*., 2011; Palusova *et al*., 1991). This study will inform local land use planning and create awareness among personnel from the local regulators and development agencies. It will also inform environmental management planning processes, risk mitigation and social impact assessment.

1.6 Aim

The aim of this study is to determine whether there is a potential risk of excessive mercury ingestion to humans associated with the consumption of leafy vegetables (wild and cultivated) in Kanana, a town in the North West Province of South Africa.

1.6.1 Objectives and key questions

Interviews were conducted with local residents in order to:

a. Identify African leafy vegetable and cultivated plant species that are utilised for food by residents of Kanana.
b. Ascertain where residents of Kanana cultivate vegetables and collect the leafy vegetables:
    - Are the wild or cultivated plants that are harvested growing in proximity to known sources of soil contamination as identified by prior studies?
    - Are the cultivated plants irrigated with water from streams or groundwater known to be contaminated from prior studies (by run-off from Kanana town and adjacent industries and mines into the Schoonspruit stream or certain borehole water)?
c. Assess consumption patterns of African leafy vegetables and cultivated plants.
d. Collect foliage samples from the three most commonly utilised leafy vegetables (from the wild, from markets and from home gardens).
e. Determine the concentrations of mercury in selected leafy vegetables commonly utilised by residents of Kanana, and answer the key question:
    - How do the mercury concentrations in the three commonly utilised leafy vegetable species compare?
f. Assess whether mercury concentrations in the leafy vegetables are within the limits set by the International guidelines the Food and Agriculture Organisation/World Health Organisation(FAO/WHO), and answer the key question:
    - Does mercury concentration in the leafy vegetables and the amounts potentially consumed at a meal by an average consumer (as defined by the WHO), fall within the limits established by FAO/WHO?

1.7 Report structure

This report is divided into five chapters. This introductory chapter has introduced the study topic and supporting literature, contextualising the study with a summary on how contamination from mining and mine waste can be transferred to edible plants, thus exposing humans to health hazards. The chapter has also presented the rationale, aim and objectives of the study and the key questions it poses. Chapter two (2) describes the study area and the methodological framework. Results of the household interviews conducted to determine consumption patterns of leafy vegetables are discussed in Chapter three (3). Chapter four (4) describes the concentrations of mercury found in *B. oleracea, S. oleracea* and *A. hybridus,* the three leafy vegetables that are commonly utilised by residents of Kanana, and the amounts potentially ingested by the average consumer. Chapter five (5) discusses the synthesis between the household survey data and the mercury concentrations in the evaluated leafy vegetables to determine whether potential health risks of mercury toxicity via the consumption of the leafy vegetables exist. Finally the chapter draws conclusions from the synthesis and makes recommendations for the protection of consumers of potentially contaminated vegetables and for future research

Chapter 2. Materials and Methods

This chapter provides a description of the study area and the methods used in the research.

2.1 Study area

Kanana falls within the city of Matlosana / Klerksdorp, which is located in the North West Province of South Africa. It is 164 km from Johannesburg and it is served by the N12 highway (Figure 2). Klerksdorp had a population of 385,782 in 2006 (Statistics South Africa, 2007) and an estimated 17,760 households in Kanana in 2008 (Golder Associates. AngloGold Ashanti, 2009). It is classified as an urban area with the largest population close to the Vaal Reefs area, which is an area in South Africa where gold and uranium mineral ores are mined from the ground by excavating surface shafts and subterranean passages (Golder Associates. AngloGold Ashanti, 2009). Kanana lies at latitude -26.95794 S and longitude 26.63696 E, in close proximity to the town of Orkney (Figure 2-3) and to mine residue deposits (TSFs or tailings dams) both from old and present-day mine operations (Figure 3-5). A tributary of the

Vaal River, called the Schoonspruit, reported to be polluted (Anglo Gold Ashanti Ltd, 2009) from Kanana itself, the industrial area of Klerksdorp and by historical tailings spillages as well as current ARD from mining operations, traverses the study area in a northerly direction (Figures 3).

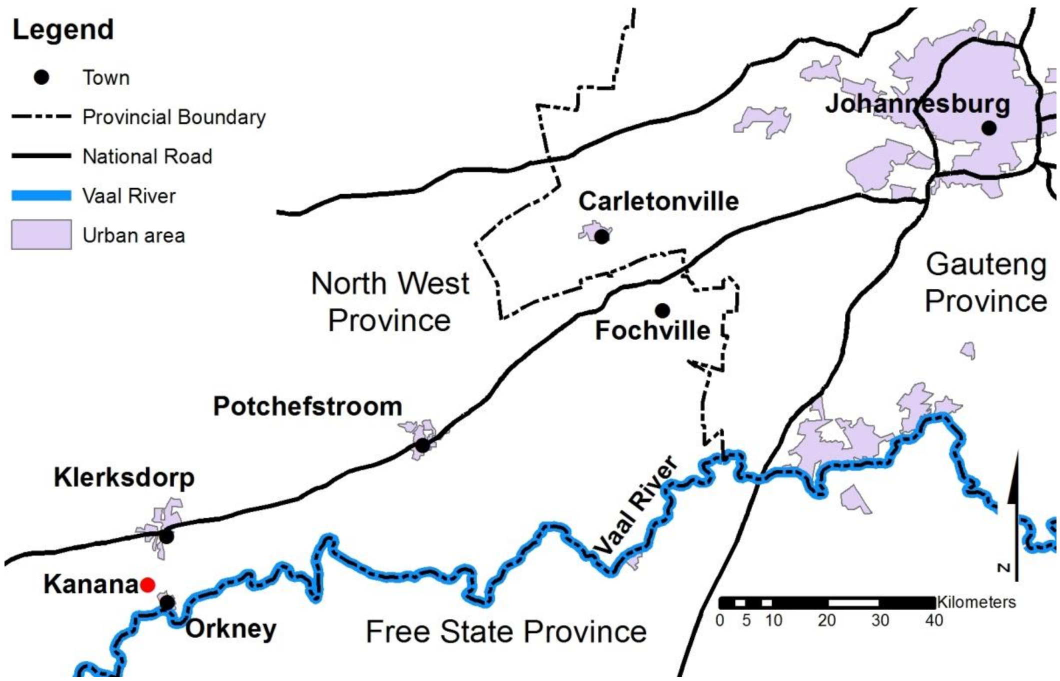

Figure 1 Locality map of the study area Kanana in relation to other towns (Source: D. Furniss 2013).

Figure 2: Aerial view of Kanana showing its proximity to TSFs, the Vaal River and its tributary the Schoonspruit (adapted from AngloGold Ashanti Ltd, 2009)

Figure 3: Historical Vaal River 1944 aerial photographs showing the location of old mining operations (digging and tailings deposits along the "Black Reef") and tailings spillages.

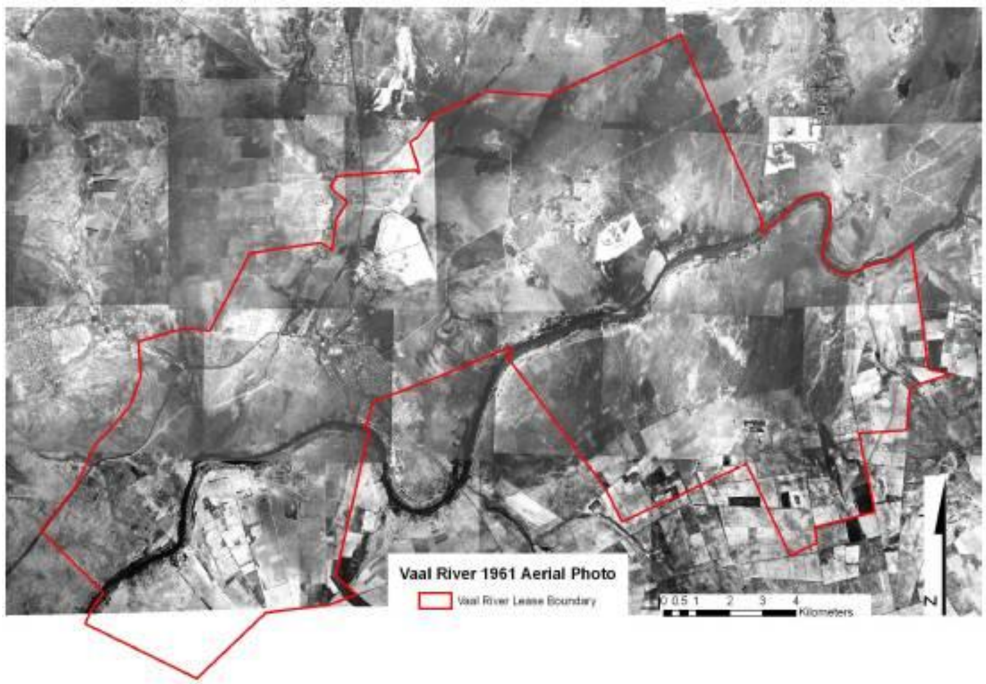

Figure 4 : Historical Vaal River 1961 aerial photographs showing the location of old mining operations (TSFs and rock dumps) and tailings spillages

2.1.1 Climate

The climate in the study area is typical of the Highveld of South Africa, semi-arid with a dominant early summer rainfall climaxing in December (Schulze, 1997) and a mean annual precipitation of approximately 500-750 mm (Dent *et al*., 1989), with inter-annual variation of 25–30% (Schulze, 1996). The area receives the majority of its annual rainfall (60%), as heavy thunderstorms between November and February (Herbert, 2008), which contribute to higher runoff and erosion. Annual potential evaporation is estimated to be between 2000 and 2250 millimetres per day (Schulze, 1997). The dry season is between May and September (Herbert, 2008). Extreme minimum temperatures occur in July of about 0-2^{o}C and maximum temperatures occur in January of about 25-27.5^{o}C (Schulze, 1997). Regular frost occurs during winter (Schulze 1997).

2.1.2 Geology and soils

The area is underlain by ancient rock formations, characterised by the Witwatersrand super group. The Ventersdorp super group, which makes up the Ventersdorp volcanic rocks, also comprises an important geological formation in the area (McCarthy and Rubidge, 2005) cited by AngloGold Ashanti, 2009). The Ventersdorp formation is composed largely of volcanic andesitic lavas and related pyroclastic various conglomerates (metamorphic rocks formed by the extremely hot temperatures associated with volcanic activity) McCarthy and Rubidge (2005, cited by AngloGold Ashanti, 2009). The Transvaal sequence and the Malmani Subgroup Dolomites of the Chuniespoort Group also make up part of the geology, the Malmani Subgroup Dolomites; dominate the study area forming an important aquifer. A number of Chert-rich and chert-poor formations of the Chuniespoort Group represent these dolomites and known to have an effect on the style of weathering of the dolomites McCarthy and Rubidge (2005, cited by AngloGold Ashanti, 2009). The area falls within the Middle Vaal Water Management area and Vaal River drainage system which drains the province in the southern area and includes various other flowing tributaries such as the Schoonspruit. The Vaal River drainage system has significantly influenced the landscape geomorphology and the local geology of the area Labuschagne (2007, cited by AngloGold Ashanti Ltd, 2009), which is varied and gives rise to different soil types. Generally the soils are loamy sand soils which are mostly derived from dolomite, with some andesite, sandstone, shale, quartzite and black reef (Robb and Robb, 1998). The soils are mostly shallow soils, moderately leached and acidic, with a generally low erosion potential (Robb and Robb, 1998). The acidic nature of the soils in the area can thus be expected to have an effect on the solubility and mobility of the metals, making them readily available to plants.

2.1.3 Topography

Generally, the topography of the area is relatively flat with undulating hills; the average elevation is approximately 1320m above sea level (Labuschagne, 2005). Mining activities have in some areas changed the visual characteristics of the landscape, with TSFs characterising the area as a mining community.

2.1.4 Vegetation

The natural vegetation type is comprised of mixed grassland and shrub-trees known as the Bushveld. The vegetation is transitional between the Grassland Biome and the Savannah Biome (Mucina and Rutherford, 2006). The Grassland Biome is poorly conserved due to the prevailing high levels of disturbance and fragmentation caused by anthropogenic activities; such as agriculture, human settlements, grazing, road building, widespread mining and industry (Mucina and Rutherford, 2006). This renders the area of an ecologically low value and sensitivity. The vegetation type is mainly Gh 12 Vaal Reefs dolomite sinkhole woodlands, Gh 10 Vaal-vet sandy grassland and Gh 13 Klerksdorp thornveld (Mucina and Rutherford, 2006).

2.2 Methodology

The study was approved by the Ethics Committee: Faculty of Sciences of the University of the Witwatersrand, Johannesburg (H110926, Appendix 1).

2.2.1. Interviews to determine the socio-economic and demographic data and the use of cultivated and African leafy vegetables.

Structured interviews were conducted to gather information on the socio-economic and demographic data and the use of cultivated and African leafy vegetables (Appendix 2). A pilot survey to test questionnaires was undertaken on the 4th of January 2012, in which six households from the population that was to be surveyed were drawn to test the protocol and questionnaires were further reviewed. Kanana was then stratified based on wards in order to reduce bias and sampling errors. The interviews (40 in total) were conducted by the researcher and two interviewers from Wits University from the 5th to the 26th of January 2012. A systematic sampling strategy was used in this study, where a random starting point was chosen and then households were sampled at every nth house in a ward. A total of 40 interviews were conducted in eight wards (5 interviews per ward).

2.2.2. Identification of plant harvesting sites and amounts consumed

During each interview, the respondents were accompanied to home gardens and harvesting sites, where whole plants were sampled. To quantify portions of leafy vegetables that respondents consumed, respondents were asked to estimate the quantities eaten per meal on a fresh volume basis from the exact freshly collected vegetables carried by the researcher, and the vegetables were weighed using an electronic weighing scale and recorded. This was done in order to determine the fresh mass of the volume estimated to be consumed, and subsequently the corresponding dried mass, and therefore the amount of mercury that respondents consuming the leafy vegetables may be exposed to. Whole plants for laboratory analysis were collected by the researcher and a research assistant, who helped with the sampling of plants. Voucher specimens were also collected to confirm species identity at the Moss Herbarium of the University of the Witwatersrand.

The daily metal intake of mercury by a subpopulation group of Kanana was determined based on the methods of Khan *et al*., (2008), described by the following equation:

$$DMI = \frac{Cmetal * Wfood * 0.085}{Bw}$$

Where Cmetal is the mean mercury concentration in the particular leafy vegetable (µg/g); Wfood is the average mass of each leafy vegetable consumed per day (g/person/day); Bw is the average body weight of an adult in the surveyed sub population (assuming a standard body weight of 60 kg for an average adult) (Joint FAO/WHO, 2007). A conversion factor of 0.085 was used to change the fresh mass of the vegetables to dry mass as metal concentrations are expressed on the basis of dry mass (Rattan *et al*., 2005). The results were then equated with the reference dose (RfDo) of (0.0016 µg/g) set out by the (Joint FAO/WHO, 2007) as a safe limit for mercury consumption.

2.2.3 Plant species sampled and sample preparations

Samples of different leafy vegetable types were collected from the study area. This included the African leafy vegetable (wild edible plant) *Amaranthus hybridus* (tepe; n=55) and home-grown plant sample species namely *Spinacia oleracea* (spinach; n=16) and *Brassica oleracea* (cabbage; n=8). A total of 79 composite leafy vegetable samples were analysed for this study (Appendix 3). Two individual plants per species were collected from each harvesting location (Figure 5), then composited to form one laboratory sample for that particular harvesting site. Seven (7) samples of the home-grown vegetables were purchased from market shops outside the study area in Orkney where locals sometimes purchase them.

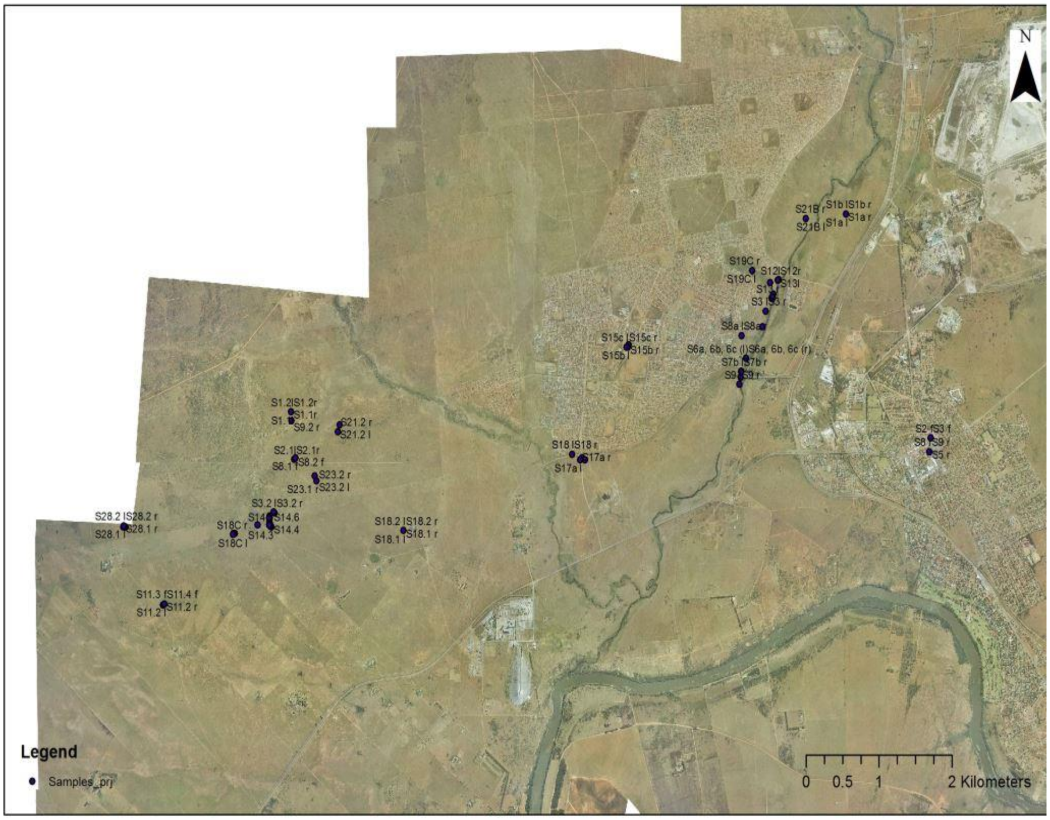

Figure 5: Distribution of harvested samples.

Each sample was put in a separate plastic bag, labelled, then packed with other samples collected from other harvesting sites in a bigger plastic bag bearing the label for that particular harvesting location and put in cooler boxes for transportation to the laboratory. A global positioning system, Model AP6540, was used to acquire the sample coordinates of each site; the habitat descriptions of the sites were also recorded. The same handling procedure was used for the samples purchased from the markets.

The plants collected from the field were separated into shoot and root. Thereafter each sample was washed in tap water once and three times in distilled water. Samples were then put on paper towels to dry and then the plants were placed in clean zip-lock bags and labelled. Talc-free blue nitrile gloves were worn at all times when handling the samples. The vegetable samples were then frozen at -20 degrees Celsius and freeze dried under vacuum at -50 degrees Celsius for 24 hours to 3 days in a Labconco freeze-dryer (USA). To preserve their mercury contents (MeHg) being volatile at standard temperature and pressure (STP) (Lusilao, 2012) the samples were stored in a freezer at -20 degrees Celsius. The samples were then coarsely ground using an agate mortar and pestle, followed by finer grinding of the sample with quartz balls in an automatic shaker at low temperature. The ground sample was then transferred into clean green–lidded urine specimen bottles labelled with a sample code.

A 0.2g sub-sample of the ground material was placed in a polyvinyl propylene micro-centrifuge tube (Eppendorf) and sent to the Chemistry Department at the University of the Witwatersrand. Sub-samples were digested in hydrogen peroxide and nitric acid within closed Teflon vessels in a microwave digestion unit (Anton Paar). The digestion solution was made up to 10 ml volume with deionised and double-distilled water (MilliQ).

2.2.4 Plant sample analysis

The samples were analysed for mercury in the ppb to ppm concentration range using AFS, alongside a Certified Reference Material (CRM) (U.S. National Standards Laboratory, Orchard Leaves). The CRM was used to indicate the accuracy of sample analytical values within the range of certified values. The samples were analysed using a Flow Injection Mercury Analyser, Model PerkinElmer (USA). The methods used for sample analysis were taken from the instrument user manual entitled: "Flow Injection Mercury/Hydride Analyses - Recommended Analytical Conditions and General Information" edited by PerkinElmer, Inc. (1998-2000), Shelton, Connecticut, USA. The results for mercury in shoots are reported in this study. Shoots were selected for this report as they were the edible portions of interest.

2.2.5 Data analysis

All data were analysed using Microsoft Excel and SARS Enterprise Guide 2006-2008 Version 4.2 statistical software (SARS Inc. Cary NC, USA).

2.2.6 Social survey data analysis

Statistical tests included descriptive analyses and data were reported as mean ± standard error (range). Data were tested for normality and where normal, the parametric Pearson's R correlation analysis was used to measure the strength of the linear relationship between variables. It is performed with a +1 for a perfect positive relationship and -1 for a perfect negative (inverse) relationship. Strong relationships are regarded as Pearson's R values greater than ± 0.4 and weak relationships are regarded as Pearson's R values less than ± 0.3 (Galpin, 2011).

2.2.7 Plant mercury concentration analysis

Data were reported as mean ± standard error, median and range and the results are means of replicates per species and per treatment. Data were tested for normality and were found to be non-normal, the non-parametric Wilcoxon-Mann Whitney Test and the Kruskal-Wallis was used with an alpha (α) at 0.05. A pair-wise Wilcoxon Mann Whitney test was undertaken for each group that was compared, adjusting the alpha for every combination that was tried.

Chapter 3. Socio-economic and demographic data and the use of cultivated and African leafy vegetables

This chapter presents the socioeconomic context of the surveyed households and their perceptions regarding the cultivation, collection and consumption of vegetables.

3.1. Household profiles

A total of 40 households were interviewed. In the majority (77.5 %) of these households SeSotho was spoken as a home language, while other home languages included isiXhosa (10.0%), isiZulu (7.5%) and SeTswana (5.0%). The mean household size was (5.2±0.3) people (mean±SE), ranging from 2 to 13 persons per household. Out of a total of 207 individuals from the surveyed households, 54.6% were female and 45.4% were male.

3.1.1 Age distribution

More than half (64%) of the population were below the age of 30 years with a mean age of 26.7 years. About 23.2% fall within the age range of 11-20, and children between the ages of 0-5 comprise (14%) of the population (Figure 6).

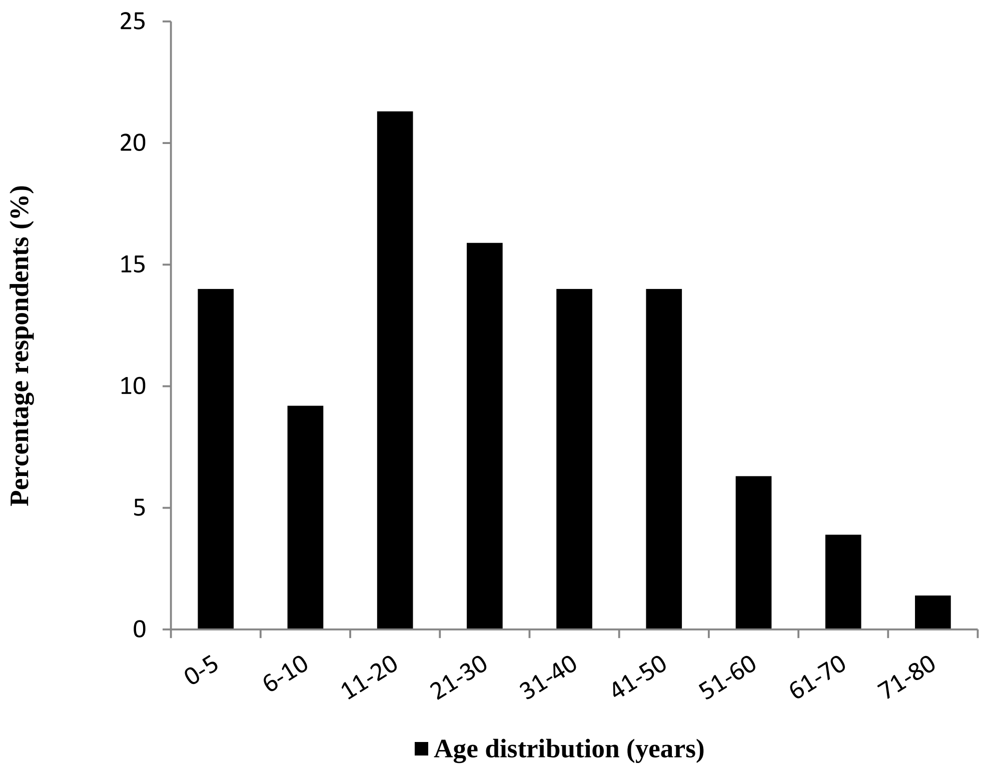

Figure 6: Age distribution within the surveyed households

3.1.2 Education levels among adults

The levels of education among adults (over age 19) were as follows: 26.8% had completed primary education, over half (52.9%) had attained at least some secondary education, 18.7% had tertiary education and only (1.6%) had no schooling at all.

3.1.3 Income and employment status

Unemployment is prevalent, with approximately 53.7% of the adults over 19 being unemployed. Among those employed in formal jobs 12.3% were miners and 8.8% were civil servants, working as police officers, teachers and nurses, and 1.8% were electrical technicians. Those in informal jobs or working in low-income employment included waitresses and domestic workers (3.6%), but the majority (75.4%) were self-employed, working as hairdressers, making baskets, welders, traders (e.g. selling at spaza shops or hawkers) and traditional healers.

The mean total monthly household incomes were (R6292±611; n=40) and ranged from R1100 to R18000. More than half (62.5%) of households survived on less than R6002 per month Figure 7). The minority (5%) that earned ≥R14000 had at least one or two members employed as civil servants (police officers, educators and/or nurses). Household incomes were mainly supplemented by state welfare grants: 82.5% received government grants and 17.5% received no grants. Of those that received grants, 20.0% recorded no other source of income. The mean number of grants received per household was (2.0±0.2; n=33) and the average grant income derived from state welfare alone was (R1170.3±157.3; n=33), ranging from R250 to R1180. The grant types were mainly for child support (79.4%), pensions (15.2%), and disability (5.4%).

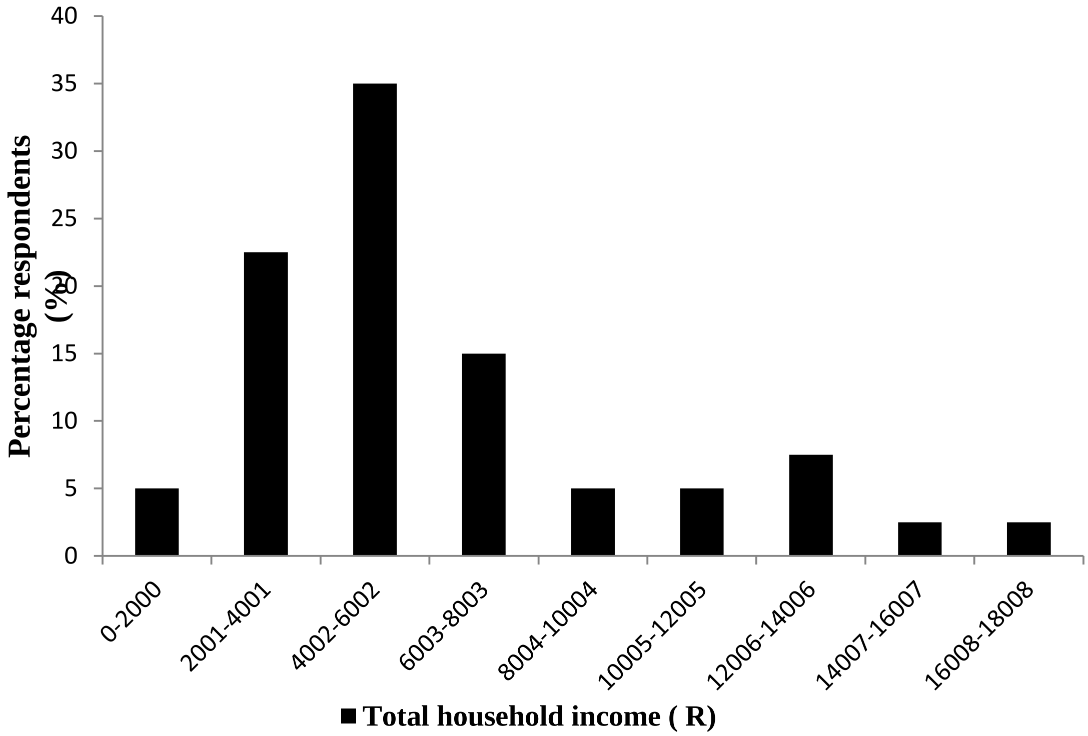

Figure 7: Total income distribution among households supplemented by state welfare grants.

3.1.4 Housing conditions

Housing in Kanana comprises both formal and informal dwellings. The formal dwellings consist of brick houses with the number of rooms ranging from 3 to 10 per household (6.3±0.44; n=22); others made of brick but smaller in size included Reconstruction and Development Programme (RDP) houses (low-cost housing units built for disadvantaged people in South Africa who had limited access to housing under the apartheid regime) with the number of rooms ranging from 2 to 4 per household (3.6±0.3; n=8) (Figure 8). The informal dwellings were usually constructed entirely from corrugated iron sheets with the number of rooms ranging from 1 to 8 per household (3.4±0.6; n=10) (Figure 9). All households interviewed used municipal tap water for domestic use, including gardening; none of the households reported using contaminated water from the Schoonspruit stream or borehole water.

Figure 8: A brick house in a formal housing area

Figure 9: A corrugated iron sheet house in an informal housing area

3.2 Home grown vegetables

The majority of the households (70.0%) had vegetable gardens located in their back yards (Figures 11-13) and 30.0% had no gardens. Households without gardens purchased vegetables from those with gardens, spaza shops (home shops established in people`s homes or backyards) in Kanana, markets in Orkney or local pension markets (markets where pensioners go to sell their vegetables). Among those with gardens, 85.7% cultivated the vegetables entirely for household consumption and 14.3% both consumed some home-grown vegetables and also earned a mean income ranging from R120 to R350 (R230±56.1; n=4) through vegetable sales. When presented with a scenario of losing a vegetable garden among households that had one, the lack of a source of nutrients and lack of extra income needed to purchase alternative foodstuffs were reported to be the major concerns.

Figure 10: A backyard vegetable garden in an informal area with *S. oleracea* cultivated

Figure 11: A backyard vegetable garden in a formal housing area with *S. oleracea* and *Beta.vulgaris* cultivated.

Figure 12: A backyard vegetable garden in a formal housing area with *B. oleracea* cultivated.

Among households with home gardens, 78.6% encountered problems with their gardens, with 22.7% of them experiencing more than one problem and 21.4% indicating that they had no problems of any kind. Problems faced among households included: lack of water (36.4%), soil infertility and insect damage (27.3% each), dust (18.2%), weeds (13.6%), erratic water supply and heat (9.1% each). However, 63.6% improve the production and fertility of their gardens by adding compost (made from eggshells, food leftovers and grass) or animal manure obtained from cattle; none reported using inorganic fertilisers.

3.2.1 Vegetables species cultivated

A wide variety of vegetables species ranging from fruits, root, pod, grain and leafy vegetables were cultivated and utilised for food by the respondents. The most commonly cultivated were *S. oleracea* (spinach) (82.1%), *S. lycopersicum* (tomatoes) (71.4%), *Zea mays* (maize) (53.6%), *B. oleracea* (cabbage) and *Beta vulgaris* (beetroot) (50% each), and the least grown were *Raphanus sativus* (radish) and *Zingiber officinalis* (ginger) (3.6% each). *S. oleracea* (spinach) and *B. oleracea* (cabbage) were the most commonly cultivated leafy vegetables (Figure 13). The mean number of vegetable species cultivated per household was (5.0±0.4; n=18).

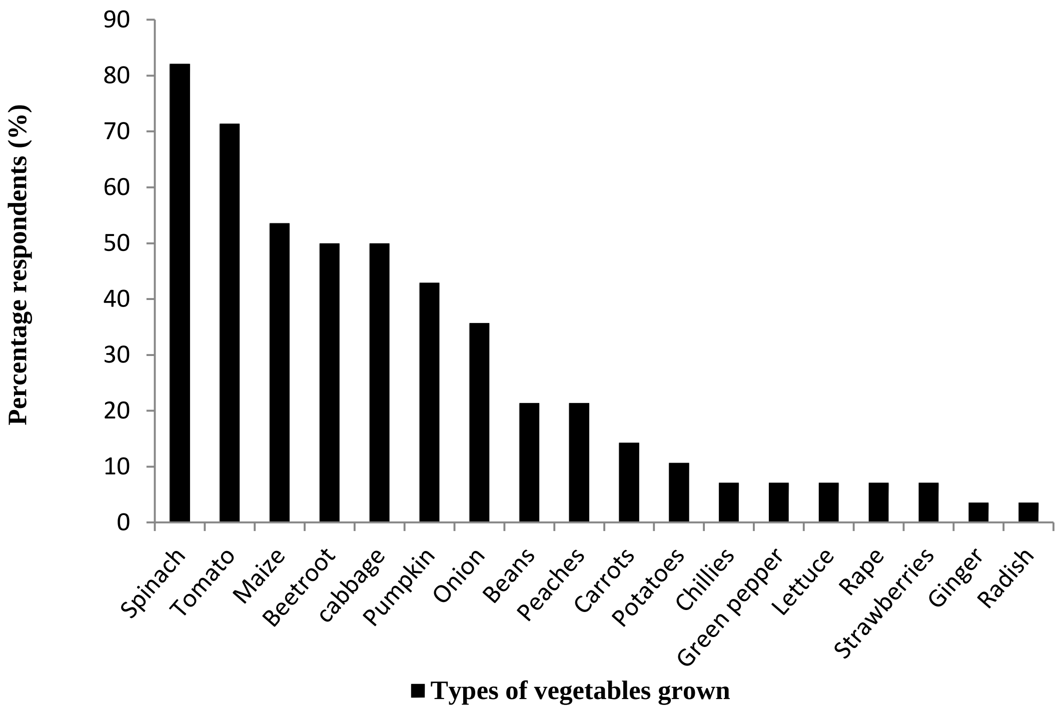

Figure 13: Vegetable species cultivated in home gardens

3.2.2 Consumption patterns of home grown vegetables

An overview of the proportional consumption patterns per cultivated vegetable species is provided in Table 1. The mean individual portions of the vegetable species consumed as main dishes were as follows; *Brassica napus* (rape) (130.1g ±19.9; n =2), (range: 110.3 -150g), *B. oleracea* (cabbage) (127.5g ±6.14; n= 14) (range 100- 175g), *S. oleracea* (spinach), (120.2g ±14.1; n =23), (range: 75 - 108.3g) *Cucurbita maxima* (pumpkins) (110.2±14.1; n=6) (range: 75-183.3g), *Lactuca. s* (lettuce) (110g; n=1) and *Phaseolus. l* (beans) (101.5±1.5; n=) (range: 100-103g). The other supplementary vegetables added to main dishes such as: *Capsicum annum* (chillies) *S. lycopersicum* (tomatoes), *Allium cepa* (onion), *Daucus carota* (carrots) were consumed in smaller portions. The frequency of consumption of the vegetable species varied among households, with leafy vegetables, *S. oleracea* (spinach) and *B. oleracea* (cabbage) being more frequently consumed than the others. *S. oleracea* (spinach) was frequently consumed (by 8.7% of individuals on a daily basis) and 91.3% consumed the vegetable at least 1-4 times on a weekly basis. This was followed by *B. oleracea* (cabbage), with 7.1% consuming the vegetable 4 times per week and 92.9% 1-2 times per week. *S. lycopersicum* (tomatoes) and *Allium cepa* (onions) were frequently consumed in various main meal dishes on a daily basis as compared to the other vegetables also utilised as ingredients. There was a relatively strong relationship between household size and quantity of home grown vegetables consumed per household per meal (Pearson`s, $r = 0.595$, $p < 0.001$).

3.2.3 Consumption modes

Different vegetable parts for various vegetables were consumed for food. These included roots, fruits, grain/seed, tuber, taproot and stems (Table 1). In leafy vegetables, leaves were consumed and in pumpkin, flowers were also consumed. The common cooking methods across households included boiling and/or steaming the vegetables and further adding ingredients such as *S. lycopersicum* (tomatoes), *Capsicum annum (chillies),* (chillies) *Capsicum annuu* (green pepper) *A. cepa* (onion), *Daucus carota* (carrots) salt and cooking oil to make the dish thick, rich and improve the taste.

Table 1: Consumption patterns and modes of vegetable species cultivated and consumed in Kanana (* = unspecified)

Common name of Vegetable/ Fruit	Individual quantities consumed in grams (g) per average meal Mean±S.E (range)	Frequency of consumption	Part eaten	Common preparation methods (mode of consumption)
Spinach (82.1%)	120.2± 6.2 (75-183)	1x Daily 8.7% 1 x Weekly: 30.4% 2 x Weekly: 47.8% 3 x Weekly: 13.1%	Leaves	Leaves are either boiled or steamed and ingredients such as cooking oil, salt, onion and tomatoes are added.
Tomato (71.4%)	44.18	1 x Daily 15.8% 2 x Daily: 68.4% 3 x Daily: 15.8%	Fruit	The fruit is mainly used as an ingredient for cooking relish, sometimes eaten uncooked or fried with oil, tomatoes, salt and spices to make a soup.
Maize (53.6%)	220	1 x Weekly: 50% 2 x fortnightly 16.7% 2 x occasionally 33.3%	Cob	Boiled or roasted
Beetroot (50%)	92.7 ± 4.3 (50-110)	1 x Weekly: 42.9% 2 x Weekly: 7.14% 1 x fortnightly: 35.7% 2 x occasionally 14.3	Root	The roots are boiled and served as a salad; sometimes vinegar and mayonnaise are added to enhance the taste.
Cabbage (50%)	127.5 ± 6.1 (100-175)	1 x Weekly: 28.6% 2 x Weekly: 64.3% 3 x Weekly: 7.1%	Head	Cooking methods varied from boiling to steaming; other ingredients such as tomatoes, oil, onion and salt are added
Pumpkin (42.9)	110.2±14.1 (50-168)	1 x Weekly: 45.5% 2 x Weekly: 36.4% 3 x Weekly: 18.2%	Leaves, flowers and fruit	The fruit is boiled, mixed with a pinch of salt and sugar. Leaves and flowers are boiled or steamed. Tomatoes, onion and salt are sometimes added.

Common name of Vegetable/ Fruit	Individual quantities consumed in grams (g) per average meal Mean±S.E (range)	Frequency of consumption	Part eaten	Common preparation methods (mode of consumption)
Onion (35.7%)	19.7 ± 4 (22.5-30.5)	1 x Daily 20% 2 x Daily 80%	Leaves and bulb	Leaves and bulbs are added as an ingredient to cooked relish
Beans (21.4%)	101.5±1.5 (100-103)	1 x Weekly: 66.7% 1 x fortnightly: 33.3	Leaves and pods	Leaves and pods are boiled, then tomatoes, onion, salt and cooking oil are added to them to enhance the taste. The vegetable is mainly eaten with pap, (a maize meal porridge)
Peaches (21.4%)	22	1 x Daily 66.7% 4 x Daily: 33.3%	Fruit	Fruit is eaten uncooked when ripe
Carrots (14.3%)	26	1 x weekly 25% 1 x fortnightly 50% 1 x monthly: 25%	Taproot	Eaten uncooked, or boiled and mixed with meat as an ingredient.
Potatoes (10.7%)	105.4	1 x Weekly: 50% 2 x Weekly: 50%	Tuber	The tubers are boiled together with cooking oil, salt, onions, spices and tomatoes eaten singly or mixed with other foodstuffs.
Chillies (7.1%)	2.5 ± 0.5 (2-3)	1 x occasionally 100%	Fruit and leaves	Fruit and leaves are added to cooked relish as ingredients.
Green pepper (7.1%)	*	*	Fruit	The flesh is mixed as an ingredient when cooking a variety of dishes.
Lettuce (7.1%)	110	1 x Weekly: 100%	Leaves	The leaves are steamed and mixed with other ingredients such as salt, tomatoes, onion and cooking oil, sometimes mixed with cooked beef

Common name of Vegetable/ Fruit	Individual quantities consumed in grams (g) per average meal Mean±S.E (range)	Frequency of consumption	Part eaten	Common preparation methods (mode of consumption)
Rape (7.1%)	130.1±19.9 (110.3-150)	1 x Weekly 50% 2 x Weekly: 50%	Leaves and stems	Leaves are boiled then mixed with cooking oil, tomatoes, onions, salt, chillies and Bisto™ (a commercial powder for making gravy)
Strawberries (7.1%)	*	1 x occasionally 100%	Fruit	Eaten uncooked when ripe
Ginger (3.6%)	*	*	Root	The roots are pounded for use in cooking or to be added to tea.
Radish (3.6%)	57.6	3 x Weekly: 100%	Leaves	Leaves are boiled with tomatoes, salt, onion and oil.

3.3 African leafy vegetables

The majority of the respondents (95.0%) gathered and consumed a variety of wild African leafy vegetables, commonly referred to as ‘morogo’, and only 5.0% reported not gathering or using these vegetables. Of the eight utilised wild species the three most commonly utilised leafy vegetables among users were *A. hybridus ‘tepe’* (100%), *Chenopodium album* ‘seruwe’ (47.4%), and leaves of wild cucumber species, *Cucurbita maxima*, *Cucurbita pepo* and *Cucurbita moschata* ‘mekopu’ (45% each) (Figure 14). When presented with the question of which African leafy vegetables grow back quickly after being harvested, 45.0% of the respondents could not specify, 37.5% said *A. hybridus* ‘tepe’ regrows within two weeks after being harvested and is readily available, 5% said *S. nigrum* and *C. maxima*, *C. pepo* and *C. moschata* and only 2.5% said all African leafy vegetables regrow quickly after being harvested. The majority (89.5% of the users) largely used the vegetables only for home consumption and only 10.5% sold wild vegetables earning a mean monthly income in the range of R200-R3000 (R1725±593.54, n=4) from sales. The vegetables were sold for R6.50 per 1kg bundle in summer and a few (5.3%) also sold *C. album* ‘seruwe’ in winter for R7 per 1kg bundle. The relationship between the number of African leafy vegetables used per household and household income (Pearson’s, r =0.159, p=0.34) was insignificant.

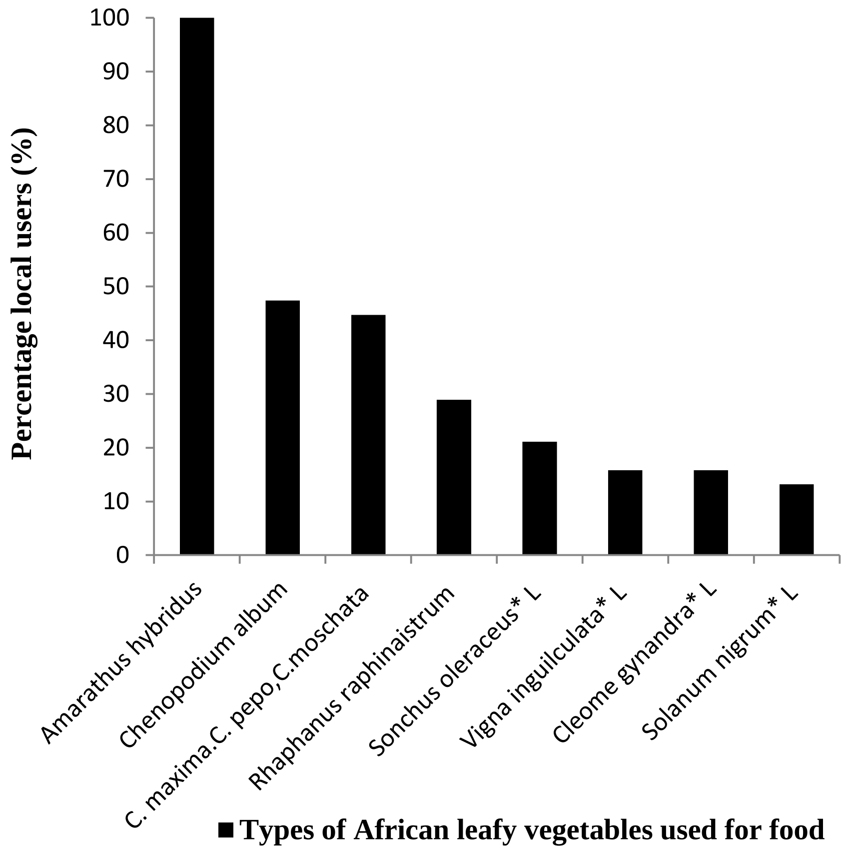

Figure 14: African leafy vegetables utilised for food by households

3.3.1 Consumption of African leafy vegetables

An overview of the consumption patterns of African leafy vegetable species commonly collected and consumed in Kanana is provided in Table 2. As observed the leaves, growth tips and tender shoots are the plant parts collected and consumed for food, with the exception of *C. maxima, C. pepo and C.moschata* 'mekopu', whose flowers were also eaten. The consumption of the plant species occurred more in summer than in winter as most of the plants were reported to grow in summer with the exception of *C. album.* Cooking methods included boiling and steaming, and ingredients such as tomatoes, onion, salt and cooking oil were also added to improve the taste. Other households further add groundnut flour made from finely ground nuts to make the meal richer by adding flavour and nutrients. The cooked leafy parts are usually eaten served with pap (maize meal that is cooked very soft like porridge) or boiled potatoes. Other households reportedly eat the cooked vegetables singly due to limited resources to purchase ingredients.

The mean individual portions per meal for the popular African leafy vegetables were highest in *C.album* (124.1g ±8.40; n=18) and food portions ranged between 88.9g and 200g, followed by *A. hybridus* with (123.8g ± 5.81; n= 38) (range: 72.4 - 200g). This vegetable was also the most frequently consumed among households, with 18.4% consuming the vegetable on a daily basis, and 44.7% consuming the vegetable once to four times per week. Similar patterns of individual food portions consumed per meal were found for *C. maxima, C.pepo* and *C.moschata* (123.1g ±7.6; n=17) (range: 75.3 -200g). Others less popular among users included *Sonchus oleraceus* L* with (122.4g ±18.2; n=8), (range: 63.4- 200g), Rhaphanus *raphinaistrum* (114.4±8.38; n=11) (range: 62 - 156g), Solanum *nigrum* L* (109.3 ±7.92; n=5), (range: 83 - 125g). This was followed by *Cleome gynandra * L* with (108.7±11.16; n=6) (range: 67.2-150g) and the least was reported for *Vigna inguilculata* L whose* average food portion was (107.5 ±5.38; n=6) and food portions ranged from 88.8g to 121.8g. There was a very strong positive relationship between household size and the quantity of African leafy vegetables a household consumed (Pearson`s, $r = 0.854$, $p<0.001$).

Table 2: Consumption patterns and modes of African leafy vegetable species commonly collected and consumed in Kanana – reported as wet mass.

Scientific Name and traditional name	Individual intake of vegetables in grams mean ± S.E (range) per average meal	Frequency consumed	Season available	Part eaten	Common preparation methods
*Amaranthus hybridus** L. "Tepe" (100%) users	123.8±5.8 (72.4-200)	1 x daily 15.8% 2 x daily 2.6% 1 x weekly 10.5% 1 x fortnightly 15.8% 1 x monthly 10.5% 1 x occasionally 10.5% 2 x weekly 7.9% 3 x weekly 13.2% 4 x weekly 13.2%	Summer	Leaves and young tender shoots	Leaves and young tender shoots are boiled/steamed, then ingredients such as cooking oil, tomatoes, salt and onion are also added and sometimes peanut flour (flour made from pounded groundnuts) is also added. The leaves are usually eaten with maize meal porridge (pap), or potatoes.
Cucurbita maxima, C.pepoand C.moschata "mekopu" (44.7%)users	123.1 ±7.63 (75.3-200)	1xDaily 11.8% 1x Weekly: 17.7% 1x Fortnightly 23.5% 1x Occasionally: 17.7% 1x monthly: 29.4%	Summer	Leaves, flowers and fruit	The leaves and flowers are either boiled or steamed; thereafter ingredients such as tomatoes, oil, salt and onion are added to enhance the taste
Chenopodium album "Seruwe" (47.4%) users	124.1 ±8.40 (88.8-200)	1x Weekly 11.1% 2 x Weekly 16.7% 3 x Weekly 11.1% 1 x Occasionally 11.1% 1 x fortnightly: 16.7% 3 x fortnightly 5.6% 1 x monthly: 27.8%	Winter	Leaves and young growth tips	Leaves and young growth tips are boiled until tender ingredients such as cooking oil, salt, onion and tomatoes, peanut flour are added
Rhaphanus raphinaistrum "Sepaile" (28.9%) users	114.4±8.34 (62-156)	1x Daily 9.1% 1x Weekly: 18.2% 2x Weekly: 18.2% 3 x Weekly: 9.1% 1x fortnightly: 27.3%	Summer	Leaves	The leaves are boiled, until they are tender, and ingredients such tomatoes, cooking oil, onion, spices and groundnut flour are

Scientific Name and traditional name	Individual intake of vegetables in grams mean ± S.E (range) per average meal	Frequency consumed	Season available	Part eaten	Common preparation methods
		1x monthly: 18.2%			added
Sonchus oleraceus L* "Lishwabi" (21.1%) users	122.4 ±18.2 (63.4-200)	2 x Weekly: 25% 3 x Weekly: 37.5% 1x fortnightly: 12.5% 1x monthly: 25%	Summer	Leaves and growth tips	The leaves and growth tips are boiled until tender, when tender water is drained, then oil, salt, onion, tomatoes are added, in some cases spices and groundnut flour are also added to enhance taste; the relish is served with potatoes or pap
Cleome gynandra L.* 'lerotho' *(15.8%) users*	108.7 ±11.2 (67.2 -150)	1x Weekly: 16.7% 2 x Weekly: 16.7% 3 x Weekly 16.7% 1x fortnightly: 33.3% 1x monthly: 16.7%	Summer	Leaves and young shoots	The leaves and young shoots are boiled, thereafter the first water is drained to remove bitterness, and another cup of water is added; when tender the water is drained and ingredients such as salt, onion, tomatoes and cooking oil are added
Vigna inguilculata L* `dinawa' *(15.8%) users*	107.5 ±5.4 (88.8-122)	1 x Weekly: 33.3% 2 x Weekly: 16.7% 1x fortnightly: 16.7% 1x occasionally: 33.3%	Summer	Leaves and growth tips	The leaves and growth tips are boiled until tender, then tomato, onions and cooking oil are added to enhance the taste; groundnut flour is also used at times to make the relish richer

Scientific Name and traditional name	Individual intake of vegetables in grams mean ± S.E (range) per average meal	Frequency consumed	Season available	Part eaten	Common preparation methods
Solanum nigrum[*] *L* "Umusobo" (13.2%) users	109.3 ±7.92(83-125)	1x Weekly: 40% 2 x Weekly: 20% 1x fortnightly: 20% 1x occasionally: 20%	Summer	Leaves and growth tips	The leaves and growth tips are boiled, water is then drained followed by the addition of salt, onions, tomatoes and cooking oil or groundnut flour is also added

3.3.2 Areas where African leafy vegetables are collected

Most respondents (84.4%) collect the wild African leafy vegetables plants from the veld (terrestrial grassland). Other areas of collection included the Schoonspruit stream (riparian zone), backyards (Figure 15), roadsides (Figure 16), wetland areas, domestic refuse dumps and the artisanal mining site. Among those that collected the plants, (4.6%) also bought the leafy vegetables from hawkers and spaza shops that sourced the vegetables from the same collection areas and also from markets; 15.6% of respondents that utilised the leafy vegetables did not harvest any of the vegetables at all, but bought them.

Figure 15*: Amaranthus hybridus* growing in the backyard of an informal house

Figure 16: *Amaranthus hybridus* growing along the roadside

3.3.3 Potential impacts of not collecting and consuming African leafy vegetables

When presented with the possible scenario of households not having access to African leafy vegetables, different concerns were raised. The results showed that 26.9% of respondents believe that they would lose a source of nutrients, 17.3% would not be affected, 15.4% depend on African leafy vegetables for food because they earn a low income and this would be a major loss of food for them, 13.5% reported not having a vegetable garden and therefore depend on these leafy vegetables for nutrients, for 11.5% the vegetables are an important traditional food and for 9.6% the African leafy vegetables are a substitute for cultivated vegetables and a further 5.8% mentioned fear of losing a source of income.

3.4 Other foodstuffs consumed by respondents

The results showed that all the surveyed households had some access to dietary selenium through various foodstuffs that can help to support the body's immunity levels against mercury toxicity (Table 3). The most commonly consumed on a daily basis were eggs

(18.4%), peanuts (27.5%) and milk (55%). Every other foodstuff was consumed at least once on a weekly basis. None reported daily consumption of meat products such as chicken, red meat or fish; the type of fish mainly used was canned pilchards. The consumption of these foodstuffs was reported by households to be on an occasional basis.

Table 3**:** Consumption of other foodstuffs

	Consumption				
Food type	**Daily (%)**	**Weekly (%)**	**Fortnightly (%)**	**Monthly (%)**	**Occasionally (%)**
Beans	0	47.5	30	20	2.5
Peanut	27.5	24.2	0	0	48.3
Chicken	0	12.5	20	25	42.5
Eggs	18.4	71.1	5.3	2.6	2.6
Red meat	0	10	15	35	40
Fish	0	13.8	25	29.6	31.6
Milk	55	42.5	0	2.5	0

Chapter 4. Mercury Concentrations in Leafy Vegetables

This chapter presents the concentrations of total mercury found in the commonly consumed leafy vegetables (cultivated and wild African leafy vegetables). The amounts of mercury ingested by consumers of these plants is then estimated using demographic and social economic data of this study, and in general using published formulae and values for typical population groupings from the literature e.g. estimated body weight (Joint FAO/WHO, 2007). The data are furthermore described in relation to international health guidelines (Joint FAO/WHO, 2007). It is important to note that variables that were beyond the scope of this study included: the amount of mercury in the cooked vegetables and the cooking water or oil used, as too many factors would impact on this (for example, the temperature, type and length of cooking, the type of cooking vessel, and the pH of the cooking medium). The amounts of mercury that are potentially absorbed by the consumers were also beyond the scope of this study (for example use of the USEPA PBET test to assess how much of a metal ingested in a foodstuff is actually absorbed in various parts of the digestive tract).

4.1. Concentration of mercury in three species of leafy vegetables

The mercury concentrations found in the three leafy vegetables commonly consumed in Kanana (*B. oleracea, S. oleracea* and *A. hybridus*) are presented in Table 4. All three species contained mercury concentrations that exceeded the WHO (1990) maximum permissible limits in food. The concentration of mercury in the leaves of the three species on a dry mass basis was in the order of *A.hybridus* (0.287 ±0.145µg/g) > *B. oleracea* (0.139 ±0.039µg/g) > *S. oleracea* (0.128 ±0.0113µg/g) (Table 4) and the maximum permissible limit is 0.02 µg/g. There was a consistent difference in the mercury concentrations of *A. hybridus* and *B. oleracea*. The mercury concentration was on average 66.7% higher in *A. hybridus* than for *B. oleracea* (Kruskal–Wallis test, H=0.0010, d.f = 1, P> 0.016; Appendix 5). Similarly, a consistent difference in the mercury concentrations in *A. hybridus* and *S. oleracea was* also observed. The mercury concentration was 76.4% higher in *A. hybridus* than for *S. oleracea* (Kruskal–Wallis test, H=3.63, d.f= 1, P> 0.016; Appendix 5). Furthermore, a variation in the mean mercury concentration between the two home grown vegetable species *B. oleracea* and *S. oleracea* was also was observed. The mean mercury concentration was 8.2% higher in *B. oleracea* than for *S.oleracea* (Kruskal–Wallis test, H=0.375, d.f= 1, P>0.016; Appendix 5)

Table 4: Concentrations of mercury in three leafy vegetable species commonly cultivated and collected in Kanana and within a radius of 7 km. Data are expressed in µg/g-dry mass (mean ± standard error (SE) the median, range and number (n) of replicate samples. Means not sharing superscript letters are significantly different from each other (Kruskal Wallis-test, α =0.016). Maximum permissible limits in dry mass are as per WHO & FAO 0.02µg/g (WHO, 1990)

Vegetable species	n	Mean (µg/g)	Median (µg/g)	SE	Range (Min-Max)	% Moisture content
A. hybridus	55	0.287[a]	0.106	0.145	0.0001 -7.822	73.9
B. oleracea	8	0.139[b]	0.104	0.039	0.013 -0.356	84.4
S. oleracea	16	0.128[c]	0.127	0.011	0.020 -0.215	86.5

4.2 Mercury concentrations (µg/g) in *A. hybridus* from various harvesting locations

The results showed varying concentrations of mercury in *A. hybridus* from five different growing locations. The concentration of mercury in the leaves of *A. hybridus* from the five growing locations on a dry mass basis was in the decreasing order of *A. hybridus* from artisanal mine tailings (0.820 ±0.725µg/g) > *A. hybridus* from Schoonspruit (riparian zone) (0.668 ±0.596µg/g) > *A. hybridus* from roadside (0.125±0.010µg/g) > *A.hybridus* from domestic refuse dumps (0.121±0.013µg/g) > *A. hybridus* from the veld (terrestrial grassland) (0.116 ±0.008µg/g) (Table 6). *A. hybridus* on a dry mass basis from all five growing locations had mercury concentrations that exceeded the WHO (1990) maximum permissible limits of 0.02µg/g in food. The mean concentrations of mercury in *A. hydridus* from the roadside and that from the Schoonspruit (riparian zone) were not statistically different from each other (Kruskal–Wallis test, H=8.830, d.f= 1, P< 0.01). Similarly there was no variation in the mean concentrations of mercury between *A.hybridus* from the Schoonspruit (riparian zone) and from the veld (terrestrial grassland) (Kruskal–Wallis test, H=8.877, d.f= 1, P=0.0029), P<0.01. For the rest of the combinations, there was a variation in the mean concentrations of mercury P>0.01 (Table 5) and (Appendix 5).

Table 5: Kruskal–Wallis test analyses results for comparison of means between treatment groups

Comparison of mean mercury concentration in the leaves of *A. hybridus* from five different growing locations using the pair-wise Wilcoxon Mann Whitney test		
Combinations of groups	Growing locations	(Kruskal–Wallis test,)
(1 ;2)	**Artisanal mine tailings and roadside**	**H=0.325; d.f= 1; P=0.57.**
(1;3)	**Artisanal mine tailings and rubbish dumps**	**H=0.267, d.f= 1, P=0.61).**
(1;4)	**Artisanal mine tailings and Schoonspruit stream (riparian zone)**	**H=0.765, d.f= 1, P=0.38).**
(1;5)	**Artisanal mine tailings and veld (terrestrial grassland)**	**H=0.621, d.f= 1, P=0.43).**
(2;3)	**Roadside and rubbish dumps**	**H=0.510, d.f= 1, P=0.48).**
(2;4)	**Roadside and stream banks (riparian zone)**	**H=8.830, d.f= 1, P=0.0030).**
(2;5)	**Roadside and veld (terrestrial grassland)**	**H=0.149, d.f= 1, P=0.70).**
(3;4)	**Rubbish dumps and Schoonspruit stream (riparian zone)**	**H=6.469, d.f= 1, P=0.011).**
(3;5)	**Rubbish dumps and veld (terrestrial grassland)**	**H=0.149, d.f= 1, P=0.70).**
(4;5)	**Schoonspruit stream (riparian zone) and veld (terrestrial grassland)**	**H=8.877, d.f= 1, P=0.0029).**

Table 6: Concentrations of mercury in leaves of A. hybridus (tepe) collected from five types of growing locations. Data are expressed in µg/g-dry mass (mean ± standard error (SE); the median, range and number (n) of replicate samples are included. Means not sharing superscript letters are significantly different from each other (Kruskal Wallis-test, α =0.01). Permissible levels in food are as per FAO &WHO 0.02µg/g (WHO, 1990).

Treatment	n	Mean	Median	SE	Range (Min-Max)
Artisanal mine tailings	3	0.820[a]	0.164	0.725	0.0288 -2.267
Road side	7	0.125[bf]	0.116	0.010	0.0980 - 0.177
Domestic refuse dump	6	0.121[c]	0.116	0.013	0.0930 - 0.166
Schoonspruit (riparian zone)	13	0.668[dfh]	0.084	0.596	0.0001 -7.822
Veld (terrestrial grassland)	26	0.116[eh]	0.109	0.008	0.0552 - 0.263

4.3 Mercury concentrations (µg/g) in *B.oleracea* from home gardens and markets

B. oleracea from the two different sources contained mercury concentrations that exceeded the WHO (1990) maximum permissible limits of 0.02 µg/g.in food. The concentration of mercury on a dry mass basis was in the decreasing order of *B. oleracea* from markets (in Orkney) (0.212±0.057 µg/g) > *B. oleracea* from home gardens (0.066± 0.020 µg/g) (Table 7). The mercury concentration was on average 83.4% higher in *B. oleracea* from the markets (in Orkney) than for *B. oleracea* from home gardens (Wilcoxon. Mann-Whitney test, $H=4.08$, d.f=1, $P>0.025$: Appendix 5).

Table 7: Mercury concentrations (µg/g dry mass) in home-grown and marketed *B.oleracea* (cabbage).Data are expressed in µg/g-dry mass (mean ± SE); the median, range and number (n) of replicate samples are included. Permissible levels in food are as per FAO &WHO 0.02µg/g

Treatment	n	Mean	Median	SE	Range (Min-Max)
Home garden	4	0.066	0.071	0.020	0.0130 - 0.109
Markets in Orkney	4	0.212	0.196	0.057	0.0997 - 0.356

4.4 Mercury concentrations (µg/g) in *S. oleracea* from home gardens and markets

S. oleracea in dry mass from the two different sources contained mercury concentrations that exceeded the WHO (1990) maximum permissible limits of 0.02µg/g in food. The concentration of mercury on a dry mass basis was in the decreasing order of *S.oleracea* from home gardens (0.133± 0.014µg/g) > *S. oleracea* from markets in Orkney (0.107 ± 0.009µg/g) (Table 8). The mercury concentration was on average 21.7% higher in *S. oleracea* from home gardens than for *S. oleracea* from markets in Orkney (Wilcoxon. Mann-Whitney test, H=1.10, d.f=1, P>0.025; Appendix 5)

Table 8: Mercury concentrations (µg/g dry mass) in home-grown and marketed *S. oleracea* (spinach) Data are expressed in µg/g-dry mass (mean ± SE); the median, range and number (n) of replicate samples are included. Permissible levels in food are as per FAO &WHO 0.02µg/g.

Treatment	**n**	**Mean**	**Median**	**SE**	**Range (Min-Max)**
Home garden	13	0.133	0.132	0.014	0.0203 - 0.2145
Markets in Orkney	3	0.107	0.100	0.009	0.0942 - 0.1250

4.5 Mercury ingestion by adults in Kanana via leafy vegetables

From the data collected from the field and the use of the prescribed formulae, the contributions of the leafy vegetables to the dietary mercury ingestion among the surveyed subpopulation were determined (Table 9). It is important to note that the vegetables were consumed at different intervals (days) and not all at the same meal, nor all on the same day. Similarly these leafy vegetables were consumed with varying frequency during the week (Tables 1-2). The weight of individuals was not measured during surveys and adult weight is estimated assuming a body weight of 60 kg (Joint FAO/WHO, 2007). Mercury consumption determined here was compared with the reference dose (RfDo) of 0.0016µg/g set out by the WHO/FAO (2007) as a safe limit; this dose is assumed not to have an effect on even the most vulnerable subpopulation which is the foetus (Joint FAO/WHO, 2007). The estimated daily mercury doses from consuming *A. hybridus* was in the following decreasing order; 0.144µg/g dry mass from artisanal mine dumps > 0.117µg/g dry mass from Schoonspruit stream (riparian zone) > 0.022µg/g dry mass from roadside > 0.021µg/g from domestic dump > 0.020µg/g from veld. The estimated mercury doses from consuming *B. oleracea* were in the following decreasing order of 0.038µg/g dry mass for marketed cabbage > 0.012µg/g dry-mass for home gardens. The estimated mercury ingestion from consuming *S. oleracea* were in the following decreasing order of 0.023µg/g dry mass from home gardens > 0.018µg/g dry mass from markets. Thus dietary mercury ingestion by adults from consuming each of these leafy vegetable species sourced from different locations exceeded the WHO 1990 RfDo of 0.0016µg/g by one order of magnitude. Whereas, the average yearly doses would be exceeded by as much as four and three orders of magnitude through *A hybridus* from the artisanal mine dumps and Schoonspruit, the areas of highest contamination.

Table 9: Daily mean mercury intake by adults in the study area from each of the food crops

Species	Individual portions per average meal,	Location/Treatment	Amount of mercury that people consume per average meal. (µg/g)	Average yearly dose (µg/g)
A. hybridus	124g (fresh mass per average meal, when uncooked).	Artisanal Mine Dump	0.144	52.56
		Schoonspruit (riparian zone)	0.117	42.71
		Roadside	0.022	8.03
		Domestic refuse dump	0.021	7.67
		Veld	0.020	7.3
B. oleracea	128g (fresh mass per average meal, when uncooked).	Market in Orkney	0.038	13.87
		Home garden	0.012	4.38
S. oleracea	120g (fresh mass per average meal, when uncooked).	Home garden	0.023	8.40
		Market in Orkney	0.018	6.57

WHO 2007: Permissible Tolerable Weekly Intake (PTWI) 0.0016µg/g bw

Chapter 5. Discussion and conclusions

This chapter presents a synthesis of the demographic, social economic, cultivation and consumption patterns of three commonly consumed leafy vegetables, which this study has established contain detectable mercury in order to determine if there are potential health risks associated with their consumption. The chapter draws conclusions from the synthesis and makes recommendations for future research.

5.1 Household profiles

Kanana is located downstream of the industrial area of the town of Klerksdorp, and adjacent to both historical and current gold and uranium mining operations, as well as artisanal gold mining activities. The sample comprised a subpopulation with a diverse culture, with SeSotho being the main home language. Other languages such as isiXhosa, isiZulu and SeTswana are also spoken but among the minority. A total of 207 individuals were interviewed in the 40 households selected for the study, each with at least five individuals living under one roof, most of them between the age ranges of 11-20 years (Figure 6). The average age was 26.7 years demonstrating a young growing population in the area, which is consistent with the findings reported by prior studies (Statistics South Africa, 2011; Golder Associates. AngloGold Ashanti, 2009). The proportions of children below the age of 10 years (23.2%) and the substantial proportion of female individuals (54.5%) demonstrated that the subpopulation under study in Kanana is more vulnerable to the effects of mercury toxicity than any other subgroup. Prior research has shown that the susceptibility to and effects of metal toxicity mainly depend on factors such as age, the amount consumed, the physiology of the consumer, the dietary status of the individual, body weight and gender, with women who are pregnant being much more at risk and children generally being more vulnerable than adults under the same duration of exposure (Liu *et al*., 2005; Howard, 2002; WHO, 1996; Castoldi *et al*., 2001). It is important to note that the variables of body weight, physiology of the consumer and if a woman was pregnant or not are beyond the scope of this study. The body weight used in this study was based on standard assumptions from an assessment of the effects of chemicals on human health and the environment (Joint FAO/WHO, 2007).

Worldwide, poorer households and communities tend to be more vulnerable to environmental risks and economic shocks than their wealthier counterparts (UNDP, 2003;

Botha and Weiersbye, 2010). They often live in marginalised areas with poor housing conditions, lack or have limited access to clean water and proper sanitation and are often faced with food insecurity (Sutton, 2012). They are also less able to mount political or legal challenges to phenomena that impact on the quality of their lives, including environmental damage, for reasons that are well documented in the human development literature (UNDP, 2003). The generally low levels of education among poor households or communities are a factor in this regard: Education plays a key role in changing the expectations that people have on government and instils the political skills and resources required to defy government decisions (UNDP, 2013). By implication, therefore, low levels of education mean that poor people are also limited in their ability to challenge private sector decisions and actions or to enforce their rights in relation to environmental damage.

5.2 Education, employment and income

Education, employment and income are strongly linked variables, with education playing a major role in determining the employment opportunities available and income attainable. This study has established that there were low levels of education in the area among adults, with over half (52.9%) having attained only some secondary schooling as the highest level of education. Due to the low levels of education and lack of skills, unemployment is prevalent in the area with over half (53.7%) of the adults being unemployed. To earn a livelihood, the majority (75.4%) of the working population are self-employed in jobs that do not require any tertiary education. Among the 22.9% employed in jobs that require a tertiary education, mining (12.3%) was the main source of employment. Findings of this study were consistent with prior studies (Golder Associates. AngloGold Ashanti, 2009; Statistics South Africa, 2007; Statistics South Africa, 2011).

In general, the surveyed households were largely living in poverty. Household incomes were low and were mainly supplemented by state welfare grants, with 27.5% having an income of less than R4001 per month. The high levels of poverty among households resulted in the majority (83%) being dependent on state welfare grants. The grant with the highest number of beneficiaries was the child support grant (79.4%). The findings of this study support those of Botha *et al.*, (2013), who found similar evidence of low incomes among households that were mainly supplemented by social welfare grants in the study area.

5.3 Housing conditions and water sources

Kanana households included families that lived in formal dwellings entirely made of brick to smaller formal Reconstruction and Development Programme (RDP) houses. Others lived in informal dwellings entirely made from corrugated iron sheets. Similar findings of the housing conditions were reported by (Statistics South Africa, 2007; Golder Associates. AngloGold Ashanti, 2009).

Contamination of natural water resources in the Witwatersrand Basin region with contaminants and metal/loids, including mercury is well documented (Naicker *et al*., 2003; Cukrowska *et al*., 2010; Lusilao, 2012). Use of contaminated water for domestic purposes such as drinking, cooking and washing are some of the pathways through which humans are exposed to contaminants and metal/loids (Sutton, 2012). Similarly, research has shown that the irrigation of vegetable gardens with contaminated water can significantly contaminate vegetables and further expose humans to metal toxicity (Mapanda *et al*., 2005). The results of this study showed that no household used water from the contaminated Schoonspruit stream or borehole water for either domestic use or gardening. All houses in the survey had access to municipal water via taps from within their houses and properties. This study revealed similar findings to those reported by (Golder Associates. AngloGold Ashanti, 2009; Statistics South Africa, 2011). Therefore, the human health risk of metal toxicity via these pathways is potentially reduced. This is in contrast to other studies conducted in the region, where domestic use and irrigation of edible plants with contaminated water by residents living in contaminated areas were reported (Sutton *et al*., 2006; Sutton, 2012) and in other countries in Africa; Ghana (Asante *et al*., 2007); Zimbabwe (Muchuweti *et al*., 2006).

World-wide the primary major pathway through which humans are exposed to toxic metals is via ingestion of contaminated foodstuffs including vegetables.

5.4 The importance of cultivated and African leafy vegetables to household food security

In this present study, the surveyed poor subpopulation was found to be among others predominantly reliant on subsistence activities such as the cultivation and gathering of wild edible plants for food safety. This trend is similar to those reported in previous studies in South Africa (Shackleton *et al.*, 2001; Shackleton *et al*., 1995). Households cultivated their vegetables locally within their private properties mainly in the backyards. This study identified similar findings as those of (Golder Associates. AngloGold Ashanti, 2009). Households without home gardens accessed their vegetables from their counterparts with gardens, local markets and also from markets outside the study area such as Orkney. The African leafy vegetables were gathered locally from communal harvesting areas which included the veld (terrestrial grassland), the banks of the Schoonspruit stream (riparian zone), roadsides, artisanal mining areas and domestic refuse dumps. Similar findings of collection areas for the wild edible plants in the area were reported by (Botha, 2013).

5.4.1 Cultivated vegetable species utilised for food among the surveyed households

The cultivation and use of these vegetables were largely for household consumption with *S. oleracea* (spinach) and *B. oleracea* (cabbage) being the most popularly utilised leafy vegetable species. These findings support those of Golders Associates. AngloGold Ashanti (2009) and Bvenura and Afolayan (2012) both of whom found the two leafy vegetables to be the most commonly cultivated in home gardens. Intermittent water supply, nutrient-poor soils and insect damage are the three primary problems that hinder vegetable cultivation among the surveyed sub population group of Kanana. Similar findings in the area were reported by (Botha, 2013). The productivity and fertility of gardens are improved by composting and use of animal manure. A study in the Eastern Cape on home gardens presents similar findings (Bvenura and Afolayan, 2012).

5.4.2 Consumption patterns of home-grown vegetables

In this present study the individual food portions of each type of leafy vegetables are slightly lower than the 202g individual vegetables portions per day as those reported in similar green vegetables in other countries Dar es Salaam, Tanzania (Othman, 2001) and also below the daily 301g and 345g of individual vegetable portions consumed per person per day in Tianjin, China (Wang *et al*., 2005). This could be because in the study area, the vegetables were prepared using various ingredients which further added volume to the cooked vegetables. There was a relatively strong relationship between household size and quantity of home grown vegetables consumed per household per meal (Pearson`s, $r = 0.595$, $p < 0.001$). From the estimated daily mercury ingestion via these vegetables, consumers who frequently consumed larger portions (more than average) of contaminated vegetables would be placed more at risk of mercury toxicity than their counterparts who consumed infrequently and in smaller portions.

5.4.3 African leafy vegetables utilised for food among households

The surveyed households utilised a variety of African leafy vegetables (wild plants), these provided vital nutrition and food security to the majority as they were largely gathered for home consumption and only the minority (10.5%) both ate and on occasion sold the vegetables to supplement their household incomes. Similar findings of the importance and use of the leafy vegetables among poor households were reported by (Shackleton, 2003;

Shackleton *et al*., 1998; Shackleton and Shackleton, 2004; Dovie *et al*., 2007). The relationship between household attributes such as income and the dependence on African leafy vegetables for food was not significant (Pearson`s, r=0.159; p=0.34; Appendix 4). Other researchers have also found this relationship to be insignificant (Paumgarten, 2006; Dovie *et al*., 2007).

A. hybridus was the most popularly utilised wild plants species. This study supports the findings of prior studies in the area (Botha *et al.,* 2013) and in other provinces in South Africa Limpopo and KwaZulu-Natal provinces (Faber *et al*., 2010). The use of the African leafy vegetables in the area was mostly in summer than in winter. Similar findings in South Africa were reported by (Shackleton, 2003). It seems, therefore, that the risk of mercury toxicity is likely to be lower in winter than in summer, because the vegetables do not all grow in winter and are therefore not available for consumption in this season.

5.4.4 Consumption patterns of African leafy vegetables

The average individual food portion for all the African leafy vegetables, were not substantially different from each other. The daily individual vegetable food portions were within the same ranges as those observed in a similar study reported by Etale and Drake (2013), but were below the recommended ≥400g/d, daily intake of fruits and vegetables as set by (WHO, 2004). There was a strong positive relationship in this study between quantities of African leafy vegetables consumed by households and household size (Pearson`s, r =0.854, p<0.0001; Appendix 4). This trend was also observed by (Dovie *et al*., 2004) in Limpopo Province, who also demonstrated that a positive relationship of (r=0.4, p<0.1) existed between the two variables.

5.4.5 Mode of consumption of vegetables

The cooking methods examined in this study were common across all vegetable species and varied from steaming to boiling; with the addition of ingredients, such as tomatoes, cooking oil, onion, groundnut flour and salt to enhance the taste and to make the food richer. Similar cooking methods for the similar plant species were reported by (Jansen Van Rensburg *et al*., 2007). The mercury intake in the cooked vegetables is unknown, but likely to be lower than for the un-cooked vegetables as mercury is volatile (Lusilao, 2012). The vegetables were either consumed singly as a relish or mixed with maize meal porridge or boiled potatoes. Findings of this study were consistent with prior studies in the area (Botha and Weiersbye, 2010), in KwaZulu-Natal Province (Faber *et al*., 2010) and in other provinces of South Africa (Jansen Van Rensburg *et al*., 2007).

5.5 Access to other sources of foodstuff

Literature has shown that dietary selenium has a protective action against mercury toxicity, in that it delays the onset of mercury toxicity or reduces the severity of its toxic effects (Cuvin-Aralar and Furness, 1991; Whanger, 1992; Chang and Suber, 1982; Sakamoto *et al*., 2013). In this present study households had some access to dietary intake of selenium albeit limited, through the consumption of other foodstuff. Similar findings of these foodstuffs being at least consumed among 186 households in the area were reported by (Golder Associates. AngloGold Ashanti, 2009). Thus, the health risks to the surveyed subpopulation are potentially reduced, because of the consumption of dietary selenium.

5.6 Comparison of mercury concentrations in the three leafy vegetable species

Plants growing in metal-contaminated environments can passively absorb or actively take up toxic metals to variable degrees depending on species and quality of soil (Chunilall *et al*., 2005). In this present study, among the three different leafy vegetable species, the highest mercury concentrations were observed in *A. hybridus* (wild plant leafy vegetable) and the lowest concentrations in *S. oleracea* (cultivated vegetable). Statistically the mercury concentration was on average 74.6% significantly higher in *A. hybridus* than for *S. oleracea* ($P > 0.016$) and 66.7% significantly higher than for *B. oleracea* ($P > 0.016$). Between the two cultivated species the mercury concentration was on average 8.2% slightly higher in *B. oleracea* than for *S. oleracea* ($P>0.016$). Apart from the vegetable species type, the results of varying concentrations of mercury in the different vegetable species observed in this study are indicative of the concentrations that are bioavailable and bioaccessible for plant uptake in the various sampling sites. Artisanal mine dumps and Schoonspruit stream are among the popularly common areas where locals collect *A. hybridus* and samples from these two sampling sites showed the highest contaminant load. Results of previous studies performed in the area (Lusilao, 2012; Cukrowska *et al*., 2010) have also demonstrated that artisanal mine dumps are severely polluted with high concentrations of mercury from gold amalgamation. Similarly, the Schoonspruit, a tributary of the Vaal river, is also known to be polluted from run-off from these artisanal mining dumps and sewage spills within Kanana, as well as historical and current gold mine operations, tailings spills, and various industrial discharge from industries in Klerksdorp (Anglo Gold Ashanti Ltd, 2009). This therefore would have added substantially to the overall higher contaminant load observed in *A. hybridus* than the other two leafy vegetable species.

5.7 Mercury concentrations in the leafy vegetables versus the FAO/WHO guidelines.

The mean mercury concentrations in *A. hybridus* harvested from various locations exceeded the 0.02µg/g guidelines set by the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO, 1990). Although the concentrations in *A. hybridus* exceeded the WHO guidelines, they were found to be substantially lower than the 7.12µg/g dry-mass reported in the leaves of *A.hybridus* found growing in contaminated soils in

KwaZulu-Natal, (Chunilall *et al*., 2005). Similarly, the mean concentration of mercury in *B. oleracea* sourced from the markets and home-gardens also both exceeded the WHO limits, however, they were substantially lower than 9.33±1.15µg/g dry mass reported in India (Lenka *et al*., 1992) and slightly higher than the value of 0.033±23.8µg/g dry-mass reported in Tuscany, Italy by (Barghigiani and Ristori, 1993). In *S. oleracea* the mean mercury concentrations in marketed spinach and home-grown vegetables were 0.13µg/g dry-mass and 0.11µg/g dry-mass respectively. They both exceeded the safe limits according to the (WHO 1990) standards. These were substantially higher than the value of 0.0022 ±0.00085µg/g dry mass reported by Temmerman *et al*., (2009) in the same vegetable species in Belgium. In general, the results have shown that all the leafy vegetables species in dry mass had higher concentrations that exceeded thresholds prescribed by the (WHO, 1990).

5.8 Exposure to mercury from consuming leafy vegetables

Based on leafy vegetables quantities consumed, dietary mercury ingestion by adults exceeded the recommended limit of 0.0016µg/g by one order of magnitude through the consumption of all vegetable species. The recommended limit of 0.0016µg/g is the dose assumed not to have an effect on the foetus, the most vulnerable subpopulation, according to (Joint FAO/WHO, 2007). In this present study, the annual dose can be as much as four and three orders of magnitude more. The threats of long term mercury exposure on the surveyed population would result in health implications such as damage to the central nervous system and chronic intoxication as reported in Indonesia by (Bose-O'Reilly *et al*., 2010a). The degrees of vulnerability to mercury toxicity could not be determined for children because quantities consumed by children and body weight of individuals were beyond the scope of this study. The finding by (Etale and Drake, 2013) Etale and Drake (2013) on their assessment of the risks of urban agriculture and metal exposure to the consumers from consuming locally grown produce in Rwanda, suggests that the children in the surveyed subpopulation (which is also a poor subpopulation) may eat from the same bowl as adults, and may therefore be more vulnerable to mercury toxicity than adults because of their lower body weights (Joint FAO/WHO, 2007).

5.9 Conclusions and recommendations

Conclusions

In conclusion the results of this study are summarised as follows.

- The subpopulation group surveyed was a young population whose household attributes showed high levels of poverty, whose means of survival are mainly supported by state welfare grants. In terms of food security, many were dependent on plants that have been gathered from the wild for food as well as those cultivated in their home hardens. *B. oleracea* and *S. oleracea* were the two most commonly cultivated and consumed leafy vegetables among households and *A. hybridus* was the most utilised African leafy vegetable among those collected from the wild. All the three leafy vegetables in dry mass exhibited mercury concentrations that exceeded the WHO (1990) prescribed limits in foodstuff. Based on all vegetable consumption patterns (e.g. quantities consumed) dietary mercury ingestion by adults exceeded the recommended (Joint FAO/WHO, 2007) prescribed thresholds by one order of magnitude with yearly dose exceeding by as much as four and three orders of magnitude. The greatest exposure to dietary mercury in the surveyed subpopulation was through *A.hybridus* sourced from the artisanal mine dumps and Schoonspruit (riparian zones), the areas of highest mercury contamination.
- Under current conditions, the subpopulation groups under study in Kanana are at risk of mercury toxicity as a result of consuming contaminated leafy vegetables (cultivated and wild). Results have further demonstrated that

vegetables sourced from markets in Orkney outside Kanana also had high concentrations of mercury. This indicates the pollution that is within the broader region of the Witwatersrand Basin.

- In addition, the existence of human health risk from metal toxicity via food ingestion from both cultivated and gathered plants is indicative that the subpopulation under study in Kanana is closely intertwined with the biophysical aspects of the environment. Issues such as deteriorating environmental quality as a result of contamination in the area including the whole (Vaal Reefs) region would therefore need special attention.
- Local regulators, development agencies and mining companies must be made aware of the potential health risks that may exist in the study area, for them to apply corrective and preventative measures, and be also sensitised to the fact that Kanana is only one of many towns likely to be impacted by mercury pollution.
- To ensure food safety and to protect the residents from metal toxicity, awareness programmes are recommended to educate communities living in the vicinity of mines to avoid the areas of highest contamination, such as the artisanal mine dumps and (in this case) the Schoonspruit stream, and to control the artisanal use of mercury
- Alternative safe gardening methods such as vegetable container gardening using soil collected from unpolluted areas can be implemented for the community (Botha *et al*., 2013). Productivity can be increased by adding composite or animal manure (a soil improvement technique already practiced by residents).

- Long-term plans should include the remediation of all contaminated harvesting sites including home gardens where feasible.

Recommendations for future studies

1. Inclusion of weight of individuals, the quality of cooking water, concentrations of mercury in the cooked plant, seasonality in plant mercury content and quantities of how much children individually consume per meal are very important variables in estimating risk of exposure to mercury. It is recommended that further research be undertaken that includes these important variables.
2. The high mercury concentration observed in the three leafy vegetable species is indicative of the concentrations available in the environment for plant uptake, and is a cause for concern. It is therefore, recommended that further research on other metal/loids (e.g. manganese, vanadium. arsenic, chromium, and uranium known to occur in the region) also be investigated in leafy vegetables.
3. The market vegetables sourced (in Orkney) outside the study area but within the region also showed high mercury concentrations. It is recommended that further studies be conducted in the broader region.

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Appendix 1: Approval of study by the Ethics Committee -Wits University

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON MEDICAL)
H110926 Bubala

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER H110926**
PROJECT TITLE	Assessment of risk associated with the consumption of wild and cultivated plants in Kanana North West Province
INVESTIGATOR(S)	Ms J Bubala
SCHOOL/DEPARTMENT	APES
DATE CONSIDERED	16 September 2011
DECISION OF THE COMMITTEE	Approved Unconditionally
EXPIRY DATE	30 September 2011
DATE 07 October 2011	**CHAIRPERSON** (Professor R Thornton)

cc; Dr J Botha

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

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 to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature

12 / 10 / 2011
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix 2: Field Questionnaire

Project title: Assessment of human consumption of wild and cultivated plants in Kanana, a gold mining town in North West Province.

Good day, my name is……………………………………………………………

Introduction: I am…..……..……………… from Witwatersrand University, We are working with AngloGold Ashanti to find out what wild food plants and home grown vegetables are eaten by people in this community and where you collect and harvest them.

This survey is a follow up of other projects in Kanana because Wits and AngloGold Ashanti value people. One project was looking at the health of the environment; another was looking at the different types of plants people from the area harvest from the veld and use in their homes. As you know plants are very important in our daily lives, for they provide us nutrients such as food.

We would like to invite you to participate in the survey, which involves answering some questions about the types of plants you harvest for food in this area. We will also need background information about your household to help us understand how you use the plants in this area, in the same way people researching a cold drink would ask about your household. The information we receive is confidential though.

The interview will probably take about 20 minutes. You are welcome to stop answering questions at any time, or if you feel uncomfortable with any question, feel free to tell us you would rather not answer that particular one. You are also welcome to ask questions of your own at any stage. Do you have any questions so far?

Participation is voluntary and you can choose to participate or not. The information will be used for a master's project at the University and for a report to the mine. We will also be submitting a report to the City Of Matlosana and reporting back to the councillors in Kanana. The City of Matlosana has given permission for us to be working here. The answers you give us will be treated confidentially. Are you available to take part in the research now?

If you are happy to participate in the study, please could you sign your name here. This form is separate, and won't be attached to the questionnaire, so that you remain anonymous.

Signature…………………………………………………………………………

Date: ……………………………………………………………………………….

Place……………… Ward……… Interviewer………………… Date…………….. Home language…………………… Gender of respondents………………Materials house constructed from? Walls………………………………Roof………………………………….No. of rooms ……………… Approximate size of house ………………………… Number of Radios……… Fridge………….. Television…………..Cell phones…………………

SECTION A: Vegetable Growing and Consumption

1. Do you have a vegetable garden where you grow vegetables? Yes…..... No………. If yes, where is the vegetable garden? If Yes Name or description of location of vegetable garden ………………………If No where do you get your vegetables from…………………………………

2. What fruit and vegetables do you grow? **Interviewer, get people to list the vegetables they grow before completing the rest of the table.**

Name of the vegetable/fruit	What do you do with the vegetable /fruit that you grow? Eat? Sell? Both eat and sell?	Which vegetable part do you eat? Leaves? Stems? Roots? Whole plant/fruit?	How many times a week do you eat the vegetable/fruit?	How do you prepare the vegetable/fruit?	How much do you cook for a meal?

3. If you sell the vegetables where do you sell them…………………………………………… Do you sell every week? Yes………….. No…………………..If not every week how often?

…………………………………………………………………………………………

4. About how much do you earn each week selling the plants? ……………………………And how much a month………………………………Do you sell throughout the year or only in certain seasons?.. If only in certain seasons which months?..

……………………………………………………………………………………..

5. Do you experience problems in your vegetable garden? Yes………….. No………………If Yes what types of problems?

…………………………………………………………………………………………

…………………………………………………………………………………………

6. Where does the water that you use to irrigate/water your vegetables come from?

……………………………………………………………………………………………..

……………………………………………………………………………………………..

7. Do you use fertiliser in your vegetable garden? Yes…...…….. No ……..........If yes how often……………………………………………………………………………………..

………………………What type of fertiliser? ……………………………………………......

8. If you stopped having a vegetable garden, would it affect you and your household? Yes……, No………How ?...

…………………………………………………………………………………………

....

SECTION B: Edible Wild Plants

9. Do you collect or use plants that you collect from the veld for food? Yes…………………No……………………

10. **Which plants from the veld (wild) do you use for food? Interviewers, get people to list the wild plants they eat and then complete the rest of the table**

Name of wild edible plant	Which part do you eat? Leaves? Stems? Roots? Whole plant?	Season the plant is available?	Do you harvest or buy this plant?	Where?	How many times a week do you eat the wild edible plant	How do you prepare the edible wild plants?	How much do you cook for a meal?

15. Do you sell plants that you harvest from the wild? Yes ………No………..If Yes Where do you sell them…………………………………………… Do you sell every week? Yes………….. No…………………..If not every week how often?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. Which wild plants do you sell?

Species	Season the plant is available?	Price /unit (eg bunch/checkers bag)	Weight of the unit

17. About how much do you earn each week selling the plants? ……………………………And how much a month………………………………..Do you sell throughout the year or only in seasons the plant is available?..

……………………………………………………………………………………………..

18. Which edible wild plants regrow faster after the previous harvest?

……………………………………………………………………………………….......

……………………………………………………………………………………………...

19. If you stopped collecting wild edible plants, would it affect you and your household? Yes…….. No……How?...

....

....

....

Section C: Household Information

20. Occupation of people in the household **NB (** If people say they are unemployed, ask them if they earn money any other way, for example, selling something, even if it's only occasional piece work**)**

Family member (son, daughter, wife, husband, granddaughter, grandson, grandmother, grandfather),	Ages	Occupation	Level of education (primary, secondary, tertiary, other (please specify)	Income	Frequency (monthly/weekly daily etc.)

21. Grants

Type	How many	How much per month?

22. What are your sources of water for domestic use?

Cooking……………………………………………………………………………………….

Drinking………………………………………………………………………………………

23. How many times a week do you eat:

Food group	Frequency (… times per ……)
Read meat	
Milk	
Eggs	
Chicken	
Fish	
Beans	
Peanut	

We have come to the end of the interview.

Thank You very much for your time and participation. I have asked you a lot of questions. Do you have any questions for me

Appendix 3: 79 composite leafy vegetable samples analysed for this study.

Sample LAB ID	Code	Species	Tissue	% Moisture Content	% Dry Mass	Dry Mass Basis	
						Hg (μg kg^{-1}) or ppb	Hg (μg g^{-1}) or ppm
3	11a+b	Amaranthus hybridus	Shoot	73.7	26.3	2267	2.267
4	9	Amaranthus hybridus	Shoot	73.38	26.62	0.1412	0.0001412
5	20a	Amaranthus hybridus	Shoot	74.55	25.45	28.78	0.02878
6	1	Amaranthus hybridus	Shoot	73.7	26.3	7822	7.822
1s	Ju-S 1.2	Amaranthus hybridus	Shoot	73.38	26.62	98.0	0.098
2s	Ju-S 3.1	Amaranthus hybridus	Shoot	74.55	25.45	112.9	0.1129
3s	Ju-S 3.2	Amaranthus hybridus	Shoot	73.7	26.3	116.3	0.1163
4s	Ju-S 4.1	Amaranthus hybridus	Shoot	73.38	26.62	117.9	0.1179
22s	Ju-S 16.1	Amaranthus hybridus	Shoot	74.55	25.45	135.7	0.1357
23s	Ju-S 16.2	Amaranthus hybridus	Shoot	73.7	26.3	130.4	0.1304
27s	Ju-S 17.4	Amaranthus hybridus	Shoot	73.38	26.66	106.0	0.106
28s	Ju-S 17.5	Amaranthus hybridus	Shoot	74.55	25.45	133.6	0.1336
29c	Ju-S 18.1	Amaranthus hybridus	Shoot	73.7	26.3	262.5	0.2625
30s	Ju-S 18.2	Amaranthus hybridus	Shoot	73.38	26.62	96.1	0.0961
31s	Ju-S 19.1	Amaranthus hybridus	Shoot	74.55	25.45	94.4	0.0944
32s	Ju-S 19.2	Amaranthus hybridus	Shoot	73.7	26.3	55.2	0.0552
33s	Ju-S 20.1	Amaranthus hybridus	Shoot	73.38	26.62	123.8	0.1238
34s	Ju-S 20.2	Amaranthus hybridus	Shoot	73.7	26.3	108.1	0.1081
35s	Ju-S 21.1	Amaranthus hybridus	Shoot	73.38	26.62	109.5	0.1095
36s	Ju-S 21.2	Amaranthus hybridus	Shoot	74.55	25.46	106.0	0.106
37s	Ju-S 22.1	Amaranthus hybridus	Shoot	73.7	26.3	108.7	0.1087
38s	Ju-S 22.2	Amaranthus hybridus	Shoot	74.55	25.45	128.8	0.1282
39s	Ju-S 23.1	Amaranthus hybridus	Shoot	73.38	26.62	99.8	0.0998
40s	Ju-S 23.2	Amaranthus hybridus	Shoot	74.55	25.45	116.4	0.1164
41s	Ju-S 24.1	Amaranthus hybridus	Shoot	73.7	26.3	81.9	0.0819
42s	Ju-S 24.2	Amaranthus hybridus	Shoot	73.38	26.62	113.3	0.1133
43s	Ju-S 26.1	Amaranthus hybridus	Shoot	74.55	25.45	99.8	0.0988
44s	Ju-S 26.2	Amaranthus hybridus	Shoot	73.7	26.3	64.1	0.0641
45s	Ju-S 27.1	Amaranthus hybridus	Shoot	73.38	26.62	72.8	0.0728
46s	Ju-S 27.2	Amaranthus hybridus	Shoot	74.55	25.45	100.4	0.1004
47s	JB-S7a	Amaranthus hybridus	Shoot	73.7	26.3	85.4	0.0854
52s	JB-S 2a	Amaranthus hybridus	Shoot	73.38	26.62	94.8	0.0948
53s	JB-S 3	Amaranthus hybridus	Shoot	74.55	25.45	72.9	0.0729
54s	JB-S 4a	Amaranthus hybridus	Shoot	73.7	26.3	67.5	0.0675
55s	JB-S 4b	Amaranthus hybridus	Shoot	73.38	26.62	83.9	0.0839
56s	JB-S 5a	Amaranthus hybridus	Shoot	74.55	25.45	87.3	0.0873
57s	JB-S 5b	Amaranthus hybridus	Shoot	73.7	26.3	82.8	0.0828
58s	JB-S 6a+b	Amaranthus hybridus	Shoot	73.38	26.62	83.8	0.0838
59s	JB-S 8a	Amaranthus hybridus	Shoot	74.55	25.45	101.0	0.101
60s	JB-S 15a	Amaranthus hybridus	Shoot	73.7	26.3	136.2	0.1362
61s	JB-S 15b	Amaranthus hybridus	Shoot	73.38	26.62	93.0	0.093
62s	JB-S 16a	Amaranthus hybridus	Shoot	74.55	25.45	95.1	0.0951
63s	JB-S 16b	Amaranthus hybridus	Shoot	73.7	26.3	94.9	0.0949
64s	JB-S 17a	Amaranthus hybridus	Shoot	73.38	26.62	166.4	0.1664
65s	JB-S 18a	Amaranthus hybridus	Shoot	73.7	26.3	118.0	0.118
66s	JB-S 18b	Amaranthus hybridus	Shoot	73.7	26.3	114.2	0.1142

Sample LAB ID	Code	Species	Tissue	% Moisture Content	% Dry Mass	Dry Mass Basis	
						Hg (µg kg^{-1}) or ppb	Hg (µg g^{-1}) or ppm
67s	JB-S 18c	Amaranthus hybridus	Shoot	73.38	26.62	226.1	0.2261
68s	JB-S 19b	Amaranthus hybridus	Shoot	74.55	25.45	147.3	0.1473
69s	JB-S 19c	Amaranthus hybridus	Shoot	73.7	26.3	108.4	0.1084
70s	JB-S 21a	Amaranthus hybridus	Shoot	73.33	26.62	90.4	0.0904
71s	JB-S 21b	Amaranthus hybridus	Shoot	74.55	25.45	145.0	0.0145
72s	JB-S2.1	Amaranthus hybridus	Shoot	73.7	26.3	177.2	0.1772
80s	JB-S 18	Amaranthus hybridus	Shoot	73.38	26.62	137.4	0.1374
83s	JB-S12	Amaranthus hybridus	Shoot	74.55	25.45	164.4	0.1644
85s	JU-S 25.2	Amaranthus hybridus	Shoot	73.7	26.3	117.7	0.1177
5s	Ju-S 5.1	Brassica Oleracea	Shoot	83.4	14.6	108.7	0.1087
24s	Ju-S 17.1	Brassica Oleracea	Shoot	85.2	14.8	71.7	0.0717
48s	Ju-S NGP 29.2	Brassica Oleracea	Shoot	85	15	69.9	0.0699
78s	JB-Cabbage 4 Klerksdorp Market	Brassica Oleracea	Shoot	83.4	16.6	146.8	0.1468
81s	JB-S15 Cabbage Costol do Sol Klerksdorp	Brassica Oleracea	Shoot	83.4	14.4	356.1	0.3561
82s	JB-14 (Costa do sol Klerksdorp)	Brassica Oleracea	Shoot	85.2	16.6	99.7	0.0997
84s	JB-Cabbage 6 Klerksdorp Market	Brassica Oleracea	Shoot	85.2	16.6	245.5	0.2455
2	29.1	Cabbage	Shoot	83.4	16.6	13.01	0.01301
1	11.1	Spinach oleracea	Shoot	88.4	14.8	20.26	0.02026
7s	Ju-S 6.2	Spinacia oleracea	Shoot	87.2	12.8	131.7	0.1317
8s	Ju-S 6.3	Spinacia oleracea	Shoot	87.6	12.4	116.8	0.1168
11s	Ju-S 9.1	Spinacia oleracea	Shoot	88.4	13.8	156.2	0.1562
12s	Ju-S 9.2	Spinacia oleracea	Shoot	88.4	7.2	133.7	0.1337
13s	Ju-S 10.1	Spinacia oleracea	Shoot	87.6	12.4	128.9	0.1289
14s	Ju-S 10.2	Spinacia oleracea	Shoot	87.6	12.4	121.7	0.1217
15s	Ju-S 11.1	Spinacia oleracea	Shoot	88.4	10.4	104.8	0.1048
16s	Ju-S 11.2	Spinacia oleracea	Shoot	81.8	18.2	144.3	0.1443
19s	Ju-S 15.1	Spinacia oleracea	Shoot	82.4	17.6	214.5	0.2145
20s	Ju-S 15.2	Spinacia oleracea	Shoot	89.8	13.8	191.2	0.1912
50s	Ju-S NGP 29.5	Spinacia oleracea	Shoot	85.8	14.2	178.2	0.1782
51s	Ju-S NGP 29.6	Spinacia oleracea	Shoot	84.4	15.6	91.4	0.0914
74s	JB-1 Spinach	Spinacia oleracea	Shoot	84.4	7.6	94.2	0.0942
76s	JB-2	Spinacia oleracea	Shoot	87.2	12.8	125.0	0.125

Sample LAB ID	Code	Species	Tissue	% Moisture Content	% Dry Mass	Dry Mass Basis	
						Hg (µg kg^{-1}) or ppb	Hg (µg g^{-1}) or ppm
	Spinach Klerksdorp						
77s	JB-4 Spinach Muldersdrift Klerksdorp	Spinacia oleracea	Shoot	84.4	8.2	100.4	0.1004

Appendix 4: Statistical data (Pearson's R correlation analyses results)

1. **Relationship between household size and quantity consumed of home garden vegetables**

Correlation Analysis

The CORR Procedure

2 Variables:	Size Quantity consumed

Simple Statistics							
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Size	91	5.43956	1.95055	495.00000	2.00000	13.00000	HH
Quantityconsumed	91	506.75824	336.16426	46115	5.00000	1540	g

Pearson Correlation Coefficients, N = 91 Prob > |r| under H0: Rho=0		
	HHSize	Quantity consumed
Size HH size	1.00000	0.59532 <.0001
Quantity consumed g	0.59532 <.0001	1.00000

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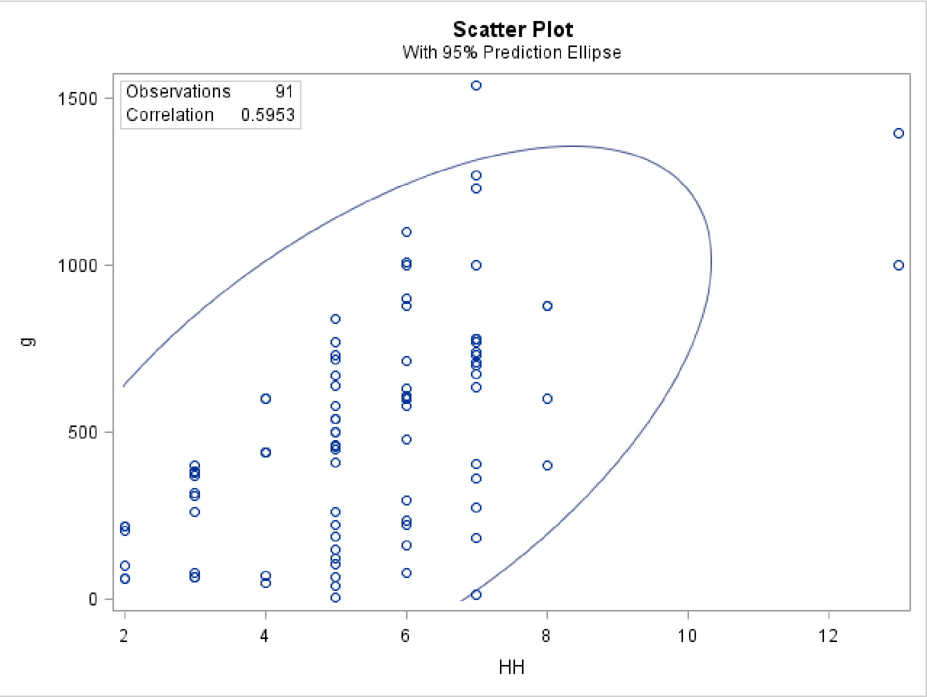
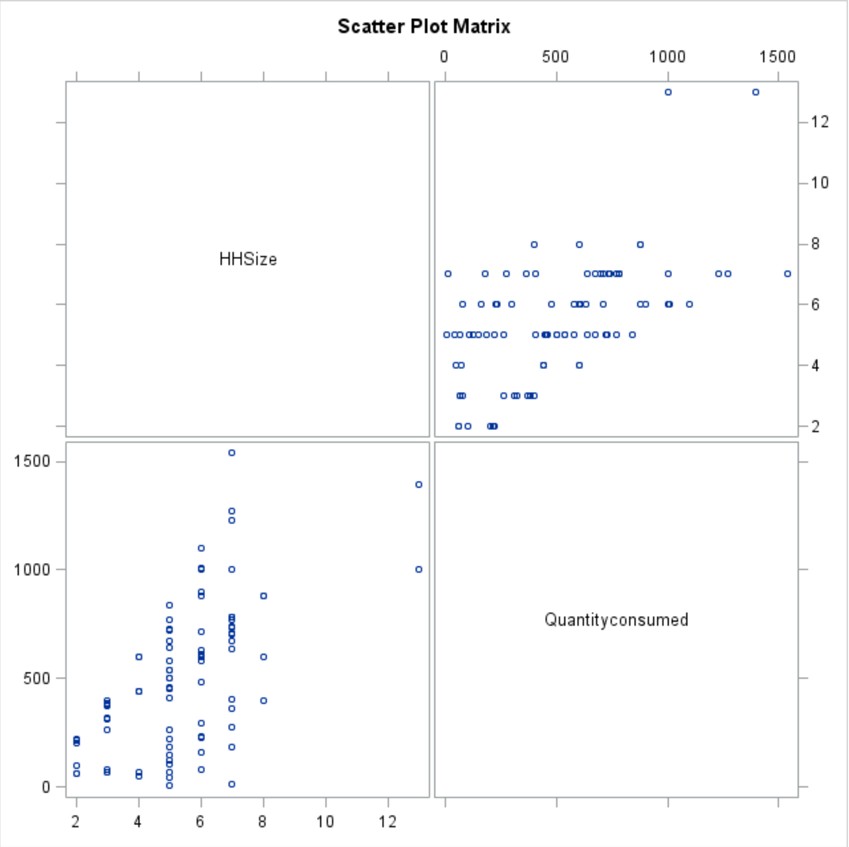
Correlation Analysis

The CORR Procedure





Generated by the SAS System ('Local', X64_7HOME) on 08 June 2013 at 3:21:28 PM

2. **Relationship between African leafy vegetable quantity consumed and Household size (Sample size n=38)**

Correlation Analysis

The CORR Procedure

2 Variables:	QuantitycookedHH HHsize

Simple Statistics							
Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
QuantitycookedHH	109	622.67890	378.53391	581.00000	200.00000	2600	QH
HHsize	109	5.09174	1.91263	5.00000	2.00000	13.00000	H

Pearson Correlation Coefficients, N = 109 Prob > |r| under H0: Rho=0		
	QuantitycookedHH	HHsize
QuantitycookedHH QH	1.00000	0.85402 <.0001
HHsize H	0.85402 <.0001	1.00000

Spearman Correlation Coefficients, N = 109 Prob > |r| under H0: Rho=0		
	QuantitycookedHH	HHsize
QuantitycookedHH QH	1.00000	0.73117 <.0001
HHsize H	0.73117 <.0001	1.00000

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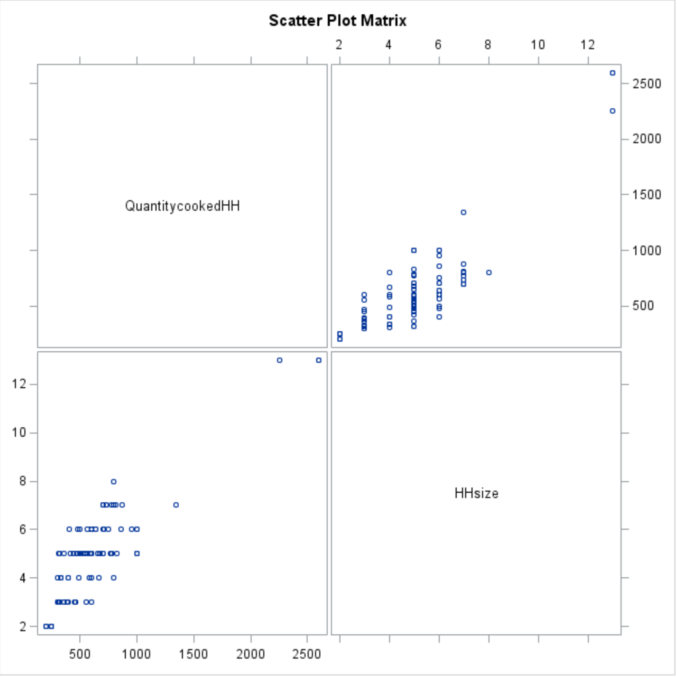
Correlation Analysis

The CORR Procedure



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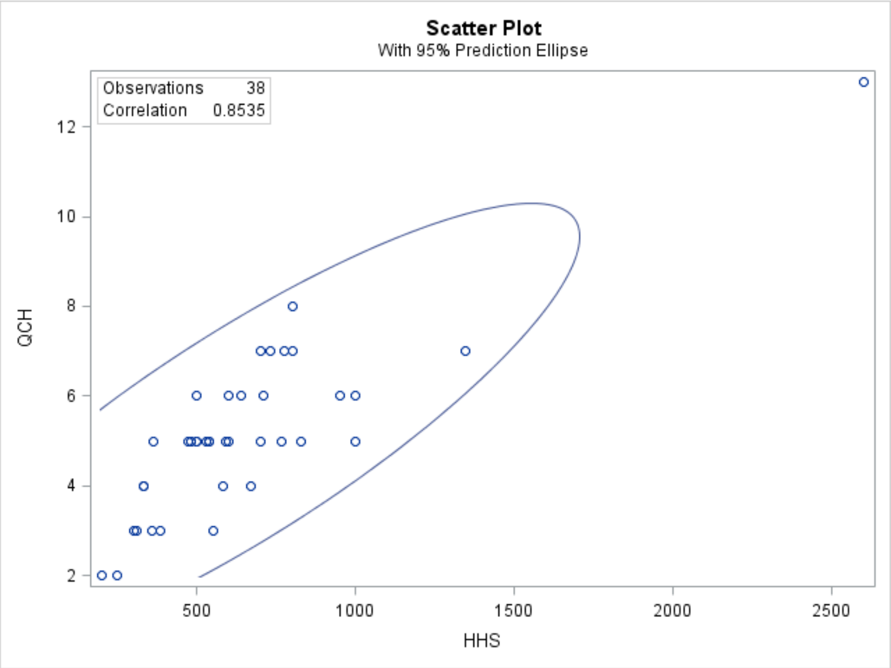
Correlation Analysis

The CORR Procedure



Correlation Analysis

The CORR Procedure

2 Variables:HouseholdSize QuantityConsumedHH

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Minimum**	**Maximum**	**Label**
HouseholdSize	38	653.18421	401.77033	24821	200.00000	2600	HHS
QuantityConsumedHH	38	5.18421	1.94318	197.00000	2.00000	13.00000	QCH

Pearson Correlation Coefficients, N = 38 Prob > |r| under H0: Rho=0		
	HouseholdSize	**QuantityConsumedHH**
HouseholdSize HHS	1.00000	0.85351 <.0001
QuantityConsumedHH QCH	0.85351 <.0001	1.00000

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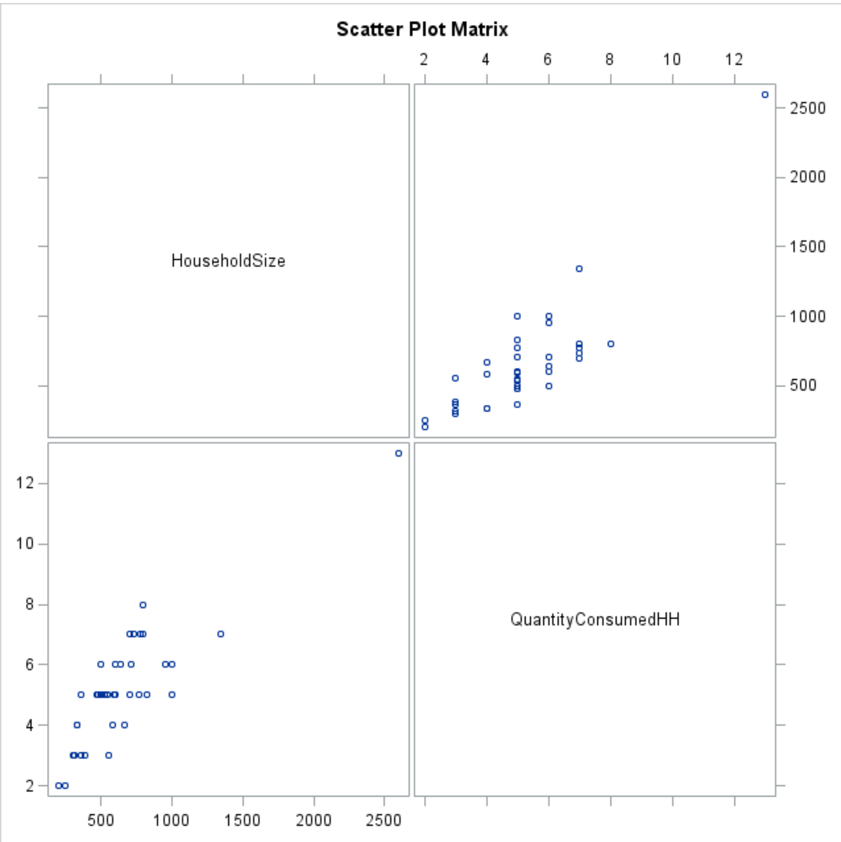

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3 Relationship between African leafy vegetable dependence/use and total household Income (sample size 38)

Correlation Analysis

The CORR Procedure

2 Variables:	Proportion of African leafy Vegetable and Total Income

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Proportion of African leafy Vegies	38	2.84211	1.10347	108.00000	1.00000	5.00000	Proportion of African leafy Vegetables used per Household
Total Income	38	6609	3908	251140	1100	18000	

Pearson Correlation Coefficients, N = 38
Prob > |r| under H0: Rho=0

	Proportion of African leafy Vege	Total Income
Proportion of African leafy Vegetables Proportion of African leafy Vegetables used per Household	1.00000	0.15933 0.3393
Total Income	0.15933 0.3393	1.00000

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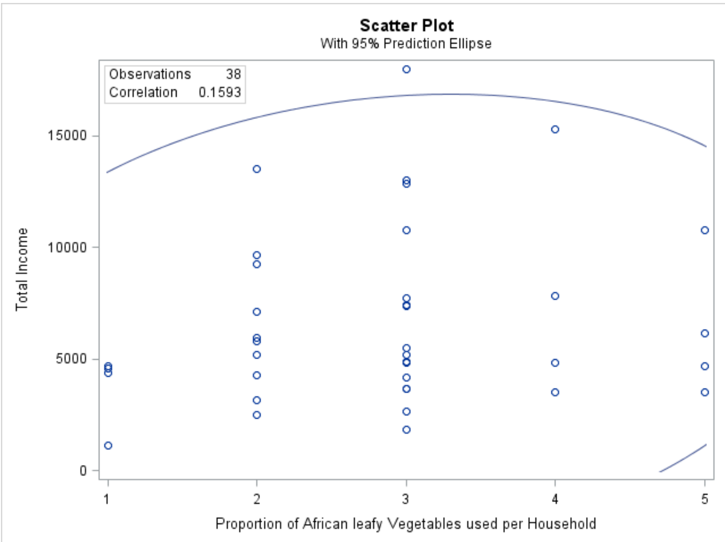
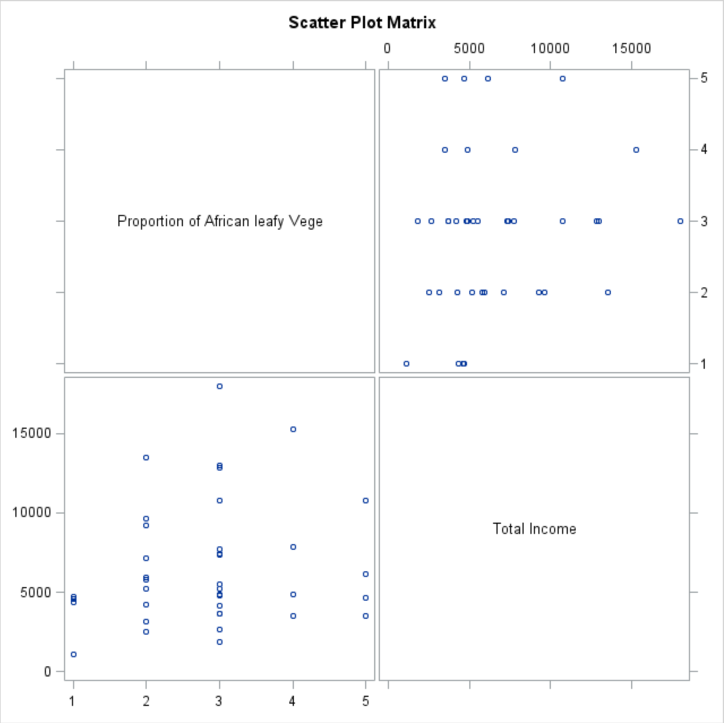
Correlation Analysis

The CORR Procedure





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Appendix 5: Statistical data (the Kruskal-Wallis test analyses results)

1.1 Comparing mercury concentrations in cabbage leaves from the market and home-gardens

Wilcoxon-Mann-Whitney Test

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Vegetables Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	4	11.0	18.0	3.464102	2.750
2	4	25.0	18.0	3.464102	6.250

Wilcoxon Two-Sample Test	
Statistic	11.0000
Normal Approximation	
Z	-1.8764
One-Sided Pr < Z	0.0303
Two-Sided Pr > |Z|	0.0606
t Approximation	
One-Sided Pr < Z	0.0514
Two-Sided Pr > |Z|	0.1027
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	4.0833
DF	1
Pr > Chi-Square	0.0433

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Vegetable Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	4	1.0	2.0	0.755929	0.250
2	4	3.0	2.0	0.755929	0.750

Median Two-Sample Test	
Statistic	1.0000
Z	-1.3229
One-Sided Pr < Z	0.0929

Two-Sided Pr > |Z|	0.1859

Median One-Way Analysis	
Chi-Square	1.7500
DF	1
Pr > Chi-Square	0.1859

Generated by the SAS System ('Local', X64_7HOME) on 20 May 2013 at 4:13:04 PM

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Van der Waerden Scores (Normal) for Variable Vegetable Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	4	-2.276367	0.0	1.141375	-0.569092
2	4	2.276367	0.0	1.141375	0.569092

Van der Waerden Two-Sample Test	
Statistic	-2.2764
Z	-1.9944
One-Sided Pr < Z	0.0231
Two-Sided Pr > |Z|	0.0461

Van der Waerden One-Way Analysis	
Chi-Square	3.9777
DF	1
Pr > Chi-Square	0.0461

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Savage Scores (Exponential) for Variable Vegetable Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	4	-2.288095	0.0	1.228488	-0.572024
2	4	2.288095	0.0	1.228488	0.572024

Savage Two-Sample Test	
Statistic	-2.2881
Z	-1.8625
One-Sided Pr < Z	0.0313
Two-Sided Pr > |Z|	0.0625

Savage One-Way Analysis	
Chi-Square	3.4690
DF	1
Pr > Chi-Square	0.0625

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Vegetable Classified by Variable Group			
Group	**N**	**EDF at Maximum**	**Deviation from Mean at Maximum**
1	4	0.7500	0.750
2	4	0.0000	-0.750
Total	8	0.3750	
Maximum Deviation Occurred at Observation 2			
Value of Vegetable at Maximum = 0.07170			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.375000	D	0.750000
KSa	1.060660	Pr > KSa	0.2106

Cramer-von Mises Test for Variable Vegetable Classified by Variable Group		
Group	**N**	**Summed Deviation from Mean**
1	4	0.250
2	4	0.250

Cramer-von Mises Statistics (Asymptotic)			
CM	0.062500	CMa	0.500000

Kuiper Test for Variable Vegetable Classified by Variable Group		
Group	**N**	**Deviation from Mean**
1	4	0.750
2	4	0.000

Kuiper Two-Sample Test (Asymptotic)					
K	0.750000	Ka	1.060660	Pr > Ka	0.7420

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1.2 Comparing mercuryconcentrations in Spinach leaves from the market and home-gardens

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Spinach Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	13	121.0	110.50	7.433034	9.307692
2	3	15.0	25.50	7.433034	5.000000

Wilcoxon Two-Sample Test	
Statistic	15.0000
Normal Approximation	
Z	-1.3453
One-Sided Pr < Z	0.0893
Two-Sided Pr > |Z|	0.1785
t Approximation	
One-Sided Pr < Z	0.0993
Two-Sided Pr > |Z|	0.1985
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	1.9955
DF	1
Pr > Chi-Square	0.1578

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Van der Waerden Scores (Normal) for Variable Spinach Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	13	1.724213	0.0	1.364773	0.132632
2	3	-1.724213	0.0	1.364773	-0.574738

Van der Waerden Two-Sample Test	
Statistic	-1.7242
Z	-1.2634
One-Sided Pr < Z	0.1032
Two-Sided Pr > |Z|	0.2065

Van der Waerden One-Way Analysis	
Chi-Square	1.5961
DF	1
Pr > Chi-Square	0.2065

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Savage Scores (Exponential) for Variable Spinach Classified by Variable Group					
Group	**N**	**Sum of Scores**	**Expected Under H0**	**Std Dev Under H0**	**Mean Score**
1	13	1.859015	0.0	1.432003	0.143001
2	3	-1.859015	0.0	1.432003	-0.619672

Savage Two-Sample Test	
Statistic	-1.8590
Z	-1.2982
One-Sided Pr < Z	0.0971
Two-Sided Pr > |Z|	0.1942

Savage One-Way Analysis	
Chi-Square	1.6853
DF	1
Pr > Chi-Square	0.1942

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Spinach Classified by Variable Group			
Group	**N**	**EDF at Maximum**	**Deviation from Mean at Maximum**
1	13	0.384615	-0.416025
2	3	1.000000	0.866025
Total	16	0.500000	
Maximum Deviation Occurred at Observation 15			
Value of Spinach at Maximum = 0.1250			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.240192	D	0.615385
KSa	0.960769	Pr > KSa	0.3144

Cramer-von Mises Test for Variable Spinach Classified by Variable Group		
Group	**N**	**Summed Deviation from Mean**
1	13	0.055138
2	3	0.238932

Cramer-von Mises Statistics (Asymptotic)			
CM	0.018379	CMa	0.294071

Kuiper Test for Variable Spinach Classified by Variable Group		
Group	N	Deviation from Mean
1	13	0.153846
2	3	0.615385

Kuiper Two-Sample Test (Asymptotic)					
K	0.769231	Ka	1.200961	Pr > Ka	0.5334

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1.3 SARS output: Comparing the mean concentrations between A. hybridus from five different locations

1. **Combination 1 (artisanal and roadside)**

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	19.0	16.50	4.387482	6.333333
Roadside	7	36.0	38.50	4.387482	5.142857

Wilcoxon Two-Sample Test	
Statistic	19.0000
Normal Approximation	
Z	0.4558
One-Sided Pr > Z	0.3243
Two-Sided Pr > |Z|	0.6485
t Approximation	
One-Sided Pr > Z	0.3297
Two-Sided Pr > |Z|	0.6593
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.3247
DF	1
Pr > Chi-Square	0.5688

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	2.0	1.50	0.763763	0.666667
Roadside	7	3.0	3.50	0.763763	0.428571

Median Two-Sample Test	
Statistic	2.0000
Z	0.6547
One-Sided Pr > Z	0.2563
Two-Sided Pr > |Z|	0.5127

Median One-Way Analysis	
Chi-Square	0.4286
DF	1
Pr > Chi-Square	0.5127

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Van der Waerden Scores (Normal) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	0.604585	0.0	1.204362	0.201528
Roadside	7	-0.604585	0.0	1.204362	-0.086369

Van der Waerden Two-Sample Test	
Statistic	0.6046
Z	0.5020
One-Sided Pr > Z	0.3078
Two-Sided Pr > |Z|	0.6157

Van der Waerden One-Way Analysis	
Chi-Square	0.2520
DF	1
Pr > Chi-Square	0.6157

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Savage Scores (Exponential) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score

ATM	3	1.457937	0.0	1.284487	0.485979
Roadside	7	-1.457937	0.0	1.284487	-0.208277

Savage Two-Sample Test	
Statistic	1.4579
Z	1.1350
One-Sided Pr > Z	0.1282
Two-Sided Pr > |Z|	0.2564

Savage One-Way Analysis	
Chi-Square	1.2883
DF	1
Pr > Chi-Square	0.2564

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group			
Group	N	EDF at Maximum	Deviation from Mean at Maximum
ATM	3	0.333333	-0.635085
Roadside	7	0.857143	0.415761
Total	10	0.700000	
Maximum Deviation Occurred at Observation 8			
Value of Categories at Maximum = 0.14730			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.240040	D	0.523810
KSa	0.759072	Pr > KSa	0.6119

Cramer-von Mises Test for Variable Categories Classified by Variable Group		
Group	N	Summed Deviation from Mean
ATM	3	0.115000
Roadside	7	0.049286

Cramer-von Mises Statistics (Asymptotic)			
CM	0.016429	CMa	0.164286

Kuiper Test for Variable Categories Classified by Variable Group		
Group	N	Deviation from Mean
ATM	3	0.333333
Roadside	7	0.523810

Kuiper Two-Sample Test (Asymptotic)					
K	0.857143	Ka	1.242118	Pr > Ka	0.4728

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2. Combination 2 (artisanal and rubbish Dump site)

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Category Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	17.0	15.0	3.872983	5.666667
Rubbish dump	6	28.0	30.0	3.872983	4.666667

Wilcoxon Two-Sample Test

Statistic	17.0000
Normal Approximation	
Z	0.3873
One-Sided Pr > Z	0.3493
Two-Sided Pr > |Z|	0.6985
t Approximation	
One-Sided Pr > Z	0.3543
Two-Sided Pr > |Z|	0.7086

Z includes a continuity correction of 0.5.

Kruskal-Wallis Test

Chi-Square	0.2667
DF	1
Pr > Chi-Square	0.6056

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Category Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	2.0	1.333333	0.745356	0.666667
Rubbish dump	6	2.0	2.666667	0.745356	0.333333

Median Two-Sample Test

Statistic	2.0000

Z	0.8944
One-Sided Pr > Z	0.1855
Two-Sided Pr > |Z|	0.3711

Median One-Way Analysis	
Chi-Square	0.8000
DF	1
Pr > Chi-Square	0.3711

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Category Classified by Variable Group

Group	N	EDF at Maximum	Deviation from Mean at Maximum
ATM	3	0.333333	-0.577350
Rubbish dump	6	0.833333	0.408248
Total	9	0.666667	
Maximum Deviation Occurred at Observation 9 Value of Category at Maximum = 0.13740			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)

KS	0.235702	D	0.500000
KSa	0.707107	Pr > KSa	0.6994

Cramer-von Mises Test for Variable Category Classified by Variable Group

Group	N	Summed Deviation from Mean
ATM	3	0.098765
Rubbish dump	6	0.049383

Cramer-von Mises Statistics (Asymptotic)

CM	0.016461	CMa	0.148148

Kuiper Test for Variable Category Classified by Variable Group

Group	N	Deviation from Mean
ATM	3	0.333333
Rubbish dump	6	0.500000

Kuiper Two-Sample Test (Asymptotic)

K	0.833333	Ka	1.178511	Pr > Ka	0.5671

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3. Combination 3 (artisanal and Schoonspruit)

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Category Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	32.0	25.50	7.433034	10.666667
Schoonspruit	13	104.0	110.50	7.433034	8.000000

Wilcoxon Two-Sample Test

Statistic	32.0000
Normal Approximation	
Z	0.8072
One-Sided Pr > Z	0.2098
Two-Sided Pr > |Z|	0.4195
t Approximation	
One-Sided Pr > Z	0.2161
Two-Sided Pr > |Z|	0.4322

Z includes a continuity correction of 0.5.

Kruskal-Wallis Test

Chi-Square	0.7647
DF	1
Pr > Chi-Square	0.3819

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Category Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	2.0	1.50	0.806226	0.666667
Streambank	13	6.0	6.50	0.806226	0.461538

Median Two-Sample Test

Statistic	2.0000
Z	0.6202
One-Sided Pr > Z	0.2676
Two-Sided Pr > |Z|	0.5351

Median One-Way Analysis

Chi-Square	0.3846
DF	1
Pr > Chi-Square	0.5351

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Category Classified by Variable Group

Group	N	EDF at Maximum	Deviation from Mean at Maximum
ATM	3	0.333333	-0.829941
Streambank	13	0.923077	0.398691
Total	16	0.812500	

Maximum Deviation Occurred at Observation 13
Value of Category at Maximum = 0.1010

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)

KS	0.230184	D	0.589744
KSa	0.920737	Pr > KSa	0.3647

Cramer-von Mises Test for Variable Category Classified by Variable Group

Group	N	Summed Deviation from Mean
ATM	3	0.150391
Streambank	13	0.034706

Cramer-von Mises Statistics (Asymptotic)

CM	0.011569	CMa	0.185096

Kuiper Test for Variable Category Classified by Variable Group

Group	N	Deviation from Mean
ATM	3	0.179487
Streambank	13	0.589744

Kuiper Two-Sample Test (Asymptotic)

K	0.769231	Ka	1.200961	Pr > Ka	0.5334

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4. Combination 4 (artisanal mine dump and veld)

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Category Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	56.0	45.0	13.962520	18.666667

Veld	26	379.0	390.0	13.962520	14.576923
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	56.0000
Normal Approximation	
Z	0.7520
One-Sided Pr > Z	0.2260
Two-Sided Pr > |Z|	0.4520
t Approximation	
One-Sided Pr > Z	0.2292
Two-Sided Pr > |Z|	0.4583
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.6207
DF	1
Pr > Chi-Square	0.4308

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Category Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
ATM	3	2.0	1.448276	0.834027	0.666667
Veld	26	12.0	12.551724	0.834027	0.461538
Average scores were used for ties.					

Median Two-Sample Test	
Statistic	2.0000
Z	0.6615
One-Sided Pr > Z	0.2541
Two-Sided Pr > |Z|	0.5083

Median One-Way Analysis	
Chi-Square	0.4376
DF	1
Pr > Chi-Square	0.5083

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Category Classified by Variable Group

Group	N	EDF at Maximum	Deviation from Mean at Maximum
ATM	3	0.333333	-0.915797
Veld	26	0.923077	0.311081
Total	29	0.862069	
Maximum Deviation Occurred at Observation 4			
Value of Category at Maximum = 0.13570			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.179603	D	0.589744
KSa	0.967189	Pr > KSa	0.3068

Cramer-von Mises Test for Variable Category Classified by Variable Group

Group	N	Summed Deviation from Mean
ATM	3	0.216464
Veld	26	0.024977

Cramer-von Mises Statistics (Asymptotic)			
CM	0.008326	CMa	0.241440

Kuiper Test for Variable Category Classified by Variable Group

Group	N	Deviation from Mean
ATM	3	0.333333
Veld	26	0.589744

Kuiper Two-Sample Test (Asymptotic)					
K	0.923077	Ka	1.513862	Pr > Ka	0.1669

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5. Combination 5 (roadside and rubbish dump)

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Roadside	7	54.0	49.0	7.0	7.714286
Rubbish dump	6	37.0	42.0	7.0	6.166667

Wilcoxon Two-Sample Test	
Statistic	37.0000
Normal Approximation	
Z	-0.6429

One-Sided Pr < Z	0.2602
Two-Sided Pr > |Z|	0.5203
t Approximation	
One-Sided Pr < Z	0.2662
Two-Sided Pr > |Z|	0.5324
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.5102
DF	1
Pr > Chi-Square	0.4751

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Roadside	7	3.0	3.230769	0.932643	0.428571
Rubbish dump	6	3.0	2.769231	0.932643	0.500000

Median Two-Sample Test	
Statistic	3.0000
Z	0.2474
One-Sided Pr > Z	0.4023
Two-Sided Pr > |Z|	0.8046

Median One-Way Analysis	
Chi-Square	0.0612
DF	1
Pr > Chi-Square	0.8046

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group

Group	N	EDF at Maximum	Deviation from Mean at Maximum
Roadside	7	0.000000	-0.610558
Rubbish dump	6	0.500000	0.659478
Total	13	0.230769	

Maximum Deviation Occurred at Observation 8
Value of Categories at Maximum = 0.09510

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)

KS	0.249259	D	0.500000
KSa	0.898717	Pr > KSa	0.3945

Cramer-von Mises Test for Variable Categories Classified by Variable Group

Group	N	Summed Deviation from Mean
Roadside	7	0.075232
Rubbish dump	6	0.087771

Cramer-von Mises Statistics (Asymptotic)

CM	0.012539	CMa	0.163004

Kuiper Test for Variable Categories Classified by Variable Group

Group	N	Deviation from Mean
Roadside	7	0.214286
Rubbish dump	6	0.500000

Kuiper Two-Sample Test (Asymptotic)

K	0.714286	Ka	1.283881	Pr > Ka	0.4141

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6. Combination 6. Roadside and Schoonspruit

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Roadside	7	111.0	73.50	12.619429	15.857143
Streambank	13	99.0	136.50	12.619429	7.615385

Wilcoxon Two-Sample Test

Statistic	111.0000
Normal Approximation	
Z	2.9320
One-Sided Pr > Z	0.0017
Two-Sided Pr > |Z|	0.0034
t Approximation	
One-Sided Pr > Z	0.0043
Two-Sided Pr > |Z|	0.0086

Z includes a continuity correction of 0.5.

Kruskal-Wallis Test

Chi-Square	8.8305
DF	1

Pr > Chi-Square	0.0030

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Roadside	7	7.0	3.50	1.094243	1.000000
Streambank	13	3.0	6.50	1.094243	0.230769

Median Two-Sample Test

Statistic	7.0000
Z	3.1986
One-Sided Pr > Z	0.0007
Two-Sided Pr > |Z|	0.0014

Median One-Way Analysis

Chi-Square	10.2308
DF	1
Pr > Chi-Square	0.0014

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group

Group	N	EDF at Maximum	Deviation from Mean at Maximum
Roadside	7	0.000000	-1.455163
Streambank	13	0.846154	1.067798
Total	20	0.550000	

Maximum Deviation Occurred at Observation 11
Value of Categories at Maximum = 0.09480

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)

KS	0.403590	D	0.846154
KSa	1.804908	Pr > KSa	0.0030

Cramer-von Mises Test for Variable Categories Classified by Variable Group

Group	N	Summed Deviation from Mean
Roadside	7	0.728393
Streambank	13	0.392212

Cramer-von Mises Statistics (Asymptotic)

CM	0.056030	CMa	1.120604

Kuiper Test for Variable Categories Classified by Variable Group		
Group	N	Deviation from Mean
Roadside	7	0.076923
Streambank	13	0.846154

Kuiper Two-Sample Test (Asymptotic)
K0.923077Ka1.968990Pr > Ka0.0125

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7. Combination 7. Roadside and Veld

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Rubbish dump	6	107.0	99.0	20.710417	17.833333
Veld	26	421.0	429.0	20.710417	16.192308
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	107.0000
Normal Approximation	
Z	0.3621
One-Sided Pr > Z	0.3586
Two-Sided Pr > |Z|	0.7172
t Approximation	
One-Sided Pr > Z	0.3599
Two-Sided Pr > |Z|	0.7197
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.1492
DF	1
Pr > Chi-Square	0.6993

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Rubbish dump	6	3.0	3.0	1.121635	0.50
Veld	26	13.0	13.0	1.121635	0.50
Average scores were used for ties.					

Median Two-Sample Test	
Statistic	3.0000
Z	0.0000
One-Sided Pr < Z	0.5000
Two-Sided Pr > |Z|	1.0000

Median One-Way Analysis	
Chi-Square	0.0000
DF	1
Pr > Chi-Square	1.0000

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group			
Group	**N**	**EDF at Maximum**	**Deviation from Mean at Maximum**
Rubbish dump	6	0.500000	-0.842012
Veld	26	0.923077	0.404490
Total	32	0.843750	
Maximum Deviation Occurred at Observation 7 Value of Categories at Maximum = 0.13570			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.165132	D	0.423077
KSa	0.934129	Pr > KSa	0.3474

Cramer-von Mises Test for Variable Categories Classified by Variable Group		
Group	**N**	**Summed Deviation from Mean**
Rubbish dump	6	0.147196
Veld	26	0.033968

Cramer-von Mises Statistics (Asymptotic)			
CM	0.005661	CMa	0.181165

Kuiper Test for Variable Categories Classified by Variable Group		
Group	**N**	**Deviation from Mean**
Rubbish dump	6	0.307692
Veld	26	0.423077

Kuiper Two-Sample Test (Asymptotic)

K0.730769Ka1.613495Pr > Ka0.1032

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8. Combination 8. Rubbish dump and Streambank

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Rubbish dump	6	89.0	60.0	11.401754	14.833333
Streambank	13	101.0	130.0	11.401754	7.769231

Wilcoxon Two-Sample Test	
Statistic	89.0000
Normal Approximation	
Z	2.4996
One-Sided Pr > Z	0.0062
Two-Sided Pr > |Z|	0.0124
t Approximation	
One-Sided Pr > Z	0.0112
Two-Sided Pr > |Z|	0.0223
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	6.4692
DF	1
Pr > Chi-Square	0.0110

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Rubbish dump	6	6.0	2.842105	1.039390	1.000000
Streambank	13	3.0	6.157895	1.039390	0.230769

Median Two-Sample Test	
Statistic	6.0000
Z	3.0382

One-Sided Pr > Z	0.0012
Two-Sided Pr > |Z|	0.0024

Median One-Way Analysis	
Chi-Square	9.2308
DF	1
Pr > Chi-Square	0.0024

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group			
Group	N	EDF at Maximum	Deviation from Mean at Maximum
Rubbish dump	6	0.000000	-1.289205
Streambank	13	0.769231	0.875842
Total	19	0.526316	
Maximum Deviation Occurred at Observation 17 Value of Categories at Maximum = 0.09040			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.357561	D	0.769231
KSa	1.558573	Pr > KSa	0.0155

Cramer-von Mises Test for Variable Categories Classified by Variable Group		
Group	N	Summed Deviation from Mean
Rubbish dump	6	0.553555
Streambank	13	0.255487

Cramer-von Mises Statistics (Asymptotic)			
CM	0.042581	CMa	0.809042

Kuiper Test for Variable Categories Classified by Variable Group		
Group	N	Deviation from Mean
Rubbish dump	6	0.076923
Streambank	13	0.769231

Kuiper Two-Sample Test (Asymptotic)					
K	0.846154	Ka	1.714430	Pr > Ka	0.0602

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9. Combination 9. Rubbish dump and Veld

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Rubbish dump	6	107.0	99.0	20.710417	17.833333
Veld	26	421.0	429.0	20.710417	16.192308

Average scores were used for ties.

Wilcoxon Two-Sample Test

Statistic	107.0000
Normal Approximation	
Z	0.3621
One-Sided Pr > Z	0.3586
Two-Sided Pr > |Z|	0.7172
t Approximation	
One-Sided Pr > Z	0.3599
Two-Sided Pr > |Z|	0.7197

Z includes a continuity correction of 0.5.

Kruskal-Wallis Test

Chi-Square	0.1492
DF	1
Pr > Chi-Square	0.6993

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Rubbish dump	6	3.0	3.0	1.121635	0.50
Veld	26	13.0	13.0	1.121635	0.50

Average scores were used for ties.

Median Two-Sample Test

Statistic	3.0000
Z	0.0000
One-Sided Pr < Z	0.5000
Two-Sided Pr > |Z|	1.0000

Median One-Way Analysis

Chi-Square	0.0000
DF	1
Pr > Chi-Square	1.0000

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group			
Group	N	EDF at Maximum	Deviation from Mean at Maximum
Rubbish dump	6	0.500000	-0.842012
Veld	26	0.923077	0.404490
Total	32	0.843750	
Maximum Deviation Occurred at Observation 7			
Value of Categories at Maximum = 0.13570			

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.165132	D	0.423077
KSa	0.934129	Pr > KSa	0.3474

Cramer-von Mises Test for Variable Categories Classified by Variable Group		
Group	N	Summed Deviation from Mean
Rubbish dump	6	0.147196
Veld	26	0.033968

Cramer-von Mises Statistics (Asymptotic)			
CM	0.005661	CMa	0.181165

Kuiper Test for Variable Categories Classified by Variable Group		
Group	N	Deviation from Mean
Rubbish dump	6	0.307692
Veld	26	0.423077

Kuiper Two-Sample Test (Asymptotic)					
K	0.730769	Ka	1.613495	Pr > Ka	0.1032

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10. Combination 10. Schoonspruit and Veld

Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Categories Classified by Variable Group					
Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Streambank	13	160.0	260.0	33.564157	12.307692
Veld	26	620.0	520.0	33.564157	23.846154
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	160.0000
Normal Approximation	
Z	-2.9645
One-Sided Pr < Z	0.0015
Two-Sided Pr > |Z|	0.0030
t Approximation	
One-Sided Pr < Z	0.0026
Two-Sided Pr > |Z|	0.0052
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	8.8766
DF	1
Pr > Chi-Square	0.0029

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Median Scores (Number of Points Above Median) for Variable Categories Classified by Variable Group

Group	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Streambank	13	2.0	6.333333	1.490712	0.153846
Veld	26	17.0	12.666667	1.490712	0.653846

Average scores were used for ties.

Median Two-Sample Test	
Statistic	2.0000
Z	-2.9069
One-Sided Pr < Z	0.0018
Two-Sided Pr > |Z|	0.0037

Median One-Way Analysis	
Chi-Square	8.4500
DF	1
Pr > Chi-Square	0.0037

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Nonparametric One-Way ANOVA

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable Categories Classified by Variable Group

Group	N	EDF at Maximum	Deviation from Mean at Maximum
Schoonspruit	13	0.846154	1.571651

Veld	26	0.192308	-1.111325
Total	39	0.410256	

Maximum Deviation Occurred at Observation 4
Value of Categories at Maximum = 0.09480

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)			
KS	0.308226	D	0.653846
KSa	1.924871	Pr > KSa	0.0012

Cramer-von Mises Test for Variable Categories Classified by Variable Group

Group	N	Summed Deviation from Mean
Schoonspruit	13	0.761122
Veld	26	0.380561

Cramer-von Mises Statistics (Asymptotic)			
CM	0.029274	CMa	1.141683

Kuiper Test for Variable Categories Classified by Variable Group

Group	N	Deviation from Mean
Schoonspruit	13	0.653846
Veld	26	0.076923

Kuiper Two-Sample Test (Asymptotic)					
K	0.730769	Ka	2.151326	Pr > Ka	0.0033

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