An Assessment of the Viability and Sustainability of the use of Humanure for Household Agricultural Purposes: A case study in Cottonlands, eThekwini Municipality

By

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Submitted in fulfilment of the academic requirements for the:
Master of Social Science Degree

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Declaration

I, Vyasha Harilal hereby declare that this dissertation, entitled: "An Assessment of the Viability and Sustainability of the use of Humanure for Household Agricultural Purposes: A case study in Cottonlands, eThekwini Municipality" is as a result of my own work and has not been submitted in part or in full for any other degree, university or institution.

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Vyasha Harilal Date

Acknowledgements

- The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

- Thank you to all who have helped me complete this dissertation:

    - Professor Brij Maharaj - Mentor and constant source of guidance, support and help.

    - Mr. Johnny Lutchmiah - Supervisor of research and dissertation.

    - Professor Olaniran – A great help and advisor with regard to the microbiological aspect of this research.

    - Dr S. Pillay – Source of support and advice.

    - Mr. D. Harilal – My dad – the greatest supporter of this research, which would not have been possible without him and all his help and input.

    - My mum, Arthi, and sister, Lerisha, for all their help with different aspects of this research, as well as support during challenging times.

    - Mr. Richard Pocock and Mr Joe Grant – Thank you for all your help with the ‘composting’ side of this research.

    - Mr. Joe West – Thank you for all your help with the trial gardens for this research.

    - Ms. Hazel Padayachee – Thank you with your assistance with lab work.

    - Lastly, thank you to anyone not mentioned above, who helped or contributed to this research in some way. It is much appreciated.

Abstract

Many South Africans face problems relating to poor sanitation and inadequate nutrition. This is especially prevalent in the peri-urban and rural areas of the country. Whilst urban areas are provided with water borne sewage, the provision of this service to peri-urban and rural areas has been neglected due to topography, water issues, high cost and apartheid legacy. The use of sanitation facilities that allow for composting of faecal matter is a viable option, which, if properly managed, can address sanitation issues and food security by providing compost for household agriculture. The aim of this research is to gauge the perception of people in the Cottonlands community, located within the eThekwini Municipality, on the use of humanure for household agriculture; as well as to determine the safety of food crops grown with humanure. Questionnaires and microbiological testing was used to determine community perceptions and food safety, respectively. Acceptance levels of using humanure for household agriculture ranged from total to non-acceptance. Observation showed visible impact with the use of humanure with crops appearing to produce more fruit, and seeming healthier overall. Microbiological food safety tests indicated unsafe levels of bacteria and pathogens associated with food borne illness. Overall, it is recommended that further research and tests be conducted as there is a great potential from this study to improve the quality of life for many, as well as contribute to sustainable environmental practices.

Abbreviations

- National Research Foundation (NRF)
- Urine Diversion Toilets (UDT)
- Ventilated Improved Pit latrines (VIP)
- Sustainable Livelihood Framework (SLF)
- Genetically modified organisms (GMO'S)
- Heterotrophic or Standard Plate Count (HPC)
- Escherichia coli (E. coli)
- Klebsiella pneumonia (K. pneumoniae)
- Enterobacteramnigenus (E. amnigenus)
- Citrobacterfreundii (C. freundii)
- European Union (EU)
- Haemolytic Uraemic Syndrome (HUS)
- Statistical Package for Social Science (SPSS)
- African National Congress (ANC)
- NPK (nitrogen, phosphorus and potassium)
- Too numerous to count (TNTC)
- The South African Department of Health (DoH)
- Colony Forming Units (CFU)

Table of Contents

List of Tables

List of Figures

List of Plates

Chapter One

Introduction and Problem Contextualization

1.1. Preamble

South Africa faces many problems that stem from its torrid apartheid legacy, which *inter alia* include poor sanitation, wide spread poverty and health conditions, food insecurity, and land and soil degradation. Many of these issues have had severe negative effects on the quality of life of rural black communities; and are perpetuated by high levels of poverty in the democratic era. Some of the factors which exacerbate poverty levels include the lack of education, healthcare, and basic provisions such as food, potable water and housing. Consequently, the poor are trapped in a vicious cycle. Without proper healthcare, education and having his/her basic needs being met, an individual may be classed as poverty stricken. Similarly, as a result of being poverty stricken, access to education, healthcare and basic amenities to meet basic needs (food, shelter and sanitation) is severely limited.

A potential solution that may alleviate some of the problems that are currently faced by the rural poor is a system of aerobic thermophilic composting, which reconstitutes human excreta as well as other organic waste into a natural and enriched compost and soil conditioner, known as humanure. The resultant compost derived from this system, commonly known as humanure, may be used for agricultural purposes and home gardens, which may increase food security for many people, as well as contribute to land and soil rehabilitation. Additionally, the conversion of human excreta for agricultural purposes eliminates the problem of human waste disposal, as well as the associated health, safety and hygiene effects of incorrect disposal and management.

Land degradation is a major issue in South Africa, as it impacts significantly on agriculture and food security (Gibson *et al.,* 2005; Scherr, 1999). Soil erosion, desertification and vegetation loss are all forms of land degradation. Desertification and land degradation are two of the most critical global environmental issues which are intricately linked with issues of food security, poverty and urbanization. As 91% of South Africa comprises land that is susceptible to desertification and a large proportion of the population is dependent on livelihoods derived from the natural resource base, it is clearly a critical issue for the country (Gibson *et al.*, 2005). Soil degradation or erosion is most severe and generally perceived to be occurring at an increasing rate in most communal croplands, grazing lands and settlements in South Africa (Gibson *et al.*, 2005). This is due to overcrowding, poor farming techniques and overgrazing due to high stocking rates. Soil degradation in the form of fluvial affects about 70% of the land in South Africa (Gibson *et al.*, 2005).

Land productivity is intricately linked to social, political and environmental issues. Land degradation is perceived to be particularly severe in communal areas and is a serious threat to the sustained supply of ecosystem services, household food security, biodiversity and livelihoods. Although 80% of the land surface area in South Africa is used for agriculture and subsistence livelihoods, only about 11% has arable potential (Gibson *et al.*, 2005). The amount of arable land in South Africa is minimal due to climatic (water scarcity, drought), environmental (soil composition) and socio-economic and political factors (apartheid land policies). It is thus vital that this small percentage of arable land is managed and used in a sustainable manner in order to maintain food security and minimise the levels of land degradation.

Measures to preserve, conserve and rehabilitate soil need to be taken, as food security is directly linked to the productivity of the land. The use of humanure as a soil conditioner may be a cost effective method of contributing to the rehabilitation of degraded land, and of maintaining the good health of productive soil. This may be attributed to the increase of organic matter and essential nutrients from the soil conditioner or compost added to the soil (Polprasert, 1996). If the good health of soil is maintained, it is likely that food security may be achieved through agricultural practises. Soil productivity may be maintained through the use of humanure, which imparts essential nutrients into the soil, ensuring that agricultural practises are able to transpire.

1.2. Contextualization of Problem

1.2.1. The Problem

The lack of access to and provision of proper sanitation facilities has resulted in the poor state of sanitation, both nationally and locally. In an attempt to combat this problem of inadequate sanitation facilities, eThekwini municipality has installed more than eighty-five thousand Urine Diversion Toilets (UDT) throughout the peri-urban and rural areas of the city (Buckley, 2010). The UDT's that were installed in the eThekwini Municipality were in response to the many problems that are associated with the Ventilated Improved Pit latrines (VIP) that were being used by those who did not have access to water-borne sewage systems. UDT's may be classified as part of the dry sanitation movement (CSIR, 2000). Within the context of the eminent shortage of usable and potable water, there are many to provide water-borne sewage facilities to all citizens of the country. Furthermore, terrain and monetary constraints results in citizens located in peri-urban and rural areas are not connected to a system of water-borne sewage (Buckley *et al* .n.d.).

Through the provision of UDT's, the city of Durban's eThekwini Municipality has managed to provide sanitation facilities for more than eighty-five thousand people within the municipality (Buckley, 2010; Bell *et al*, 2010). However, the issue of what is to be done with the output from the UDT's is yet to be determined (Bell *et al*, 2010). Furthermore, through recent investigation of UDT's in the Municipality, it would seem that the system is not functioning in the manner that was anticipated. This problem may stem from a lack of proper education and effective monitoring of the utilization of UDT's. Moreover, the stigma attached to the use of UDT's may also be partially responsible for the failure of the system (Wilkinson *et al*, n.d.).

The health impacts of poor sanitation are severe, as water contaminated by waste can lead to outbreaks of diseases such as cholera and other water-borne diseases. For examples, there was a cholera outbreak in parts of Kwa-Zulu Natal in the year of 2000 (Bell *et al*, 2010). Since many people do not have access to proper sanitation, pits dug in the ground or on the banks of rivers are used as lavatories. This has a serious impact in terms of the resultant pollution and contamination of rivers, as well as ground water, due to the presence of pathogenic bacteria and micro-organisms (Emmanuel, 2009).

The composting process, however, ensures that pathogens from faecal matter are destroyed, thus rendering compost from human waste to be non-toxic and useful for soil enrichment. The process involves faecal matter and other organic material being subjected to high temperatures over a certain period of time in aerobic conditions (Golueke, 1972).

Apart from potential health impacts that may result from poor sanitation and an inefficient composting system, it is essential to consider the presence of pathogens in soil. Pathogens present in soil may become resident in edible plants grown in said soil during their growth phase. If consumed, such produce may have serious negative impacts on the health and well-being of those who consume the produce. As a result, food security may not necessarily be enhanced if produce grown is unsafe for consumption. This highlights an important link between microbial levels in produce, food safety and food security; a connection that will be explored through this investigation.

Hence, through the use of this system of composting human waste, fertiliser of the highest quality is produced, and the risks associated with human waste in terms of health concerns are eliminated (Were, 2007). Composting is a fairly common concept. However, the idea of composting human waste, in addition to other organic waste is not one that is widely accepted. It is difficult to get rid of human waste (Jenkins, 2005). However, it is one of the most important types of waste material that needs to be dealt with as every single person on the planet produces this type of waste (Jenkins, 2005). Therefore, finding a sustainable manner in which to deal with this type of waste is imperative.

It has already been established that disposing of untreated waste in the ground or in water systems is dangerous and can be hazardous to the environment and human health. Diverting all sewage to waste water treatment plants is not possible either. As previously mentioned, this is due to financial constraints, as well as the unsustainable nature of providing water-borne sewage to the entire population of the country, within the context of the imminent shortage of potable water. Furthermore, terrain in certain areas does not allow for infrastructure to be put in place, as areas may be excessively hilly and uneven (Buckley *et al*, n.d.).

Due to the direct benefit of improved sanitation that this system promotes, health and nutritional levels of the community will also improve due to the enhanced quality and physical condition of the land (Were, 2007).

1.2.2. Rationale for Study

Against the above background, the problem that this research hopes to address relates to waste management, or more specifically, human waste management, and food security. It is a fact that each and every person on this planet produces waste. Although the amount of waste that each person produces may vary, depending on diet, it is not something that can or should be avoided (Polprasert, 1996). Waste may have several damaging impacts on the physical environment, if not tended to in the appropriate manner (Polprasert, 1996; Sharma *et al*, 1997). Therefore, a solution needs to be found with regard to what is to be done with human waste that is not taken care of by water-borne sewage technology. It is of increasing concern that the amount of arable land in our country is rapidly decreasing, a fact which may be largely attributed to the incorrect use of the land (Gibson *et al.*, 2005).

Hence, the motivation of this study is based primarily within the field of human waste disposal and household agriculture. The researcher assumes that if human waste, which is available in abundant quantities at no cost, can be reconstituted into a soil conditioner, this will aid in rehabilitating the land and enable households to produce sufficient yields, with subsequent achievement of food security. In short, the problem identification is firstly, that not everybody has access to modern sanitation technology, namely, water borne sewage. Therefore, a solution needs to be found for those who do not have access to this technology, as current solutions are not functioning as anticipated. Secondly, an increasing percentage of the population lack food security, as the land that is being cultivated does not have the capacity to produce yields, and that the price of chemical fertilizers is higher than many can afford.

Water-borne sewage facilities are costly and somewhat unsustainable, due to the use and quantity of water that these systems require (Buckley, 2010). Water is a precious resource that is fast becoming scarce. Consequently, waterless methods, or methods that require a smaller amount of water when dealing with this type of waste will be invaluable. One such community that lacks water-borne sewage facilities, and has to rely on UDT's as the main form of sanitation system is Cottonlands, situated north of Durban, within the boundaries of the eThekwini Municipality. This community, apart from lacking water borne sewage systems, is also, to a large extent, dependent on household agriculture for food security. Hence, it is a suitable case study for the research that is being undertaken.

1.3. Aims and Objectives

1.3.1. Aim of Study

- To assess the viability and sustainability of the use of humanure for household agricultural purposes with specific reference to Cottonlands in the eThekwini Municipality.

1.3.2. Objectives

- To ascertain the Cottonlands community's perception of the use of humanure for small-scale agriculture.
- To investigate the process of producing humanure.
- To evaluate the health and safety risks associated with the use of humanure.
- To determine the effectiveness of using humanure for agricultural purposes.

1.4. Chapter Sequence and Summation

The introductory chapter of this dissertation comprises of an introduction to the research topic being undertaken, as well as a background to the research problem. The study will be contextualized through an explanation of the origin of the problem, and the rationale for the study. Furthermore, this introductory chapter details the aims and objectives of this dissertation, which are critical components of the study that will aid in ensuring that the research remains focused and defined.

This will be followed by a comprehensive review of principle theories, frameworks, approaches and literature upon which this dissertation will be based. Principle theories relevant to this dissertation are related to zero waste management and the theory on waste management. The sustainable livelihoods framework is also a fundamental element of what will be the theoretical review. Furthermore, the theoretical review will include detailed discussions on pertinent issues related to the research topic, citing relevant scholarly articles, books and other appropriate academic material. Issues such as the potential health impacts of the incorrect use of human waste; organic agriculture; food security; waste disposal and land degradation and restoration will be discussed in detail in this chapter. Case studies of countries that have embraced the concept of using humanure will also feature in this part of the study.

A description of the study area and the methodology for this investigation will be highlighted in the third chapter of this dissertation. This study will employ a mixed method approach, in terms of using both qualitative and quantitative methods. Surveys will be carried out with households from the study area in an attempt to gain the communities' perception towards the use of humanure. The method of composting human waste, the analysis of the resultant humanure, and a microbiological analysis of the produce grown in the trial gardens will be discussed to achieve the objectives of this research.

The emphasis on the fourth and penultimate chapter of this dissertation will be on a presentation of the results obtained from the implementation of the methodology described in the previous chapter; as well as an analysis and discussion of such results. Graphical and tabular representations will feature prominently in this chapter.

The fifth and final chapter will include an evaluation of the research. As a final point, recommendations and an overall conclusion will be presented in this chapter.

1.5. Conclusion

This chapter has served to introduce the topic of this study – 'An assessment of the viability and sustainability of the use of humanure for household agricultural purposes'. Agriculture forms an integral aspect of the livelihoods of many people who reside in peri-urban and rural areas. In many cases, agricultural activities are the source of food security. Waste management is a critical issue that needs to be addressed urgently, as the improper disposal and management of waste has the potential to seriously and negatively affect agricultural production, as well as cause severe health disorders in communities. The management of waste, specifically human waste, can be directly linked to agricultural production, as human waste can be reconstituted into a compost or soil conditioner, commonly known as humanure. This study aims to assess the viability and sustainability of the use of humanure at a household agricultural level. Scientific testing of the resultant compost and produce grown using humanure, together with surveys conducted with households from the study area will enable the researcher to achieve the aims and objectives of the study. The surveys that are to be conducted are a critical aspect of this study as the perception of the community with regard to the use of humanure will be ascertained.

Chapter Two

Theoretical Framework and Literature review

2.1. Introduction

The theory of zero-waste management and the sustainable livelihood framework are central to the theme of this research. This chapter will assess these two theories, and their relevance to this research, while the second part of this chapter will focus on the literature review. This will comprise a discussion of literature pertinent to this study, which *inter alia* include the following themes: agriculture, land degradation, humanure, microbiology and food safety. Relevant case studies will also be cited to add scholarly depth to this research.

2.2. Theoretical Framework

2.2.1. The theory of waste management - Zero-waste management

The theory of zero-waste management is based on a holistic framework that advocates the elimination of waste, as opposed to the management of it (Curran andWilliams, 2010). Zero-waste management operates on the notion that waste is non-existent. All 'waste' material should be viewed as a resource, thereby reducing the volume of disposable materials that have to be disposed of in landfill sites or by other means (Curran and Williams, 2010). Conventionally, the generation of waste in the production line is common practice, with the waste products being diverted to landfill and incineration sites, which is termed the 'disposal culture' (Curran and Williams, 2010: 1).

It seems that the 'disposal culture' is a global phenomenon, evidenced by the popularity of goods packaged in 'disposable' material; such as plastic water bottles, polystyrene take-out containers and the vast array of electronic disposable or one-use items. As Joseph Jenkins (2005:6) stated, “for waste is not found in nature — except in human nature.” There have been efforts by the food industry in Seattle, USA to break the cycle of the ‘disposal culture’. All single-use packaging for food is required to be recyclable or compostable (Ferry, 2011).The theory of zero-waste management rejects the ‘disposal culture’ (Curran and Williams, 2010:1) in favor of the closed loop system, in which all material has a use or application. In an article written for The Wall Street Journal, David Ferry state “the prime benefits in adopting zero-waste are environmental; many cities that have enacted zero-waste plans say they have taken up the task in the name of sustainability” (2011:1).

The theory of zero-waste management may be applied to the management of human waste. There is an urgent need for human waste management to be seriously remedied in South Africa, as well as globally. Thus, zero-waste management plans can be adopted with regard to human waste management. Human waste is generally managed through a system of water borne sewage in urban areas, where the appropriate infrastructure and technology have been provided. However, there are many peri-urban and rural areas in the South Africa that lack proper human waste technology. Efforts to manage human waste thus far have not been successful. Zero-waste management, as applied to the specific field of human waste management, would entail viewing human waste as a resource, and not as waste material that has to be disposed of. This has been emphasized by Jenkins (2005:7-8):

> “Feces and urine are examples of natural, beneficial, organic materials excreted by the bodies of animals after completing their digestive processes. They are only “waste” when we discard them. When recycled, they are resources, and are often referred to as manures, but never as waste, by the people who do the recycling. We do not recycle waste. It’s a common semantic error to say that waste is, can be, or should be recycled. Resource materials are recycled, but waste is never recycled. That’s why it’s called “waste.” Waste is any material that is discarded and has no further use. We humans

> have been so wasteful for so long that the concept of waste elimination is foreign to us. Yet, it is an important concept."

The concept of "disposable culture" (Curran and Williams, 2010:1) seems to have intricately wound itself into all facets of our lives, to the extent of preventing us from realizing the benefit of resources that we are mindlessly 'flushing' away; without thought of the consequences.

Human waste management can serve to improve agricultural practices and increase food security. This is because human waste, through proper management, may be converted into a rich, organic soil conditioner and compost, at a very low cost. This is the principle of the theory of zero-waste management: material that is commonly termed as waste will more often than not have other uses (Winter, 2007). Hence, through the application of the theory of zero-waste management, human waste is a resource which may aid in bridging the gap between waste management, agriculture and food security. However, the issue of human waste is not one that is easily and openly dealt with. This is an issue that has been concealed in society – 'society's dirty secret' – and is not discussed. Yet, it is this negative attitude toward human waste management that is the root of the problem. This is echoed by Jenkins (2005:6):

> "Perhaps one reason we have taken such a head-in-the-sand approach to the recycling of human excrement is because we can't even talk about it. If there is one thing that the human consumer culture refuses to deal with maturely and constructively, it's bodily excretions. This is the taboo topic, the unthinkable issue. It's also the one we are about to dive headlong into."

The theory of waste management has been criticised, as it is unclear as to why we need a theory on how to manage waste. As Prongracz (2002:114) states:

> “Waste management is a practical discipline, seeking solutions to specific waste problems. Given that the everyday problems of waste management are so important to solve, it may even appear that theorising, instead of acting, is a waste of time or effort.”

Although this may stand to reason, Prongracz (2002:114) further states:

> “There is no such thing as absolute waste: a thing that would be waste under every condition, at every time, and for everyone or everything. Precisely due to the fact that waste *is* a concept, calls for it to be analysed conceptually.”

Hence, the emergence of the theory of waste management, and especially the focus zero-waste management. These theoretical approaches underpin this study, especially in terms of the way in which human waste, among all other types of waste is managed, as opposed to being disposed of in landfill sites or in water bodies, and ultimately becoming pollutants.

Table 2.1: Some general definitions of waste

1	EU	Waste shall mean any substance or object in the categories set out in Annex I, which the holder discards or is required to discard.
2	OECD	Wastes are materials other than radioactive materials intended for disposal, for reasons specified in Table 1.
3	UNEP	Wastes are substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.
4	Lox	Waste is either an output with (‘a negative market’) ‘no economic’ value from an industrial system or any substance or object that has’ been used for its intended purpose’ (or ‘served its intended function’) by the consumer and will not be re-used.
5	McKinney	Waste is the unnecessary costs that result from inefficient practises, systems or controls.

6	Bararn	Waste is the difference between the level of output of useful goods and services that would be obtained if all productive factors were allocated to their best and highest uses under rational social order, and the level that is actually obtained.
7	Hollander	Waste is something that needs to be expelled in order that the system continues to function.
8	Elwood &Patashik	Waste, like beauty, is in the eye of the beholder.
9	Gourlay	Waste is what we do not want or fail to use.
10	Prongracz	Waste is an unwanted, but not avoided output, whence its creation was not avoided either because it was not possible, or because one failed to avoid it.
11	Prongracz	Waste is a man-made thing that has no purpose; or is not able to perform with respect to its purpose.
12	Prongracz	Waste is a man-made thing that is, in the given time and place, in its actual structure and state, not useful to its owner, or an output that has no owner, and no purpose.

Table adapted from (Prongracz *et al*, 2004:474)

Prongracz *et al* (2004) discuss the above definitions, and infer that the discourse on waste management seems to be a reaction to waste itself. Furthermore, many of the above definitions define waste as a substance that is 'not useful', 'needs to be expelled', 'required to discard' or 'will not be re-used'. These definitions seem to influence waste disposal, and the manner in which it is viewed and treated; as a waste and not a resource. There appear to be many factors which are influencing the field of waste management. Two of the factors that appear to be most influential include the above definitions of waste, and the subsequent negative connotations which they promote, and the embedded culture of non-discussion of certain types of waste, especially human waste.

There are arguments against the zero-waste management approach, as it is purported by some that incineration of all waste is a preferable option. Contrary to this belief, incineration is not a preferred option, due to the resultant emission of greenhouse gases, and the fact that this approach is a 'clean' one (Mataki, 2011). Supporters of the zero-waste management approach maintain that "incineration destroys, rather than conserves, resources" (Ferry, 2011:1). The advantage of the zero-waste approach is that it is a sustainable cycle with no harmful effects on our natural systems. According to Larry Chalfan, executive director of the non-profit Zero-waste Alliance in Portland Ore:

> "Zero-waste looks at what nature has given us as a model, everything at the end of its life, whether it's a flower or a dead body, is recycled; there are no toxic substances or 'waste' built up anywhere to cause harm to future generations. Everything is a resource to be used again." (Winter, 2007:1).

The zero-waste management approach can be applied to the field of waste management, and more specifically, human waste management. The benefits of adopting this approach would be many-fold, as not only would the physical environment be enriched, but the quality of lives of people would be enhanced. This approach may be adopted as part of the Sustainable Livelihood Framework (SLF).

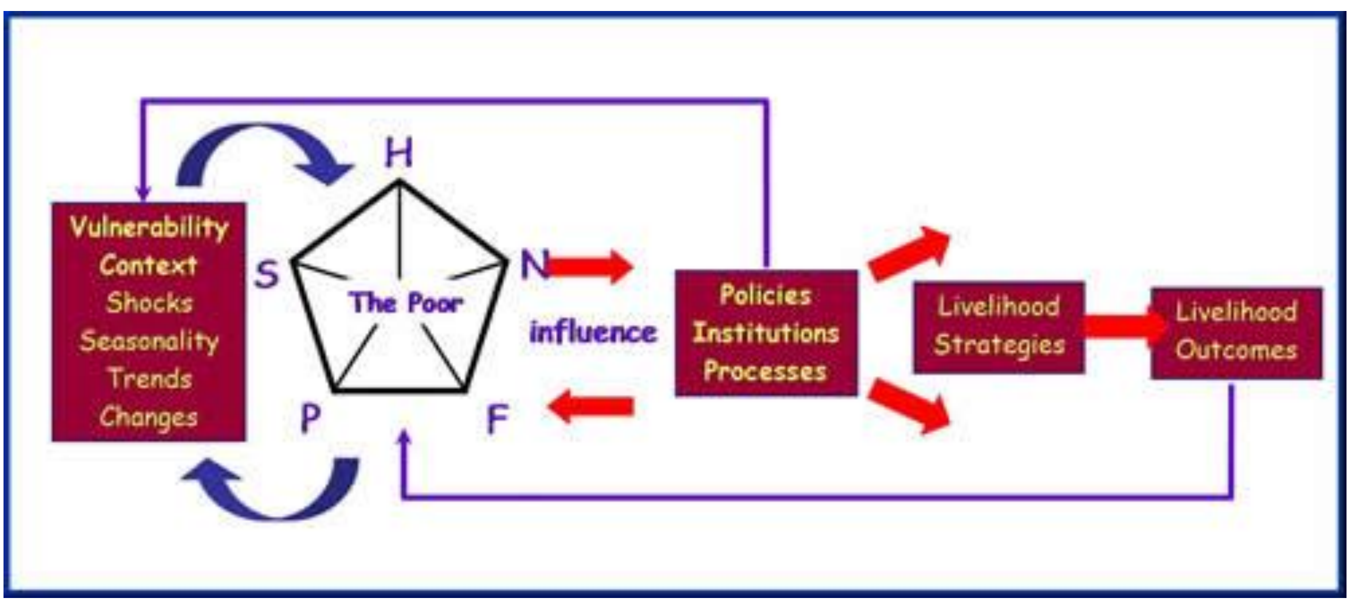
2.2.2. The Sustainable Livelihoods Framework

The sustainable livelihoods framework (SLF) is an approach that provides an understanding of livelihoods of the poor. It does this by examining the main factors that affect the lives of these people. The framework is centered on assets of poor people, and how this can increase the ability of people to withstand shocks such as natural disasters, violence or family deaths (Allison and Ellis, 2001). Allison and Ellis (2001: 379) state:

"The concept of a 'livelihood' seeks to bring together critical factors that affect the vulnerability or strength of individual or family survival strategies. They are thought to compromise, chiefly, the assets possessed by people, the activities in which they engage in order to generate an adequate standard of living and to satisfy other goals such as risk reduction, and the factors that facilitate or inhibit different people from gaining access to assets and activities."

Against this background, "A livelihood comprises the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household" (Allison and Ellis, 2001:379). The SLF incorporates primary elements that meet the terms of the aforementioned definition, and illustrates the relations between each of these elements. The SLF illustrated in Figure 2.1, clearly shows the various elements and interactions that make up this framework.

Figure 2.1. Schematic representation of the SLF



Source: Adapted from http://www.ifad.org/sla/index.htm

2.2.2.1. Livelihood Assets

As can be seen from Figure 2.1, the SLF is a people centered framework. People are at the center of the web of livelihood assets. The Human Capital (H) is based on the characteristics of the people, such as knowledge and skills (for example, indigenous knowledge); ability to work, learn and acclimatize to new situations; education levels; and the health and nutrition of people. The health and nutrition of people is of great importance as a person who is not in good health or is malnourished may not have the capacity to work or adapt to new situations that may arise. Therefore, health and nutrition is a critical aspect of the SLF. Additionally, people who are not in good health generally require assistance, which further reduces human capital (NRI, n.d). All assets in the SLF are interrelated. Impacts on any one variable can have repercussions on the other ones. This may be illustrated by the above mentioned link between human capital and other assets (NRI, n.d).

Natural Capital (N) is based on the natural resources that are used by people, such as air, land, water, plant and animal reserves, forests and other environmental resources such as wetlands. Social Capital (S) is based on the networks and connections that are formed between people, based on familial ties or patronage. Social capital is made up of both formal and informal groups of people who follow common rules. Leadership is an important aspect of social capital, as under the proper guidance of a leader, people are able to follow the common societal rules (NRI, n.d). Physical Capital (P) refers to the infrastructure, tools and technology required by people for day to day activities. Infrastructures such as roads, buildings, water and sanitation, energy and communication facilities are all vital aspects of people's livelihood. Without Physical Capital, people would not be in a position to access the other types of capital.

The tools and technology of Physical capital encompass the apparatus required for production. It also includes agricultural gear needed for the growth of crops. Traditional technology also forms a part of tools and technology, much like indigenous knowledge (NRI, n.d).Financial capital (F) is based on the monetary resources that are available to people, which include any savings that a person may have, subsidies such as pension, earned income and services that offer credit facilities such as loans. Financial Capital is often thought of as the most important type of capital, as other types of capital may be purchased with financial capital (NRI, n.d). The SLF is based on these assets. However, these are not the only assets to which people or households have access. The access to these and other similar assets directly affect the livelihoods of people.

As mentioned above, the framework is centered on the assets of poor people. More specifically, the focus is on how the management of these assets can influence the nature of response to shocks (Allison and Ellis, 2001). The various assets, apart from increasing the ability of people to withstand shocks, also enables them to withstand changes in population patterns, the environment, technology and the changes that globalisation brings about. Collectively, these shocks and changes are known as the vulnerability context of the SLF.

2.2.2.2. Vulnerability Context

The vulnerability context of the SLF gives rise to policies, institutions and processes which are introduced to aid people with regard to access to assets. The policies, institutions and processes are influenced and modelled by people and the assets become available, as can be seen in Figure 2.1. Livelihood strategies take account of the assets that people have access to, in view of their vulnerability context. These strategies also take into consideration the policies, institutions and processes that either sustain the livelihoods of people or impede them. The result of various livelihood strategies that may be instituted is the livelihood outcome. The livelihood outcome is directly related to people and their various assets. (Morton and Meadows, 2000)

The SLF is a holistic framework which does not single out a particular cause of poverty, but rather recognises that deprivation and destitution can be attributed to many factors, which are most likely to be interconnected with each other. This is validated by Majale (2002:3) who states:

> "The sustainable livelihoods approach is a holistic approach that tries to capture, and provide a means of understanding, the fundamental causes and dimensions of poverty without collapsing the focus onto just a few factors (e.g. economic issues, food security, etc.). In addition, it tries to sketch out the relationships between the different aspects (causes, manifestations) of poverty, allowing for more effective prioritisation of action at an operational level"

It may be argued that poverty is characterized by a 'cause and effect' type condition. Hence, it may not be possible to identify a single cause of poverty, but rather many interrelated causes. Poverty is a cycle that perpetuates itself. This is evident by the millions of people globally who seems to be stuck in this vicious cycle. Once entrenched in poverty, without external aid, it is extremely difficult and challenging for people to break free of the cycle. (Morton and Meadows, 2000)

2.2.2.3. Principles of the SLF

The SLF is grounded in the knowledge that poverty is a diverse issue, with many faces. As Solesbury (2003:14) states "conceptually it drew on changing views of poverty, recognising the diversity of aspirations, the importance of assets and communities, and the constraints and opportunities provided by institutional structures and processes". Furthermore, he goes on to state that "in practical terms it placed people – rather than resources, facilities or organisations – as the focus of concern and action; and emphasised that development must be participatory and improvements must be sustainable" (Solesbury, 2003:14).

This is the basis of the SLF, as it is a people centered framework. It recognises that people themselves need to be involved in poverty alleviation strategies if these are to be sustainable in the long term. Furthermore, as indicated by Majale (2002), this framework is overarching and considers all factors that are at the root of poverty, exploring the relationship that exists between them in an attempt to determine solutions. Some of the factors that the framework considers are adverse trends or shocks, basic lack of assets, and poorly functioning policies and institutions.

According to Dorward (2001), these principles of the framework are: people centered, responsive and participatory, dynamic, sustainable, multi-leveled, holistic and conducted in partnerships. A people centered approach indicates that the goal of poverty alleviation can only be truely achieved if the lives and existing strategies of people are taken into consideration. The imposition of a foreign solution on people already caught in a cycle of poverty may only serve as a means of further entrenchment. Therefore, the social environments of people, as well as their ability to adjust must be taken into consideration, if the framework is to be successful.

With regard to demand led, livelihoods should be generated by providing goods that are in market demand, at prices which will ensure a profit. Dynamic implies that people have various means through which they hope to achieve their livelihood, and these means should be supported by those in a position to help. People should not be limited to one livelihood strategy; they should be allowed to diversify. All practises within the SLF need to be sustainable in the long term, in order to achieve the ultimate goal of poverty alleviation (Krantz, 2001).

Furthermore, a one-level direct approach to poverty reduction, where solutions are formulated without consultation at ground level, is not what the SLF promotes. The SLF indicates that poverty alleviation will only be achieved in a sustainable and long term setting if a multi-level approach is adopted, whereby activity at the ground level is the basis of policy development. This alludes to the next principle of the SLF, namely, a ‘holistic framework’, which attempts to consider all factors (human capital, natural capital, social capital, physical capital, and financial capital) which impact on poverty and people. The last principle of this framework, conducted in partnership, indicates that strategies for poverty alleviation and livelihood improvement need to be conducted in association with stakeholders that include government, private parties and the public in order to achieve sustainable results (Dorward, 2001).

2.3. Literature Review

2.3.1. Agriculture

Agriculture is an integral part of society; globally, nationally and locally. In every part of the world agricultural practices date back hundreds of years, each of which has contributed to development in the field. There have been iconic eras in agriculture, such as the green revolution and the red revolution, each of which have had a role in shaping rural development. Agriculture is not only concerned with the production of crops; it is an all-encompassing field that deals with the rearing of livestock, plants and crops, as well as aqua based practices (McIntyre *et al*, 2009). Furthermore, agriculture influences many other fields. Ecosystem services and the social sector are perhaps two of the most important fields that agriculture influences. Communities and lifestyles are modelled by agriculture, providing employment and livelihood for many. Ecosystem services such as water supply and carbon sequestration or release are also influenced by agriculture (McIntyre *et al*, 2009).

Due to climate change and its knock-on effects, such as land degradation, temperature increases and reduced access to natural resources, agriculture has reached a critical point. Scientific developments in the field such as the introduction of genetically modified organisms (GMO’S) have also placed caused concern in the social sector; which agriculture plays an important role in, as the safety of using GMO'S has been questioned by many, despite the lack of reports of negative health effects from GMO's (Schauzu, 2000). Globally, increasing temperatures have led to different weather patterns and land use change, each of which severely affects agriculture; as current changes in weather patterns are impacting on agricultural yields (Olesen and Bindi, 2002; Schimidhuber and Tubiello, 2007).

Along with impacts on agriculture, land use and soil changes occur as knock-on effects of climate change, which in turn impacts on agriculture. This is explained by Montgomery who notes:

> "Although soil fertility generally declines with accelerated erosion, soil fertility is itself a function of agricultural methods and site conditions such as soil type, nutrient, and organic matter content." (2007a:13268).

Agricultural practices may become unsuitable due to change in the characteristics of the land and soil. Land degradation, exacerbated by incorrect agricultural practices and climate change, impacts on the quality of soil. Soil is an essential factor of agriculture, as Twyman *et al* (2004; 81) states:

> "Soils are an integral part of natural capital, and their management is vital for sustained and productive use. Soil fertility management practices have evolved in the two cross-border areas, based on the use of both organic and inorganic fertilisers, and practices that directly or indirectly address wind- and water erosion problems."

Land and consequently soil degradation is a serious issue that needs to be addressed. Soil degradation, "although less dramatic than climate change or a comet impact, can prove catastrophic nonetheless, given time" (Montgomery, 2007b:5). Communities that depend on agriculture for their livelihood will become vulnerable.

Agriculture has served as a means for many to achieve food and financial security, with many urban, peri-urban and rural communities reliant on agriculture for food security. However, this is becoming increasingly difficult due to the issues relating to accessibility of land and the condition of the land itself. This is confirmed by Bryceson (2000 cited in Baiphethi and Jacobs, 2009:472):

> "based on a case study of seven countries (Nigeria, Ethiopia, Tanzania, Congo-Brazzaville, Malawi, Zimbabwe and South Africa), the countries were all undergoing "de-agrarianisation" and "depeasantisation". This was driven mostly by, restrictions on access to land (South Africa). While the country is self-sufficient in food production, this has been accompanied by considerable levels of household food insecurity."

It is evident from the above that in South Africa, as well as other developing countries, agriculture is a critical livelihood strategy. Agricultural practises at the household level have ensured for decades that families are food secure through their own production of food, as the market price of food was, and still is, unaffordable to many. This is reiterated by Ruel *et al* (1998), who discusses critical components affecting household food security, and cites the ability to earn an income and the price of food as two factors.

This highlights an important link: food security- income-agriculture, as highlighted by Schmidhuber and Tubiello (2001). As stated above, many families attain food security through practicing household agriculture (Ruel *et al*, 1999). Others attain food security through purchasing power, enabled through employment (Ruel *et al*, 1999). However, employment is not available to all, with many people falling into the category of being unemployed or being causally employed, with no guarantee of a fixed income for purchasing power. The reliance on the market for the attainment of food security, through purchasing power can also be problematic. As Ruel *et al* (1999:1918) state:

> "With urban-dwellers' dependence on purchases in the market for food, the level of food prices can seriously affect an urban household's food security. Food prices depend on a number of factors, including the efficiency of the food marketing system, the household's access to food subsidies or other food programs, and other macroeconomic policies."

Similarly, food security achieved through household agriculture is placed at risk due to land degradation, improper farming practices and lack of access to agricultural land (White Paper on Agriculture, 1995).

2.3.2. Food Security

The issue of food security is a complex and multifaceted one. Food security, as defined by the Food and Agriculture Organization (FAO), cited in Schmidhuber and Tubiello (2007:19703) is:

> "a situation that exists when all people, at all times, have physical , social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."

According to the Agriculture at Crossroads Global Report,

> "food security exists when all people of a given spatial unit, at all times, have physical and economic access to safe and nutritious food that is sufficient to meet their dietary needs and food preferences for an active and healthy life, and is obtained in a socially acceptable and ecologically sustainable manner" (WFS, 1996 as cited in McIntyre *et al*, 2009:10).

Thus, it is evident that the matter of food security deals with people not only having access to food, but to a variety of food, which aids in achieving a balanced diet and also with people having the ability to purchase food, as discussed above. Those people who do not produce their own food rely on purchasing power to achieve food security or on social welfare grants from the government (Ruel *et al*, 1999). This may lead to the issue of social differentiation among people. Food security among the working class is usually achieved through the ability to purchase food. Food security among those who are unemployed is usually achieved through the production of food through cultivation or through purchase with money made available through grants (Ruel *et al*, 1998).

There are two different levels of food security, namely: chronic food security and transient food security (Saad, 1999). Chronic food insecurity may be described as persistent periods of not having access to food. These periods are not however permanent. Transient food insecurity is brief, short lived periods of food insecurity that people experience. There are many triggers of chronic and acute food insecurity. Some of these triggers include poverty, poor governance, economic mismanagement and a high unemployment rate (Saad, 1999). Food insecurity that is induced by poverty is triggered by deprivation, which in turn is linked to poverty. High unemployment rates result in a large number of people not having the purchasing power to achieve food security. As Klasen and Woolard (2000:1) state "This country is South Africa which is currently experiencing one of the highest reported unemployment rates in the world."

There are various methods through which one may attain food security, namely: the production of one's own food; through purchasing power; the reliance on welfare grants and through having social and cultural claims which ensures food security. Social and cultural claims refer to systems that ensure that all members of a community are food secure as a result of familial ties. Baipethi and Jacobs (2009:460) as cited in Ruel *et al* (1998) state:

> "there is a general consensus that households access food mainly through three sources. These are the markets, subsistence production and transfers from public programmes or other households."

One's purchasing power is reliant on an income that one receives. Therefore, if one's purchasing power is taken away, so too is one's food security. The same may be said for a reliance on welfare grants. The production of one's own food seems like a guaranteed method of attaining food security, insulating households from external factors that may compromise their food security. This is further explained by Baipethi and Jacobs (2009:462), who state:

> "Subsistence production and/or smallholder production can increase food supplies and this cushions households from food price shocks, thereby improving household food security."

However, there are many factors that need to be taken into consideration. These include climatic factors that may affect food production, land and soil types that influence the type of food that may be grown and the amount of land that is available for the production of food. Additionally, a lack of agricultural knowledge may also prove to be a barrier to people seeking the attainment of food security through the production of their own food (Baipethi *et al*, 2010). In areas where there is poverty and where soil and fertility problems are prevalent, compost and humanure can be used to improve and increase agricultural output.

2.3.3. Compost and Humanure

Compost is a material that resembles soil, and is often added to soil for optimal health and growth of plants. Compost is derived from the process of composting various materials, and may be defined as "enhancing the consumption of crude organic matter by a complex ecology of biological decomposition organisms" (Solomon, 1993:1). There are different methods of composting, such as aerobic or anaerobic composting processes. Aerobic composting occurs within the presence of oxygen; whilst anaerobic composting occurs with an absence of oxygen, resulting in the production and release of methane gas. Thus, it may be said that aerobic composting is a cleaner method of composting, as no green-house gas such as methane is produced. As Hoyos *et al* state:

> "The composting process is a biological exothermic oxidation of organic matter, followed by a maturing phase, carried out by a dynamic and rapid succession of microbial populations. The organic matter is transformed into a final stable humus type product (compost) through its mineralization and humification. This product is a hygienic material, free of unpleasant characteristics." (Hoyos *et al*, 2002:162).

Aerobic composting, performed under the correct conditions, activates thermophilic bacteria which produce heat spikes in the range of 50 to 70 degrees Celsius (Hoyos et al, 2002), within the compost pile. Reaching the correct temperatures, heat has the potential to render potentially harmful bacteria, pathogens and helminths ineffective and safe for agricultural purposes (Rihani *et al*, 2010).

Humanure is compost that is made with the addition of human excrement. It is a substance rich in potassium, phosphorus and nitrogen, which are essential elements for plant growth and key additives to chemical fertilisers (Wilkinson *et al*, n.d.). These elements are found abundantly in human excrement (Were, 2007). From a 'humanure' point of view, "human excrement, including faecal material and urine, are not considered waste materials that need to be disposed of. They are resource materials that should be recycled and reclaimed for use" (Jenkins, n.d:1).

This is not the outlook of the majority, as human excrement is associated with many stigmas and taboos. Kelly (2010), introduced the concepts of 'faecophobic' and 'faecaphilic' as a form of differentiation. 'Faecophobic' refers to "strong taboos against handling and talking about human faeces" and 'faecaphilic' is having "no taboos … to use faeces and urine to build the fertility of soils: (Kelly, 2010:13). There are many people who adopt a 'faecophobic' view, possibly due to cultural influence. Many cultures are 'faecophobic' due to the belief that human excrement is taboo and dirty and should not in any way be handled. However, once the stigmas and taboos are overcome, the value of human excrement as compost, humanure, may be recognised.

The composting process involves the biological decomposition of organic matter. Thermophilic composting is "the aerobic decomposition of organic matter that includes a hot stage dominated by heat producing bacteria" (Jenkins, n.d:8). These bacteria are essential for thermophilic composting, as the hot stage is a necessary stage in which harmful bacteria and pathogens are destroyed due to the high temperatures (Jenkins, n.d.). As Jenkins (n.d.:8) notes, "research has shown that human pathogens find the thermophilic environment hostile and that they will rapidly die off in such an environment." Rendering humanure free of harmful bacteria and pathogens is essential, as humanure that remains unsanitised may pollute soil and groundwater. This is reiterated by the Guidelines for Human Settlement and Planning (n.d.), which notes that soil and groundwater contamination may result from unsanitary human excrement.

Jenkins (n.d.:10) explains the thermophilic process that a humanure compost pile undergoes:

> "Humanure compost piles will undergo several stages of decomposition in addition to the initial thermophilic stage. After the hot phase has ended, the organic material will continue the process of biological degradation and transformation into humus aided by non-thermophilic microorganisms, macroorganisms such as earthworms and other insects, and fungi. These additional stages allow for further decomposition of the organic material to produce a plant-friendly and agriculturally beneficial final product. The composting process therefore incorporates both the element of temperature and the element of time. Combined, they produce an end product that is safe, sanitary, pleasant smelling, stable, can be stored indefinitely and can be used for growing human food."

It is through the abovementioned process that harmful bacteria and pathogens that may be present in human excrement are destroyed. The typical pathogens that are present in excrement are discussed in the next section.

2.3.4. Pathogens

Excrement from various organisms and species contain numerous types and strains of bacteria and pathogens, many having the ability to be harmful to human health if ingested, or if mere contact is made (Jenkins, 2005). Humanure, which contains a percentage of human excrement, will inevitably contain certain pathogens and bacteria that are harmful, and need to be eradicated. Taking into consideration the reluctance to use human excrement for agricultural use, especially for food production, it is necessary to examine the bacteria and pathogens likely to be found in the growing medium. However, since the number and types of bacteria and pathogens are too large of a population to identify, it is necessary to identify certain indicator pathogen and bacteria which will indicate the safety of using human excrement in agriculture for food production (Tortorello, 2003).

2.3.4.1. Indicator Pathogens

Indicator pathogen and bacteria are those strains that are used as "a sign of quality or hygienic status in food, water, or environment" (Tortorello, 2003:1208) and are able to survive in hostile conditions with relative ease. Judging excrement by the survival rate of these pathogens is a useful method of testing the hygiene of humanure. Indicator pathogens and bacteria of human excrement include Heterotrophic or Standard Plate Count (HPC), Coliform bacteria, Escherichia coli (E. coli), faecal Streptococci, Pseudomonas Aeruginosa, Clostridium Perfringens, Legionella Pneumophilia, and Helminth ova. These pathogens will be discussed in greater detail below.

I. Heterotrophic or Standard Plate Count (HPC)

The HPC consists of a diverse group of bacteria that "have a wide range of metabolic capabilities and culture requirements and constitute a wide range of risks to public health" (LeChevallier and McFeters, 1985: 1338). HPC is intended to reveal the number of bacterial colonies in the substance tested, but "the test itself does not specify the organisms that are detected" (Koch, 2003:2).Not all of these colonies fall into the category of harmful bacteria, however, it is still a good indicator of bacterial activity. As the Guidelines for Canadian Drinking Water Quality (2006:3) state, "HPC results are not an indicator of water safety and, as such, should not be used as an indicator of potential adverse human health effects."

Health impacts: As Gandham (2012) suggested, HPC bacteria should not be viewed as a health concern. However, certain bacteria that may be present in the HPC could be opportunistic bacteria which could negatively impact on individuals with debilitated immune systems (Koch, 2003: 9). Legionella and Pseudomonas Aeruginosa are two heterotrophic bacteria that have been linked with opportunistic infections that have mostly been hospital acquired (Gandham, 2012 and Koch, 2003). Some of these infections include “wound infections, urinary tract infections, post-operative infections, respiratory infections and infections in burn patients” (Gandham, 2012). Therefore, HPC may be used as an indicator for possible negative health impacts for persons with compromised immunity. Opportunistic infections will be more likely to develop as a result of compromised immunity.

II. Coliform Bacteria

Coliform bacteria may be defined as “Gram-negative, oxidase-negative, aerobic or facultative anaerobic non-spore-forming rods, able to grow in the presence of bile salts, and which ferment lactose to produce acid and gas within 48 h at 37_C” (Tortorello, 2003: 1210). This definition is based on the methods of identification of the coliform bacteria. Previously, the bacteria of the total coliform group was thought to indicate the presence of faecal matter, as E.coli bacteria was the most abundant type of bacteria recovered from human faecal matter. Thus, it was assumed that the presence of total coliforms indicated the presence of E.coli bacteria (Stevens *et al*, 2003: 4). Stevens *et al* (2003:4) state that “the total coliform group of bacteria was originally used as a surrogate for E. coli (the name coming from ‘coli-form’ or like) which, in turn, was considered to show feacal pollution.” and that “total coliforms were adopted and considered to be equivalent to E. coli until more specific and rapid methods became available”.

Table 2.2: Family, Genera and Species of Some Common Coliforms

FAMILY	GENERA	SPECIES
Enterobacteriaceae	Escherichia	Escherichia coli (E. coli)
	Klebsiella	Klebsiellapneumoniae (K. pneumoniae)

	Enterobacter	Enterobacteramnigenus (E. amnigenus)
	Citrobacter	Citrobacterfreundii (C. freundii)

Source: (Stevens *et al*, 2003:4)

Coliform bacteria are thought to belong to four specific genera of the Enterobateriaceae family, namely, Citrobacter, Enterobacter, Esherichia and Klebsiella, as shown in Table 2.2. It is noted however, that the definition of Coliform bacteria does not match all the strains of the abovementioned bacteria. Furthermore, it may be said that some bacterial strains from differing genera may match up to the definition of Coliform bacteria (Cornell University, 2007:1). Additionally, bacterial strains from differing genera which may match up to the definition can also be of non-faecal sources and are therefore a false positive or wrongful indication of faecal contamination or presence (Doyle and Erickson:2006). Therefore, as Payment *et al* (2003: 29) note, "Coliform bacteria are also no longer regarded as indicators of faecal contamination, but are of use as indicators of general microbial quality. This acknowledges that some coliform bacteria may be part of the natural bacterial flora in water and proliferate in biofilms."

The reasoning for the concern by Payment *et al* (2003) is that coliforms, in general, have been found to occur in soil, water and plants under normal, sanitary conditions. Furthermore, coliforms are not necessarily an indication of faecal contamination, as some of the bacteria in the coliform group occur naturally in the intestine of animals and humans (Stevens *et al*, 2003). This is confirmed by Stevens *et al* (2003, 16) who state:

> "Many coliform bacteria, other than E. coli, form a small component of the normal intestinal population in humans and animals. It is well recognized and reported that E. coli is the only coliform that is an exclusive inhabitant of the gastrointestinal tract (Edberg et al., 2000). Most coliforms have an environmental origin and include plant pathogens and normal inhabitants of soil and water environments."

This is reiterated by Tortorello (2003:1210), who states "*Enterobacter*, *Klebsiella*, and *Citrobacter* includes species that are normal inhabitants of plants and the environment; thus, a positive coliform test does not necessarily indicate fecal contamination". This discovery took away credibility from coliforms as indicators of faecal pollution and unsanitary conditions as a result of faecal matter content. Faecal coliforms were subsequently used as indicators of faecal pollution instead.

Health impact: The aforementioned quote from Stevens *et al* (2003) indicates that many coliform bacteria are found normally occurring in the intestinal tract of animals and humans. Cornell University (2007) also states that most coliform bacteria, with the exception of harmful strains of mainly E.coli bacteria, are not associated with any foodborne illness. Table 2.3 summarises coliforms that are a potential health hazard.

Table 2.3: Coliforms that may cause illness

Bacteria	**Illness**	**Symptoms**
Enterohemorrhagic E. coli (EHEC)	Hemorrhagic Colitis	Bloody diarrhea, severe abdominal cramps (nausea, vomiting), fever rare
	Produce Shiga-like toxins (verotoxins, verocytotoxins),	Affect primarily the large intestines
	Hemolytic Uremic Syndrome (HUS)	Toxins in blood, kidney disease; young & old at risk (can be fatal)
Enteroinvasive E. coli (EIEC)	Multiplies inside intestinal (colon) epithelial cells, spreads to adjacent cells	No enterotoxins, bloody or non-bloody diarrhea (large amounts) caused by cell damage

Enteropathogenic E. coli (EPEC)	Adheres to intestinal mucosa, destroying or modifying cells	No enterotoxins, diarrhea, most common in children under 1 yr old
Enterotoxigenic E. coli (ETEC)	Attaches to and colonizes small intestines	Traveller's diarrhea in young and adults; sudden, acute, non-bloody, very watery

Information adapted from Stevens *et al* (2003)

III. Faecal Coliforms

Faecal coliforms may be defined as "gram-negative bacilli, not sporulated, oxidase-negative, optional aerobic or anaerobic, able to multiply in the presence of bile salts or other surface agents that have equivalent properties, and are able to ferment lactose with acid and gas production in 48 h at the temperature of 44 +/- 0.5 degrees C" (Doyle and Erickson, 2006: 1). Faecal coliforms are said to have similar characteristics of the coliform group discussed above, with the exception that the circumstances allowing fermentation differ, as can be deduced from the definitions. While fermentation proceeds at approximately 37 degrees C (Tortorello, 2003) for coliforms, faecal coliforms ferment at approximately 44 degrees C (Doyle and Erickson, 2006).

Thus, faecal coliforms may be a sub group of total coliforms. The most common indicator of faecal coliform is E.coli, a genus of bacteria found present in the intestine of humans and animals, and generally not found naturally occurring. There are, however, other strains of bacteria that are able to ferment at approximately 44 degrees C to qualify as a faecal coliform. This is reiterated in the following quote "*E. coli* is regarded as the most sensitive indicator of faecal pollution. The large numbers of *E. coli* present in the gut of humans and other warm-blooded animals and the fact that they are not generally present in other environments support their continued use as the most sensitive indicator of faecal pollution available" (Edberg *et al*., 2000 as cited in Stevens *et al*, 2003: 23). Although used as an indicator of faecal pollution, faecal coliforms are said to be not the most effective indicator. Tortorello (2003: 1210) indicated that "species that have this capacity also are known to be present naturally in the environment; thus the fecal coliforms are not specific indicators of fecal pollution of water, either."

This is substantiated by Fujioka and Shizumura (1985: 986) who states:

> "pathogens such as human enteric viruses have been recovered from natural waters that were determined to be safe based on low densities of fecal coliforms, fecal coliforms have been reported to be capable of multiplying in environmental waters under some conditions, some fecal coliforms such as Klebsiella pneumoniae do not have a fecal source, and laboratory results show that fecal coliforms are less resistant than some pathogens (such as human enteric viruses) to chlorination or less stable in natural waters."

It is due to these reasons that faecal coliforms as an indicator of faecal pollution is questioned. Fujioka and Shizumura (1985) further state that Streptococci and Clostridium Perfringens bacteria appear to be more reliable alternative indicators.

The health impacts of faecal coliforms are much the same as that of total coliforms, due to faecal coliforms being a sub group of total coliforms. Table 2.3 lists illnesses and symptoms typically caused by coliform bacteria.

IV. Streptococcus/Streptococci

Streptococcus bacteria are "gram-positive and a member of the lactic acid bacteria" (Hoskins *et al*, 2001: 5709). This group of bacteria includes a collection of human pathogens, which are known to cause opportunistic infections (Hoskins *et al*, 2001:5709). This indicates that although this type of bacteria has the potential to cause illness and disease, it will do so when the immunity of a person is compromised, hence, opportunistic infections.

V. Pseudomonas Aeruginosa

Pseudomonas Aeruginosa, a gram negative bacterium, is one of the major pathogens from nonfermentative bacteria; causing infections in many due to its resistance to antibiotics (Hancock, 1998).

VI. Clostridium Perfringens (C. perfringens)

Clostridium perfringens are "sulfite-reducing, spore-forming, clostridia, which are hardy rod-shaped anaerobic bacteria" (Stevens *et al*, 2003:24), known to be the "most widely distributed in nature" (Shimizu *et al*, 2001: 996). Although these bacteria are directly associated with faecal matter, as they have been isolated from the intestine of many animals and humans as normal flora; this type of bacteria is also commonly found in the environment in soil (Steven *et al*, 2003 and Shimizu *et al*, 2001). Fujioka and Shizumura (1985: 991) note that this bacterium is one of the reliable and more telling indicators of faecal contamination due to "its resistance to chlorination and environmental factors closely resembles that of enteric virusus."

Health Impacts: C. perfringens bacteria are classified into five groups based on their production of the four major toxins, namely, alpha-, beta-, epsilon-, and iota-. Each of the five groups is associated with certain illnesses as summarised in Table 2.4.

Table 2.4: Diseases caused by C. perfringens

C. perfingens Group Type	Disease/Illness
A.	Gas gangrene (clostridial myonecrosis), food poisoning, necrotic enteritis of infants, necrotic enteritis of poultry
B.	Enteritis of poultry foals, and goats
C.	Enterotoxemia of sheep (struck), necrotic enteritis in animals, human enteritis necroticans (pigbel)
D.	Enterotoxemia of sheep (pulpy kidney disease)
E.	Enteritis of rabbits

Source: Rood and Cole (1991: 622)

Angelotti (1961, 193) notes that C. perfringens was one of the principal causes of foodborne diseases in the British Isles; with atypical Type A C. perfringens bacteria responsible.

VII. Legionella Pneumophila

Legionella pneumophila is defined as "a Gram-negative, facultative intracellular bacterium capable of growing within human alveolar macrophages" (Roy *et al*, 1998: 663), and is said to be a "fastidious and not easily detected" (Fields *et al*, 2002: 506) bacteria. The genus Legionella was founded in 1979 following an outbreak of pneumonia three years previously. Once the genus was founded, the causative bacterium was identified as Legionella pneumophila. Legionella is also currently known to have the ability to infect very diverse hosts, ranging from slime molds to protozoa to mammalian cells. (Fields *et al*, 2002). The Public Health Agency of Canada (2010) states that Legionella can be transmitted by aerosols and aspiration of contaminated water, and may be hosted by humans.

Health impacts: As (Roy *et al*, 1998: 663) notes, "infections by this organism can result in an acute pneumonia known as Legionnaires' disease." This disease is often thought of as an unusual illness, but is really a severe form of pneumonia, which is frequently misdiagnosed due to the ignorance and lack of common knowledge about the bacteria and disease. Symptoms caused by Legionnaires' disease include confusion, headache, diarrhea, abdominal pain, fever, chills, and myalgia as well as a non-productive cough. The mortality rate of this disease is reported to be 15-25%. Legionella is also responsible for the cause of Pontiac fever, a non-pneumonic form of L. pneumophila infection. Symptoms of Pontiac fever are flu-like, including fever, tiredness, myalgia, headache, sore throat, nausea, and a cough that may or may not be present. Unlike Legionnaires' disease, persons with Pontiac fever do not require hospitalization or medication such as anti-biotics. Furthermore, no reported deaths associated with Pontiac fever have been reported (Public Health Agency of Canada, 2010).

VIII. Helminth ova

Helminth ova are worm eggs that pose serious health threats to humans and animals. These ova are known to be extremely resilient to hostile conditions, and are able to survive outside of the host for long periods of time. One of the hardiest, Ascaris ova is known to have many layers of protective material as its outer shell, thus ensuring that the egg survives in most conditions. Ascaris ova belong to the nematode group, and are used as an indicator of all helminth eggs. Temperature and pH do affect the survival of the helminth ova, with high temperatures and low pH values rendering the ova inactive (Maya, 2012: 4771). Helminths are parasitic and are the cause of intestinal disease and illness for many.

Health impacts: Health impacts caused by helminth ova are very serious. Those with inadequate and unhygienic sanitation and a lack of basic services are most vulnerable to infection. As Crompton and Savioli (1993: 1) state:

> "Similar health problems have existed among poor people in the cities of developing countries even before urbanization became the force that it is today. Many of the present residents of the urban slums were actually born there and, together with the recently arrived rural people who are trying to adapt to the urban situation, they form a group that is relegated to the margins of social, political and economic activity. Both the migrants and the long-established slum-dwellers carry the burden of intestinal parasitic diseases because the meager resources of the city authorities are overstretched and their services for water supply, sanitation, garbage disposal, health care and hygiene are inadequate."

It is evident from the above quote that there are certain people who are more prone to contracting diseases and illnesses associated with helminths due to circumstance. However, this does not completely rule out others from contracting these diseases as well. The table below summarizes the common intestinal parasitic infections caused by helminths.

Table 2.5: Common intestinal parasitic infections caused by helminths

	Ascariasis	**Trichuriasis**
Causative agent	Ascaris lumbricoides	Trichuris trichiura
Global prevalence (millions)	1000	800
Infective stage	Egg, containing second laval stage	Egg, containing first larval stage
Usual location in humans	Early larvae undergo migration via liver, adults in jejunum	Mucosa of large intestine, especially of the colon
Parasitological diagnosis	Eggs in stools	Eggs in stools
Clinical diagnosis	Abdominal pain, nausea,	Diarrhoea, finger clubbing,

	anorexia, respiratory complications	stool blood, rectal prolapse
Morbidity	Nutritional disturbance, acute complications, e.g., biliary and intestinal obstructions	Chronic colitis, anaemia, reduced growth rate
Treatment	Levamisole, mebendazole, pyrantel	Mebendazole

Source: Information adapted from Crompton and Savioli (1993: 3)

The above discussion on pathogens is also relevant to food safety. Just as harmful bacteria and pathogens may contaminate soil and groundwater, edible plants grown in contaminated soil may also take up these pathogens and bacteria during their cultivation and growth. Produce with certain levels of bacteria and pathogens may lead to food borne illness in some. It is therefore essential to monitor microbial levels in fresh vegetable produce.

2.3.5. Food Safety

Food safety may be measured by the presence or absence of microbial elements, at predetermined limits. The presence of these elements in unsafe quantities can have a severe negative impact on the health of those who consume the contaminated food (WHO, n.d.). Different food types may be susceptible to different types of bacteria. Bacteria that may exist in and render meat products unsafe may differ from bacteria that may exist in and render vegetable products unsafe. According to Abadias *et* al (2008:122), “fresh produce can be a vehicle for the transmission of bacterial, parasitic and viral pathogens capable of causing human illness and a number of reports refer to raw vegetables harbouring potential foodborne pathogens.” Four of the most common bacteria that are associated with determining the food safety of fresh vegetable produce are Listeria, Salmonella, Shigella and E.coli; which can taint fresh vegetable produce at any stage of growth, harvest or post-harvest (Abadias *et* al, 2008; Gilbert *et al*, 2000). This is reiterated by the European Commission's Scientific Committee on Food (2002:7), who state "during growth, harvest, transportation and further processing and handling the produce can, however, be contaminated with pathogens from human or animal sources."

2.3.5.1. Surface and Internal Contamination of produce

Many bacteria that are associated with causing food borne illnesses may be present in soil, the growing environment and in the water used to irrigate crops. Consequently, surface contamination of produce may occur. Surface contamination may be quashed if the skin or peel of the produce is removed (WHO, n.d.). However, there is a chance of cross contamination from the peel of the produce to the inner portion. Internal contamination, unlike surface contamination, is unable to be cleansed by removal of the outer portion of the produce (WHO, n.d). Bacteria become resident within the produce, under the outer layers, resulting in internal contamination. Internal contamination of produce may be removed through processing. Minimally processed goods, such as fresh vegetable and fruit produce, are susceptible to both internal and surface contamination (Lynch, Tauxe and Hedberg, 2009). There are cases of fresh vegetable produce becoming contaminated, either internally or on the surface. Some of these incidents have resulted in serious illness and death. It is for this reason that food safety measures are important.

2.3.6. Case study: E.coli contamination of fresh vegetable produce in Germany - 2011

It is of utmost importance that the microbiological safety of foods is maintained to prevent contamination, and consequent severe health hazards for consumers of the fresh vegetable produce (Lynch, Tauxe and Hedberg, 2009). Food safety is especially important when using humanure for the growth of food, as there are many potential disease causing pathogens and bacteria that are present in the gut of humans, and hence in faecal matter (Fooks and Gibson, 2002). There have been cases where harmful and disease causing bacteria have contaminated fresh vegetable produce, consequently infecting many consumers of the produce. One such case study was the contamination of fresh produce in the European Union (EU) region in 2011.

In Germany, an unidentified bacterial disease had claimed the lives of 16 people, as at 01 June 2011. It was suspected that the outbreak originated from fresh vegetable produce sourced from European farmers. Due to this, many countries in the region were forced to place restrictions on vegetable imports, while retailers across the region withdrew all produce from their stores. This had a severe negative impact on farmers, costing them millions of Euros. At this time, authorities were unsure of the cause of the outbreak, but were able to identify a strain of E.coli as the responsible bacteria (the Guardian, 2011, Sample). This strain of the bacteria resulted in Haemolytic Uraemic Syndrome (HUS), a disease which is commonly linked to kidney failure and bloody diarrhea. Sample (the Guardian, 2011:20, Sample) notes that:

> "the new strain of E coli causes' disease by colonising the gut and producing a toxin called Shiga. Many patients experienced bloody diarrhea and in the most serious cases the infection caused a life-threatening condition called haemolytic uraemic syndrome (HUS)."

The number of infected people increased to 470, reported on 01 June 2011 (Mail and Guardian online, 2011a, Curta).

Authorities and health officials were unsure of the source, but cautioned citizens against consuming raw vegetable produce such as raw cucumbers, tomatoes, or lettuce, which were presumed to be the most probable source of the bacterial contamination. Through investigation, all cases of food poisoning across Europe were linked to Germany; more specifically, to people who had recently travelled to northern Germany, where the outbreak had started in mid-May of 2011 (Mail and Guardian online, 2011b, Curta). By 03 June 2011, the number of lives claimed by the outbreak of the disease had risen to at least 18 and the number of reported infections of HUS increased to 499 people (Mail and Guardian online, 2011, Bronst). Approximately 2000 cases of food poisoning were reported by the Regional German health authority, with symptoms including diarrhea, fever, vomiting and stomach cramps (Mail and Guardian online, 2011, Bronst). As reported by the European Center for Disease Prevention and Control, the number of lives claimed had risen to 22 by 06 June 2011.

The World Health Organisation identified the cause as a rare strain of E.coli bacteria that was not commonly associated with strains related to food poisoning. Furthermore, cases of food poisoning had been spread to many other countries, including Britain, France, Spain, Sweden, and the United States of America. Each of these reported cases were related to travel with Germany (Mail and Guardian online, 2011b, Curta).

By 10 June 2011, it was reported that the death toll due to the E.coli contamination outbreak was 29, with 2900 people affected by food poisoning related symptoms. Bean sprouts were also added to the list of suspected carriers of the disease causing bacteria. Due to the uproar surrounding the outbreak, countries such as Russia and Saudi Arabia had issued a 'blanket ban' on all imports of vegetables from the EU region (Sunday Times, 2011, Sapa-AP). Ian Sample, reporting for The Guardian reported that bean sprouts were officially linked to the outbreak of disease associated with vegetable produce from Germany. According to Sample (2011:20) "Bean sprouts from an organic farm in northern Germany caused the E coli outbreak that has killed 31 people and infected thousands more, German officials said on Friday." Due to this finding, warnings against the consumption of fresh vegetable produce such as cucumbers, tomatoes and lettuce were lifted, as well as 'blanket import bans' imposed by Russia. The head of Germany's risk assessment agency stated "Lettuce, tomatoes and cucumbers should be eaten again – it is all healthy produce." (Sample, 2011:20)

2.4. Conclusion

The theory of zero waste management, where 'waste' is viewed as a resource, is fitting for this research. Human excrement has long since been viewed as a toxic waste, which has a stigma attached to it. Through the application of this theory, human excrement may be viewed as a freely available resource which may be used to make humanure, contributing to ensuring food security at household level; as well as the non-hazardous disposal of human excrement. This chapter has comprised of a compilation of literature relevant to this study, including agriculture; food security; food safety and indicator organisms. Food security is an important aspect of the literature, as it is linked to agriculture and food safety. Agricultural practices may contribute to food security at household level, but this may be negated by unsafe, contaminated produce. A case study of fresh vegetable produce contamination in Germany has been used as an example to illustrate the importance of food safety standards. The consumption of contaminated food can have dire consequences. The background of the study area, as well as a discussion of the methods employed in this study will be discussed in the following chapter.

Chapter Three

Study Area and Methodology

3.1. Introduction

This chapter will focus on the study area in which this research is based, as well as the methods employed to achieve the objectives of this study. It is divided into two sections, namely, 'background to study area' and 'methodology'. It should be noted that information with regard to the study area is largely absent, possibly due to its peripheral location. The researcher has attempted to describe the area through observation and information gained through interaction with community members.[1]

3.2. Background of Study Area

The study area for this investigation is Cottonlands, located within the borders of the eThekwini Municipality, some 50 kilometers north of the Durban CBD. Cottonlands was originally sugarcane farming land. However, the area underwent a change, and transformed into a rural/residential area, through rezoning. The area is once again undergoing change, from a rural to a peri-urban area, as services such as water and electricity being are made available to the community.

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[1] It should be noted that information with regard to the study area is largely absent, possibly due to its peripheral location. The researcher has attempted to describe the area through observation and information gained through interaction with community members.

Cottonlands is located in close proximity to the town of Verulam, which is north of the city of Durban. Although the town is a multi-racial one, the population of the Cottonlands community is comprised predominantly of isiZulu speaking people. The community, which comprises of approximately 2500 households, displays characteristics of both rural and urban areas, due to its proximity to Verulam, thus making it a peri-urban area. Services such as sanitation remain an issue in Cottonlands, as there is a lack of or limited infrastructure available in the area. The area acts as a transition zone, as it is geographically close to the towns of Verulam and Tongaat, and close to landmarks in the Municipality such as the King Shaka International Airport, as illustrated in Figure 3.2. Despite the physical closeness of the airport to the community; the area and services offered in the community have not seen much improvement in recent years.

The community still lacks facilities such as clinics and hospitals, transportation modes such as railway stations or formal, roads. This is illustrated in Figure 3.1, where it is evident that the area of Cottonlands is free of any hospitals, railway stations, sewer pipes or roads. Furthermore, residents of Cottonlands in need of medical services have to travel to the next town, Tongaat, where the nearest hospital is located. The neighboring towns of Verulam and Tongaat service the community of Cottonlands, as these towns are equipped with the amenities and facilities that the residents require. Efforts to uplift the area have been made by the municipality, in the form of a community based mushroom farm, where locals are employed and are involved in the day-to-day running and upkeep of the farm. Currently, there is an eco-village that is being built in the area. It is apparent that development is occurring in the area, albeit at a slow pace. Recreational facilities such as sporting centers and shopping malls are not present in the immediate area[2]. These facilities can, however be found in towns located in close proximity to the study area. These include the towns of Verulam and Tongaat.

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[2] It should be noted that information with regard to the study area is largely absent, possibly due to its peripheral location. The researcher has attempted to describe the area through observation and information gained through interaction with community members.

The eThekwini municipality is made up of different wards. Each ward is allocated a local councilor, who is in charge of his/her specific ward. The area of Cottonlands falls under Ward 66 of eThekwini Municipality. There is a primary school located in the community, a relatively new development, which is widely used by the members of the community. Though there are informal traders in the area, there are a few emerging formal traders in the area, who are establishing their businesses in the peri-urban community. The main road that runs through the community is tarred. All other access roads going into the community are dirt and gravel roads. Many of the households in the area have prepaid water and electricity meters, with public taps situated at central points throughout the community. Not all residents of the area appear to be employed, with many women appearing to tend to household duties and men working outside of the household to earn an income[3].

[3] It should be noted that information with regard to the study area is largely absent, possibly due to its peripheral location. The researcher has attempted to describe the area through observation and information gained through interaction with community members.

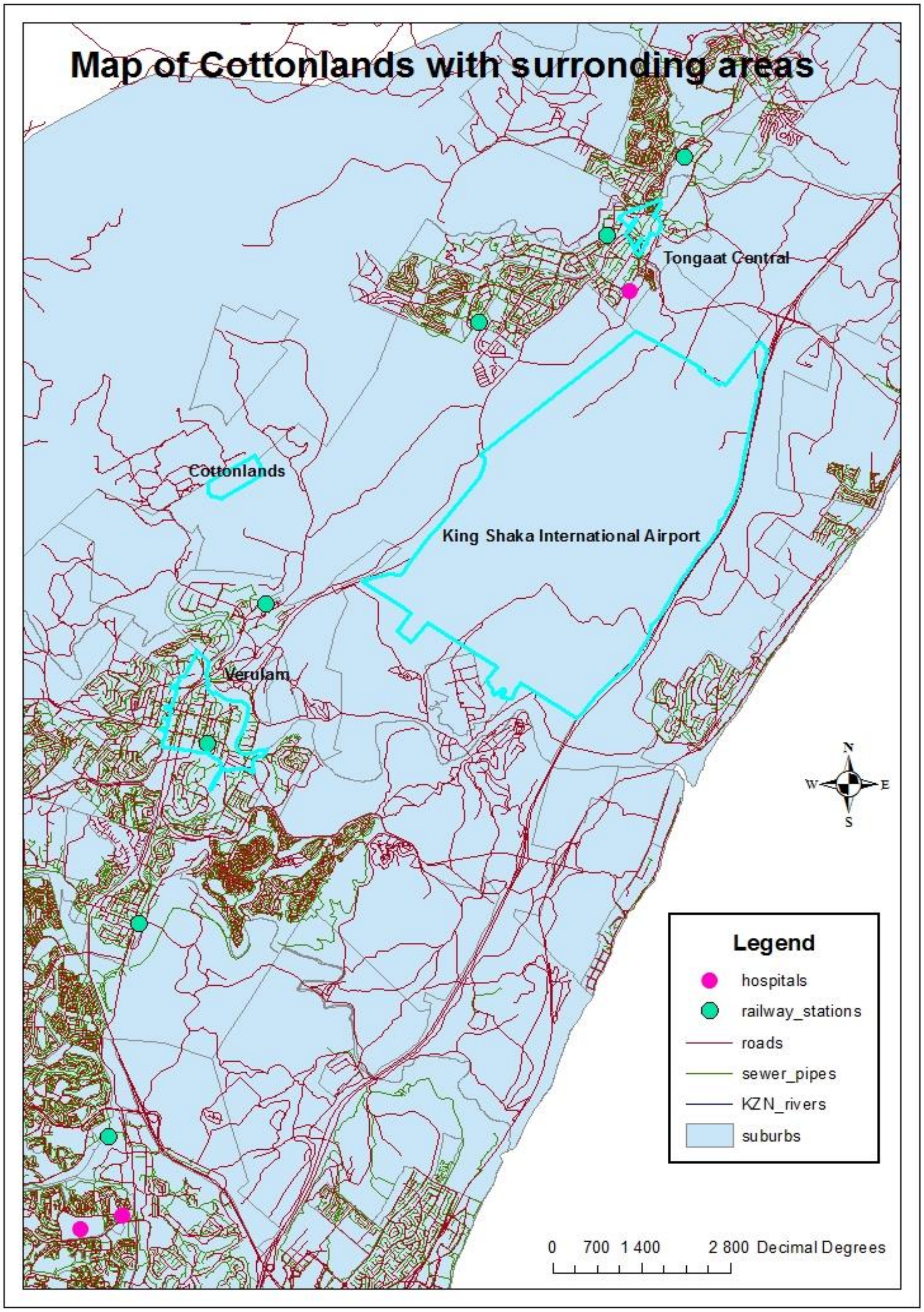


Figure 3.1: Map of Cottonlands with surrounding areas

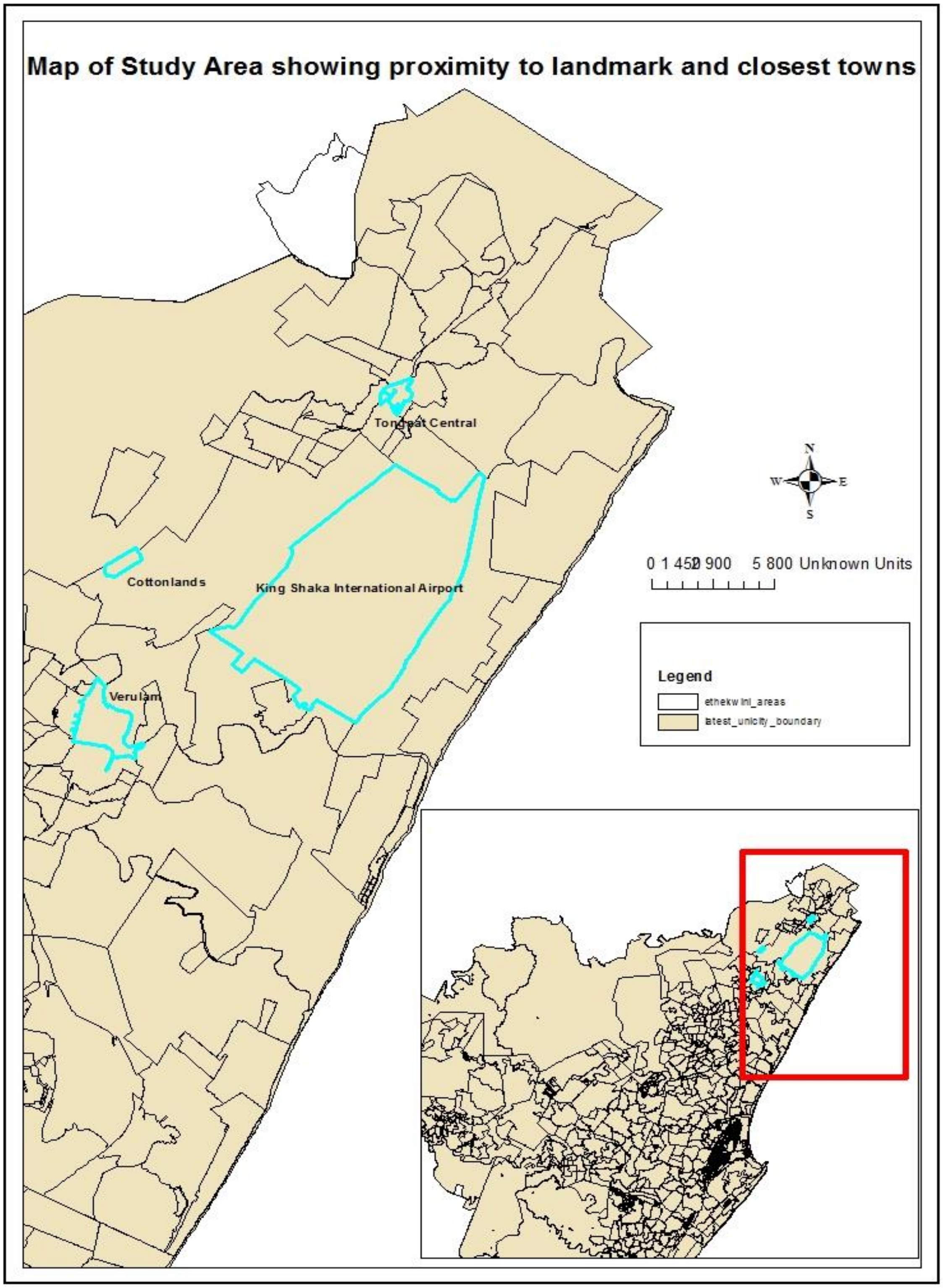


Figure 3.2: Map of Study Areas showing proximity to landmark and closest towns

3.3. Methodology

3.3.1. Methods and Techniques

This study employed a mixed method approach, through the use of both qualitative and quantitative methods. Using a combination of these methods may achieve a more in-depth and holistic result. Qualitative methods deal with observations and perceptions, whereas quantitative methods focus on numbers and facts. According to Babbie (2011:11) "the distinction between qualitative and quantitative data in social research is essentially the distinction between numerical and non-numerical data."

Quantitative research methods are defined as "one in which the investigator primarily uses postpositivist claims for developing knowledge (i.e., cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data" (Creswell, 2013:18). Furthermore, qualitative research methods may be defined as "research using methods such as participant observation or case studies which result in a narrative, descriptive account of a setting or practice" (Guest *et al*, 2013:2).

3.3.2. Non-probability Sampling

When using non-probability sampling, it is impossible to know if all the representative elements of the study population have been included in the sample. It is possible that some of the elements of the study population may not be included in the sample. Due to this, the degree to which the sample truly represents the study population is difficult to ascertain, making any generalization that may be drawn from the sample questionable. Non-probability sampling is another type of sampling method that is commonly used. Non-probability sampling may be used when it is not possible to execute probable sampling methods due to factors like a complete sampling frame being unavailable or time and financial constraints (Judd and Kidder, 1986).

3.3.2.1 Purposive Sampling or Judgment Sampling

In purposive sampling, the researcher subjectively selects the sample. While selecting the sample, the researcher aims to get a sample that is, or appears to be representative of the population that is being researched. Furthermore, the researcher will try to make certain that the sample is representative of the population including a wide range of elements from one extreme to the other. Purposive sampling is a type of sampling that is often used in situations such as political polling. This may be attributed to the fact that previous polling results in the area create a pattern which may serve as an indicator of what electorate results may be. (Judd and Kidder, 1986).

A drawback with this type of sampling is that different researchers will have different views on which elements of a population to choose to be a part of the sample. As is the case with any non-probability sample, there is a risk of bias of an unknown extent. The risk of a bias to a certain extent does not decrease with an increase in the size of the sample. (Dixon *et al*, 1989).

3.3.2.2 Convenience or Accidental sampling

A convenience sample is made up of elements of a population who are available in a convenient way to the researcher. The researcher does not have specific elements from the population that are required to be in the sample. Rather, elements from the population are added to the sample until the desired size for the sample is reached. Thus, this method of sampling is void of the concept of randomness; therefore, the likelihood of bias in the sample is high. Over-representation of elements in the population may occur. As a result, any generalization that may be drawn from a sample formed through convenience sampling is very risky. The only way to evaluate the bias of such samples is to conduct a parallel study with a probability sample. However, this is very monotonous, time consuming and costly. This method of sampling is often used by researchers who have restricted access to resources and experience time constraints. When this method of sampling is employed, the limitation of the method must be clearly understood. (Judd and Kidder, 1986). An advantage of this method of sampling is that it is confined to a part of the population that is reasonably accessible to the researcher. (Dixon *et al*, 1989).

3.3.3. Sample Size

The sample size that was used in this study was a sample of 50 households from the Cottonlands community, which was the area in which this research was based.

3.3.4. Surveys

Surveys may be classified as either interviews or questionnaires. A questionnaire may be described as a document consisting of a series of questions which is answered by the respondent; whilst an interview may be described as a process which is documented and completed by the interviewer or researcher, based upon the answers provided by the respondent (Trochim, 2006). Interviews are an important process used in order to gather information required. It is important to note that within human geography and the social sciences, there is a significant emphasis on human interaction in order to understand underlying reasons that changes occur or why specific situations take place. An interview according to Key (1997) is explained as “direct face-to-face attempt to obtain reliable and valid measures in the form of verbal responses from one or more respondents. It is a conversation in which the roles of the interviewer and the respondent change continually”.

The various forms of interviews are: panel interviews, group interviews, telephonic interviews and face-to-face interviews. Structured interviews can be advantageous as this type of interview ensures a relatively easy and quick interview, where the interviewer is well prepared. This type of interview also prevents respondents from digressing from the topic, as there is a set of standardized questions that need to be answered. The surveys that were conducted for the purposes of this study comprised of many different types of questions, namely, open ended questions, closed ended questions and multiple-response questions. All the data derived from the surveys was input into Statistical Package for Social Science (SPSS) for analysis. Through analysis of the data, the critical questions of this study were answered.

SPSS is a computerized program which was used in the analysis of the questionnaires used in this study. This program is a very powerful statistical analysis and data management system. The program has many functions that allows for the use different methods in data analysis, and also allows for visual output of data in the form of graphs and figures.

3.3.5. Secondary data

Secondary data sources such as journal articles and academic publications were used in this research project. Secondary data may be described as data which has previously been collected by a researcher and published. Secondary data from reliable sources such as academic journals and book publications undergo stringent review processes to ensure that the data contained within the articles is worthy.

3.4. Methodology Chosen for this research

3.4.1. Qualitative Methods

Questionnaires were administered to the community, at a sample size of 50, using a purposive sampling method. Non-probability sampling was employed, using purposive and snow-ball sampling techniques, discussed in section 3.3.2, as the questionnaires were aimed at heads of households in the area. A few heads of households in the community were contacted, and asked to refer the researcher to other heads of households in the area. The local school hall in the community was used as a central meeting point for all the respondents, where the questionnaires were individually administered. Individual administration of the questionnaires was essential, due to language barriers. Translators were employed to help overcome these language barriers. Although the use of questionnaires is generally classified as a quantitative data method, they may also be used for descriptive purposes, as is the case in this study, thus qualifying them as a dual quantitative/qualitative research tool.

Another research tool, visual analysis, was employed in this study. Produce from the applied and control plots were compared, according to a set of predetermined characteristics, to determine the effectiveness of using humanure. The produce that was sampled for microbiological levels was also subjected to a visual study, which examined the appearance of the vegetable. Signs of visible disease and blemished areas were regarded as undesirable. All produce samples, from both applied and non-applied trial plot and tyre gardens were subjected to visual analysis. This type of analysis is loosely based on the type of criteria that consumers use to deem fresh vegetable produce suitable for consumption or not.

3.4.2. Quantitative Methods

In addition to the use of questionnaires, other methods were employed in this study to achieve the objectives of the research. Humanure was produced through an aerobic, thermophillic method; microbiological testing was carried out on the humanure to determine the safety of humanure for small-scale agricultural food production and crop produce was also tested microbiologically for certain bacteria and pathogens to determine food safety.

3.4.3. Humanure

Two separate batches of humanure were produced, to investigate the consequence of using different amounts of faecal matter in each batch. The first batch of humanure was made and left to molder for a period of one year, and constituted 5% faecal matter content; whilst the second batch was made and left to molder for a period of three months and constituted 10% faecal matter content. It is usually recommended that any compost should be left to molder for a period of time to ensure mineralization occurs, and that maximum benefit is gained from the end product (Golueke, 1972).

The humanure was made primarily from organic material such as Napier fodder grass, used wheat straw sourced from the local mushroom farm in the community, cow dung and faecal matter sourced from the vaults of UDT's in the community. It is essential to add cow dung to the mix, as it acts as an inoculant for the compost due to the micro-organisms found in the dung. These organisms are ideal for breaking down the Napier fodder grass and wheat straw. All of the above, with the exception of the faecal matter and some Napier fodder were mixed together and placed into a 1000 liter perforated polypropylene bag. The center of the mix was hollowed out, and the faecal matter was filled in the cavity. The faecal matter was mixed with chunks of Napier grass to keep the mix aerated.

Table 3.1: Humanure mix

Ingredient	**Humanure One (%)**	**Humanure Two (%)**
Napier fodder	20	20
Cow dung	10	10
Wheat straw	60	55
Existing compost	5	5
Faecal matter	5	10

The faecal matter was placed in the center of the pile, as the temperature was expected to be warmest at the center. This would ensure that the pathogens present in the faecal matter would be exposed to high, mesophilic and thermophilic temperatures (Golueke, 1972), which would ensure that the survival rate of these pathogens was low. This is attributed to the fact that high temperatures render pathogens and parasites such as helminth ova inactive (Crompton and Savioli, 1993). The cow dung and existing compost that was added to the humanure mixture served as an inoculant for the mix, due to the beneficial and necessary micro-organisms present in the compost and soil. These micro-organisms would populate the heap and boost the composting process.

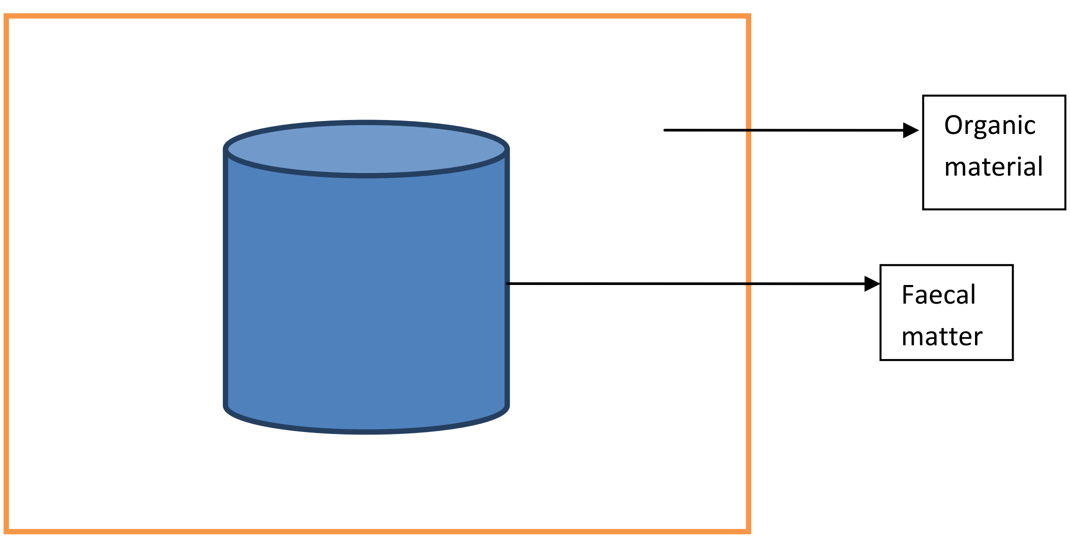


Figure 3.3: Schematic representation of humanure mix in polypropylene bag

3.4.4. Trial Gardens

The two batches of humanure that were made were used in two separate household garden trials, each with a control and test. The two trials that were carried out were a standard household garden trial plot, and a tyre garden trial. These two types of gardens were selected for the trials as they were appropriate models for the community. Some of the households have adequate space in their yards to accommodate plot gardens, whilst the majority of households do not have extra space in their yards to accommodate such a garden. For these households, where space constraints are preset, tyre gardens are suitable due to their compact nature. Plate 4.1 shows the plot garden with the test and control, or applied and non-applied. The first batch of humanure, which was allowed to molder for a period of one year, was applied. The plot dimensions measured 2 meters by 2.5 meters each.

Plate 4.1: Applied and Non-Applied garden plots

The second trial garden was carried out using a technique called tyre gardening. This type of gardening is suited to areas where there is not much land available for planting or if land is fallow and degraded. Through the use of this method of gardening, plants are grown in a mix of soil and compost which is concentrated in the tyre. This method is especially suited to the community of Cottonlands, as many of the households are in close proximity to each other. There is limited space available for plots of land to be cultivated, yet some sort of household level agriculture is necessary to maintain or contribute to food security.

Tyre gardening is a low cost and effective method of gardening and carrying out household level agriculture, as used tyres are readily and abundantly available at a low cost, if any at all. Tyre gardens encourage the production of food at a household level, providing insulation for households against the rising costs of food. This ensures some level of food security for households, simultaneously decreasing their dependency on the market (Anon, 2011). Used or second hand tyres that are sourced from landfill sites can be used for household agriculture, promoting food security; even in places where space is constrained (Sanders, 2006). The method of this type of gardening is illustrated in plate 4.2. Tyres are trimmed of the upper lip, to create more surface area. The bottoms of the tyres are line with plastic, with a small area for drainage of excess water. Growing medium, be it soil, soil and compost or just compost is put into the cavity of the tyre and seedlings or seeds are planted. A layer of mulch is added to the top to prevent the growth of weeds.

Plate 4.2 Prepared tyres lined with plastic and planted tyres

Plate 4.3 Nearly complete tyre garden

3.4.5. Produce Testing

In order to satisfy in part, the third objective of this research, the produce grown in the above garden trials was tested for certain bacteria and pathogens to determine food safety. The produce was tested to ensure food safety and that no pathogens or bacteria that may have been lingering in the soil and humanure were internalized by the vegetables. The bacteria and pathogens that were tested for include E.coli, Listeria monocytogenes, Salmonella and Shigella. These are the most common indicators of food safety in vegetable produce.

3.4.5.1. Food Safety Tests – Method

The method to test for each different type of bacteria remained the same, the only difference being the medium that was plated for each test. The same medium was used to test for Shigella, Salmonella and E.coli, and different media for Listeria monocytogenes. Each of the samples was tested for internal contamination, as surface contamination was not appropriate in this instance.

Samples were collected from trial garden sites, washed in sterilised water and portioned into 10 gram samples. These samples were crushed in a pestle and mortar, and added to 90 millilitres of sterilised water, working on the assumption that 1 gram is equivalent to 1 millilitre. Serial dilutions, with a 1:10 ratio were used. Four test tubes were filled with 9 millilitres of sterilised water for each sample. One millilitre of sample was aspirated from the beaker of 90 millilitres sterilised water and 10 grams of sample after being agitated, and added to one of the pre-filled test tubes, creating the first dilution of 10^{-2} . The test tube was placed in a test tube agitator, to ensure that the sample and buffer were thoroughly mixed. Once again, 1 millilitre of this solution was aspirated and added to the next pre-filled test tube, creating the second dilution of 10^{-3}. This process of agitation, aspirating and adding was repeated to create the third and fourth dilution, 10^{-4} and 10^{-5}, respectively.

From each dilution, for each sample, 0.1 millilitres of solution was plated onto SS Agar and Listeria Brilliance Agar. These agars were used to monitor the growth of Salmonella, Shigella and E.coli (SS Agar) and Listeria monocytogenes (Listeria Brilliance Agar). Once solution was plated on an agar plate, a sterilised, disposable spreader was used to evenly spread the solution over the medium. Once all plating was complete, plates were incubated for a period of 24 hours at 37 ° C, as detailed in table 3.3. After the required incubation period, plates were removed from the incubator and colonies growing on each plate were counted. Different bacterial colonies were differentiated by their appearance on the agar. The table below describes the appearance of the different bacteria on the agars used. Colonies are counted up until 300, and are considered ‘too numerous to count’ if the number of colonies exceeds this limit (Ministry of Health of the People’s Republic of China, 2010).

Table 3.2: Bacterial growth on Agar media

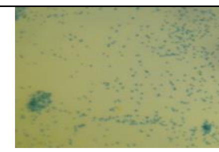
Agar	Colony Type	Colony Description	Example
SS Agar	Salmonella	Colourless with black centers	
	E.coli	Rose – dark pink colonies	
	Shigella	Colourless colonies	
Listeria Brilliance Agar	Listeria monocytogenes	Blue/green center with a halo	

Table 3.3: Time and temperature required for incubation

Bacteria/Pathogen	**Time (hours)**	**Temperature (Celsius)**
Salmonella	24	37
Shigella	24	37
Listeria monocytogenes	24	37
E.coli	24	37

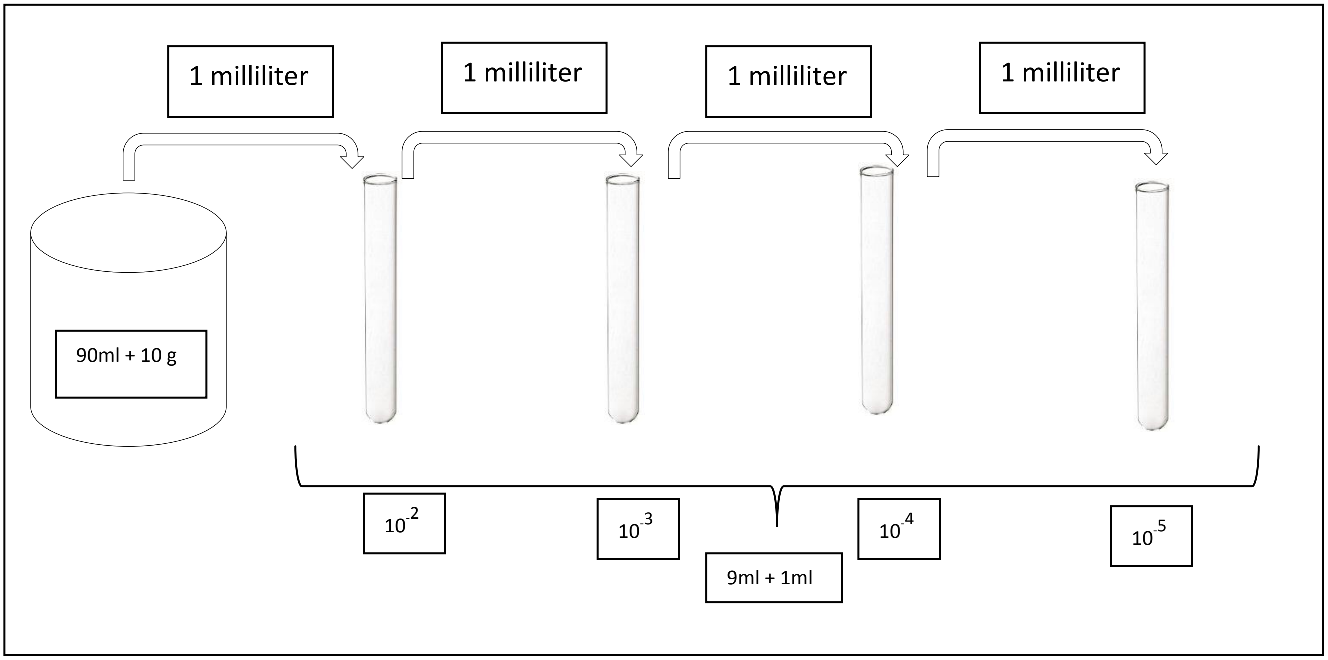


Figure 3.4: Schematic representation of serial dilution method used

3.4.6. Plate Count and Colony Forming Units (CFU)

$$\text{CFU/ml} = \frac{\textit{Number of Colonies} \times \textit{Dilution Factor}}{\textit{Volume of Sample Plated}}$$

The above formula notes the method of calculating CFU/ml; where the 'Number of Colonies' refers to the colonies counted on the plate after incubation; 'Dilution Factor' is the dilution of the sample plated and 'volume of sample plated' is the amount (in millilitres) of sample spread on each plate.

Four dilutions were done for each sample (10^{-2}; 10^{-3}; 10^{-4}; 10^{-5}). The varying dilutions are necessary for the plate count method, as often, if bacterial colonies are present, the number of colonies exceed 300 in larger dilutions. Therefore, colonies are counted on the subsequent plate. Produce was tested for internal contamination, as opposed to surface contamination, as much of the produce can be consumed raw, after washing. The crops that were planted varied, and included a root crop, leaf crop and fruiting crop. Table 3.3 details the crops grown and their respective categories.

Table 3.4: Crops planted in trial garden

Root	**Leaf**	**Fruit**
Beetroot	Spinach	Cherry Belle Radish
Turnip (Early purple top)	Beetroot leaves	Okra (Clemson spineless)

3.5. Limitations and Challenges

Some challenges were encounted during the course of this study, and some limitations were also identified. These included:

I. The information available on the topic of humanure is not comprehensive.

II. The study was carried out on a small scale, due to space constraints.

III. With regard to the testing of the humanure, many labs did not want to carry out tests to determine if the composting process eliminated harmful pathogens and bacteria. Humanure was tested in December 2012 at BN Kirk Labs.

IV. With regard to planting of the trial gardens, the timeline for this part of the project was offset by months due to weather conditions. There was a period of extremely heavy rainfall followed by a period of particularly hot weather, which made planting the trial garden unfeasible. The plants will have been either washed away or wilted and dried up under the abovementioned conditions. As a result, planting of the trial garden occurred in January 2013, when the weather was slightly more suitable.

V. Testing the resultant produce for food safety was the crux of this research, as if the produce grown with humanure is contaminated, it is unsuitable for use in food gardens. Many labs in the country were consulted, each providing exorbitantly priced quotes, not inclusive of all the necessary tests. As an alternative, a Professor from the School of Microbiology and Genetics agreed to teach me the method of testing for the bacteria and pathogens, as I have no experience in microbiological laboratory work. Ultimately, this worked out for the best, as I have gained some experience and knowledge in this field of work, as well as had hands on approach with this aspect of my research.

3.6. Conclusion

This chapter has provided a description of the study area of this research, an account of methodologies in general and specific methods employed in this study. Both qualitative and quantitative methods were employed, adding depth to the research. Through a combination the two methods, a social acceptability survey as well as a scientific study was conducted. Laboratory analysis facilitated the scientific aspect of this study, which was used in the testing of humanure for pathogens, as well as microbiological testing of produce from the trial gardens for food safety. The next chapter will provide an analysis and discussion of the results of this research.

Chapter Four

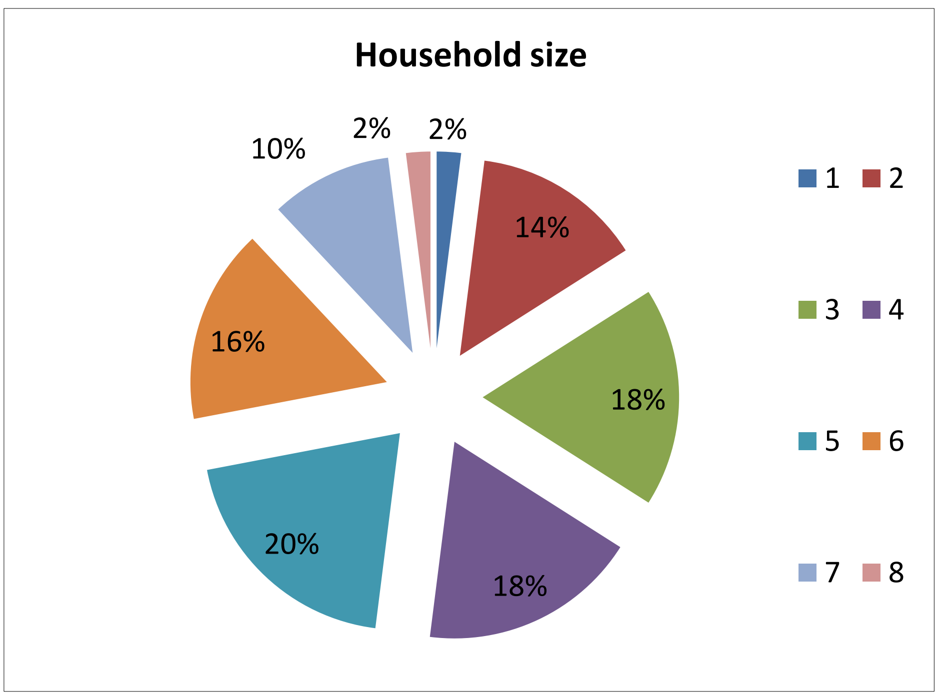
Results, Analysis and Discussion

4.1. Introduction

This chapter will present an analysis and discussion of the results of this study. The social acceptability aspect of this study will be presented first. Data was gathered through the use of questionnaires in the study area, Cottonlands. An assessment of the microbiological test results of the humanure made for this study will follow. Results and discussion of the food safety and visual plant health aspect of this study will comprise the final section of this chapter, including microbiological and visual analysis.

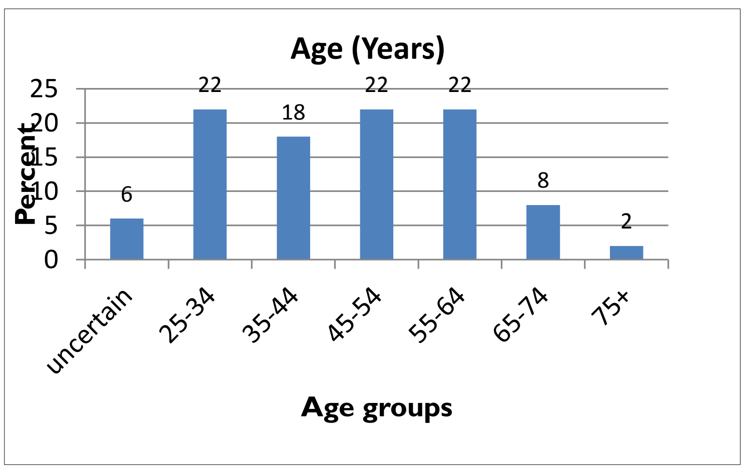
4.2. Demographics

Figure 4.1: Demographics



Out of the 50 households surveyed, a household size of 5 people is most common, with 20% of households indicating a size of 5 people. Larger household sizes are prevalent in the community, as 28% (16% (6 people) + 10% (7 people) + 2% (8 people)) collectively of all the households surveyed have households larger than 5 people. Additionally, smaller household sizes are doubly prevalent, with 52% (of households collectively having less than 5 people per household. These smaller household sizes may be due to a variety of factors, such as family members migrating to urban areas for employment and education. The size of the larger households may be attributed to tradition, where extended family members form part of a household, not just immediate family. Moreover, the larger household sizes may be an indication of poor family planning, a problem which is not unique to this area.

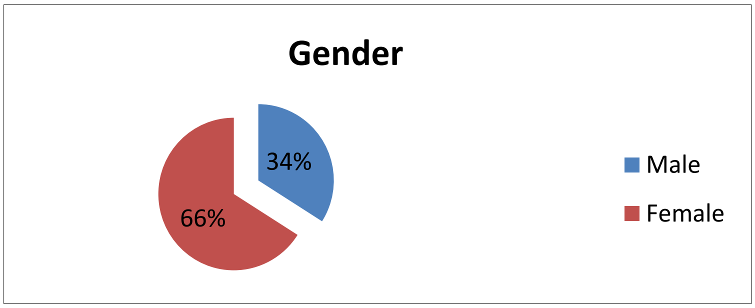
Figure 4.2: Age (Years)



As can be seen from the Figure 4.2, the ages of the heads of household surveyed varied. All of the respondents were legal adults, some of whom were pensioners. Six percent of the respondents were uncertain of their age, as they did not know the year in which they were born. Most of these respondents were elderly; suggesting that they were not aware of their date of birth due to the way the system was years ago. In the age group '55-64' years of age, all of these respondents collect a pensioners grant monthly. Thus, collectively, approximately 38%

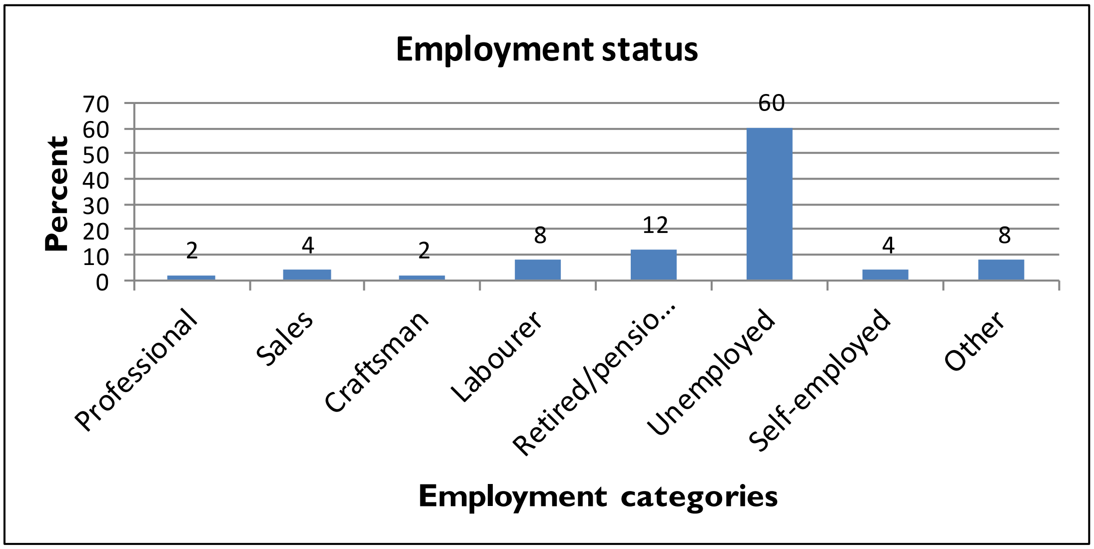
of households surveyed are run by heads of households who are over sixty years of age. The average age of respondents, calculated through a formula for the mean of grouped data is 47.6 years.

Figure 4.3: Gender



With regard to gender, 66% of respondents were female and 34% male (Figure 4.3). This indicates that there is definitely an increase in female headed households. There were many reasons given by these women for being the household head. Some of these reasons include that they are single or unmarried mothers with a family; they are the breadwinners of the household, thus making them the head; or they are widows, and became the head of household after the passing of their spouse.

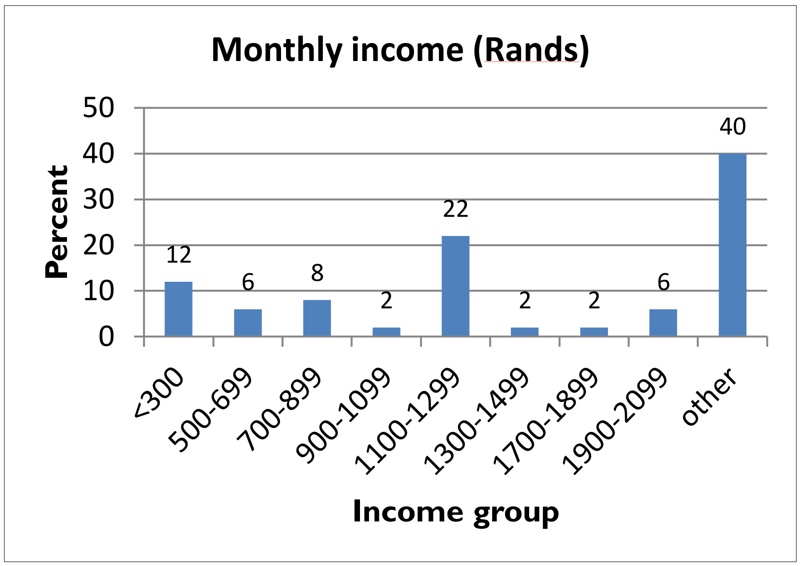
Figure 4.4: Employment status



The employment status of the respondents may be linked to the age in years of the respondents. As stated above, approximately 38% (Figure 4.2) of household are run by pensioners. However, from the graph, only 12% (Figure 4.4) of respondents indicated that they are retired and rely on a pensioners grant. This indicated that despite the age of the respondents, many of them are still in some form of employment to sustain their households. From the employment categories stated in Figure 4.4, only 2% of respondents have placed themselves in the 'professional' category. This may indicate that the majority of the respondents are without formal education and skills training.

The unemployment rate of the community is very high, and may be attributed to a number of possible causes; including a shortage of jobs due to the slump in the economy, lack of formal skills which prevents many of the respondents from applying for available jobs, or jobs available are a distance away from their homes, ruling these jobs out, as it is not possible for the head of household to be away from home. With regard to the respondents who indicated 'other', these respondents indicated that they were informally employed, doing odd jobs for people as and when needed. This is an extremely risky way to live, as a monthly income is not guaranteed. As the head of the household, it is his/her responsibility to ensure that all members of the household are taken care of. This is a nearly impossible task when the head of household is unable to secure a monthly income.

Figure 4.5: Monthly income (Rands)

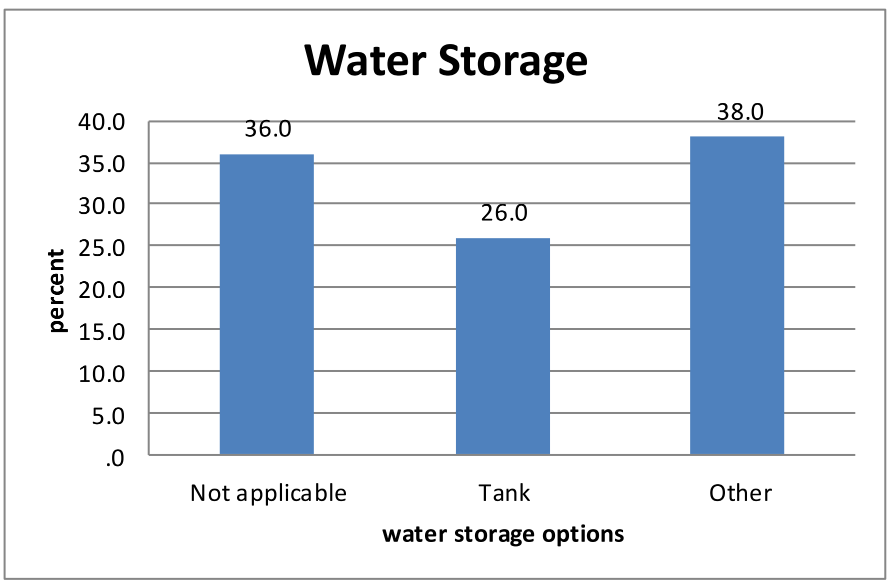


It is disturbing to note that 12% (Figure 4.5) of household operate on less than R300 per month. Considering the cost of living, and the above mentioned household size, it is evident that R300 per month is not sufficient to run a household. Collectively, 28% of households operate on a monthly income of no more than R1099 per month (Figure 4.5). Although more than R300 per month, it still seems an insufficient monthly income to meet the basic needs of household members. From Figure 4.2, the graph on age (in years), it is evident that many of the heads of households are elderly. It could be assumed that many of these respondents, as well as the members of their households would require medication from time to time to target certain ailments that are usually brought on by old age. However, a household operating on a monthly income of no more than R1099 per month would not be able to afford this. Forty percent of respondents indicated ‘other’. When questioned on how much ‘other’ earns, the household per month, the respondents answered that there was no fixed amount; it was whatever they could earn from casual jobs that had been taken on during the month. This may be related to the above graph, Figure 4.4, on employment status, where 60% of the respondents are ‘unemployed’. This, again, is a questionable way of living, as the absence of a fixed monthly income sufficient to cater for the needs of all members of the household is essential.

The demographic profile of Cottonlands was examined, through the analysis of aspects such as household size, age, gender, employment status of the respondents as well as their monthly income. Households access to water and their water storage methods will be examined in the following section. This section on water access and storage is relevant to the study, within the context of the location of the study site, which lacks infrastructure supporting household water pipes and infrastructure.

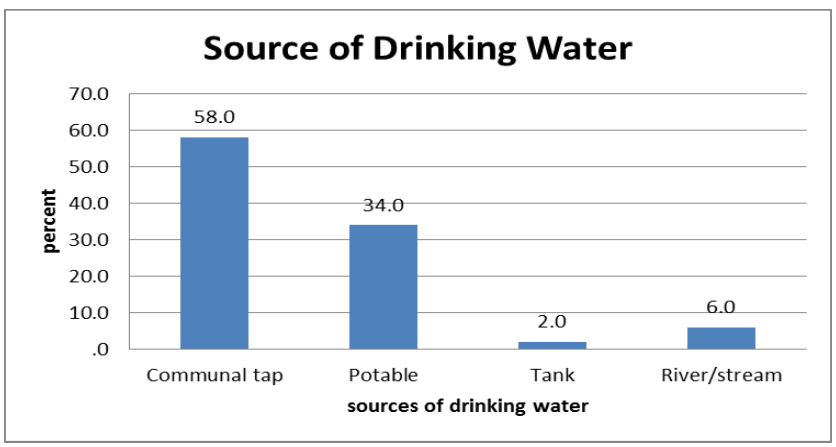
4.3. Water Access and Storage

Figure 4.6: Water Storage



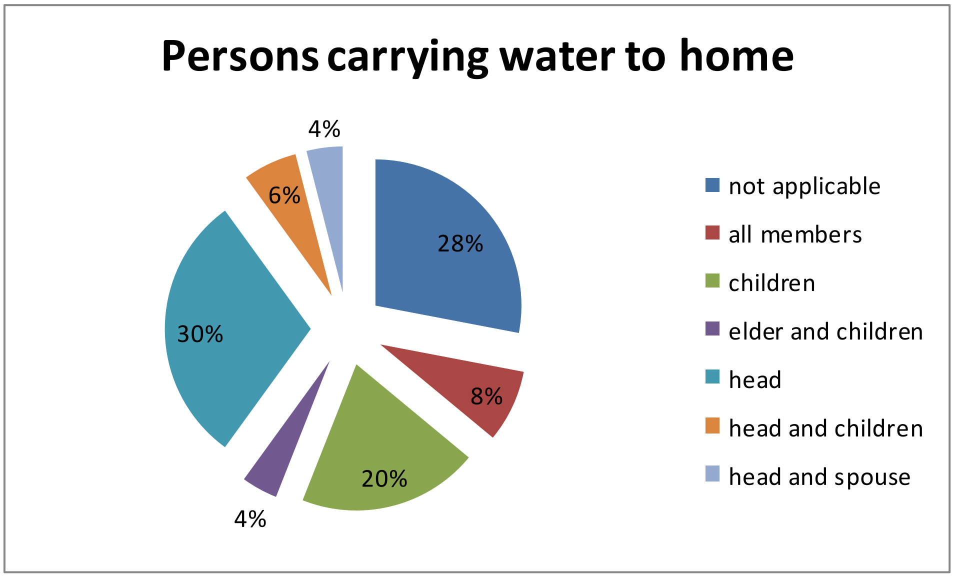
Not all households had private taps. Many of the households surveyed stored water in tanks or other containers to avoid going to a communal tap whenever water is needed. Twenty six percent of respondents indicated that they utilised tanks as a method of water storage, whilst 38% of respondents indicated 'other' (Figure 4.6). When questioned on what 'other' was, respondents answered that buckets, cans and any other container that could be used for water storage was used. Reasons given for this was that water storage tanks were not affordable, therefore alternate storage methods were necessary. Thirty-six percent of respondents indicated that water storage was 'not applicable' to them. Reasons given for this included that the household had a private tap, or that the household simply did not store water. Whenever water was needed, a member of the household would collect it from the nearest source.

Figure 4.7: Source of Drinking Water



Fifty-eight percent of the respondents use a communal tap, whilst 34% of respondents had a source of potable water in their household. As illustrated in Figure 4.7, "Water Storage", respondents used tanks as a method of storing water. Two percent of respondents used the water that was collected in their storage tanks as their main source of water. Six percent of respondents use a river or stream as their source of drinking water, which is extremely dangerous due to the health hazard that it poses. Many, if not all, of the rivers and streams in the area appear to be polluted heavily by raw sewage, amongst other pollutants, possibly due to the poor state of sanitation.

Figure 4.8: Persons carrying water to home

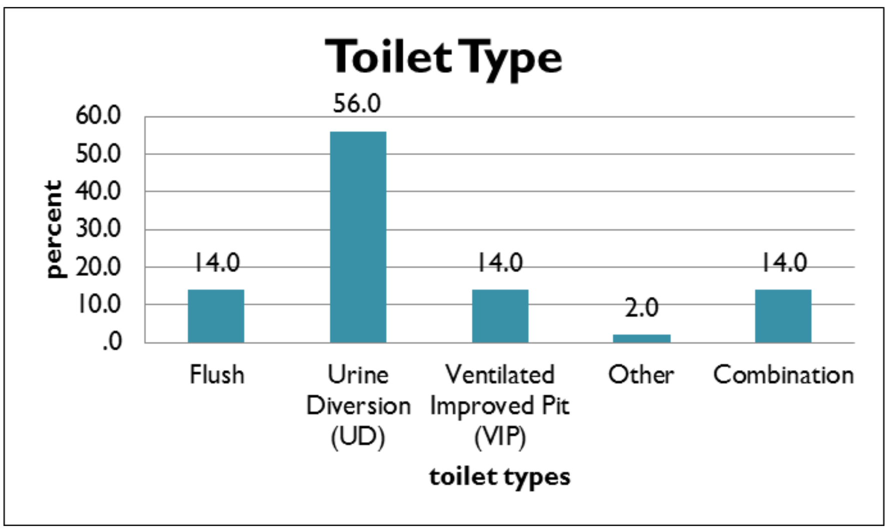


With regard to persons carrying water to the household, 28% of respondents indicated that this was not applicable to them. Again, this may be due to the fact that these households had private taps in their household. It may be seen that it is most common for either the head or children of the household to collect and carry water to the household, and in 6% of households a combination of the head and children (Figure 4.8). Only in 8% of households is this duty shared amongst all household members. In 4% of households, elders and children were responsible for this duty. Collection and carrying of water to a household was a physically taxing task, which may be very difficult for children and elders to do. It was possible that in the 4% of the sample that relied on elders and children to carry out this task, the household was made up of these people only.

The issue of sanitation is an important aspect of this study. Human excrement needs to be disposed of in a safe, non-hazardous manner to eliminate the risk it could potentially pose. The type of sanitation systems used in the community will be analysed, as will their disposal techniques.

4.4. Sanitation

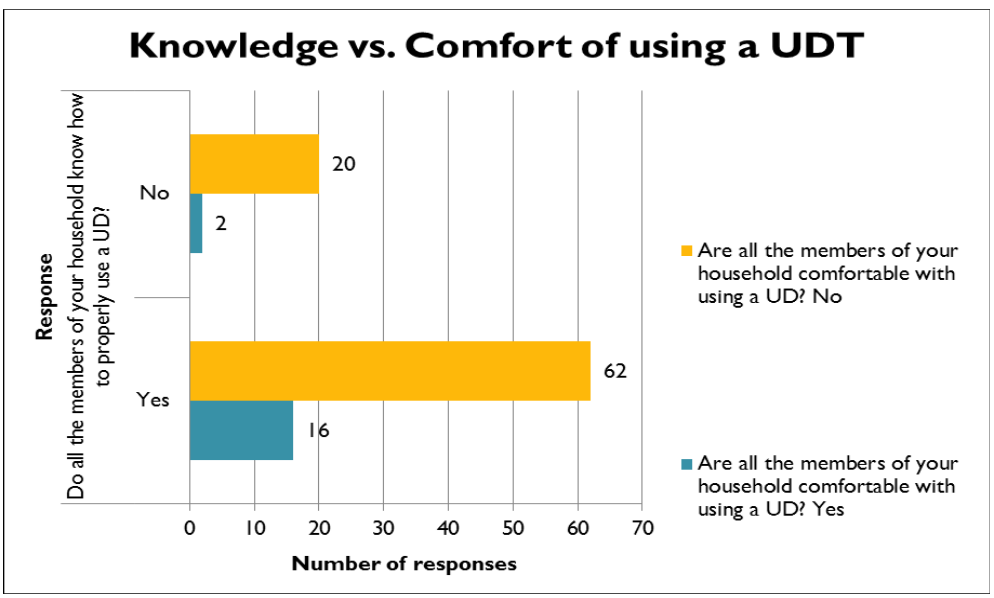
Figure 4.9: Toilet Type



The households surveyed had access to and used different types of toilets. The different types of toilets are: flush, urine diversion (UDT), ventilated improved pit (VIP), other, and combination. With regard to the 'combination', 14% stated that they had a UDT, as well as another type of toilet in their household, usually a flush toilet. Fifty-six percent of households had UDT's (Figure 4.9), as these toilets were installed as a municipal initiative to target the problem of inadequate sanitation in the region. Despite UDT's being the most common type of toilet in this community, it was not the most favoured, as it is often viewed as 'lower grade'. There were many issues which stemmed from class and social stigma, with the use of UDT's.

Flush toilets were viewed by many as the sanitation system for the ‘upper class’; thus, those who had UDT’s fitted in their households felt as if they were being treated differently, or poorly. This created a serious problem, as many households rejected these toilets outright. Many of the UDT’s that were constructed were being used as storage space or were being broken down. Fourteen percent of respondents indicated that they used ventilated improved pits (VIP’s). This is disturbing, as VIP toilets have been done away with, mainly because of health hazards being most prevalent. There is a shocking dichotomy in that although we have progressed into a technologically advanced era, there are thousands of people who still struggle with a basic need such as sanitation.

Figure 4.10: Knowledge vs. Comfort of using a UDT

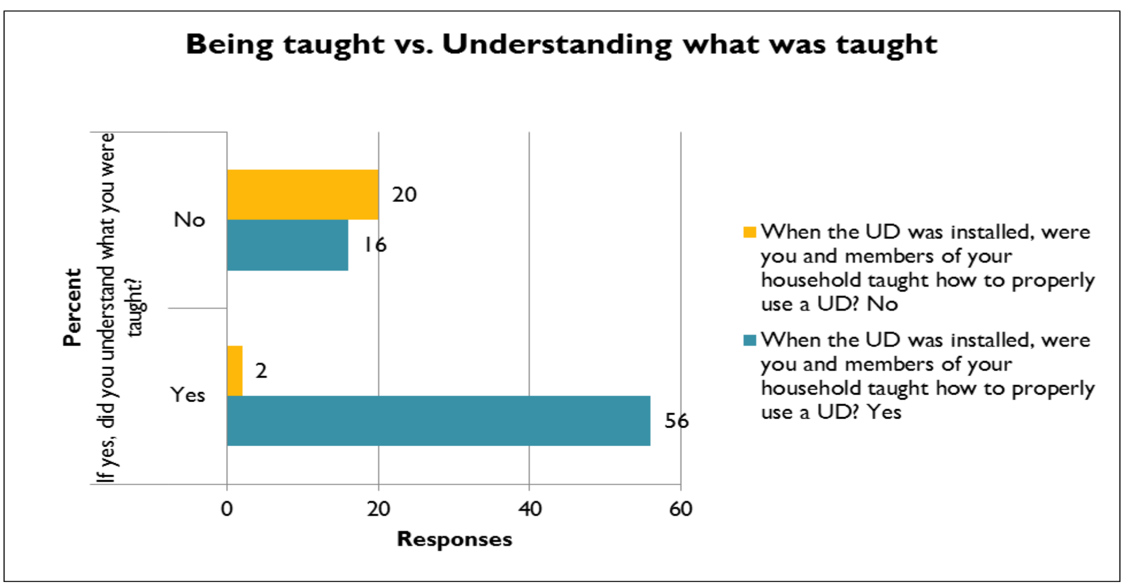


Over three quarters (78%) of the sample population knew how to properly use a UDT; however, only 16% of these households were comfortable with using a UDT (Figure 4.10). An overwhelming 82% of the respondents were uncomfortable with using a UDT, and of these, 22% did not know how to properly use a UDT. Sixty-two percent of the respondents did know how to use a UDT, but were uncomfortable with using the facility.

Upon installation of the UDT, households in the community were taught how to use it. However, it was apparent that not all the respondents understood what they were taught. This has a direct impact on the operation of the system, as if it is not used in the correct manner, the system is ruined.

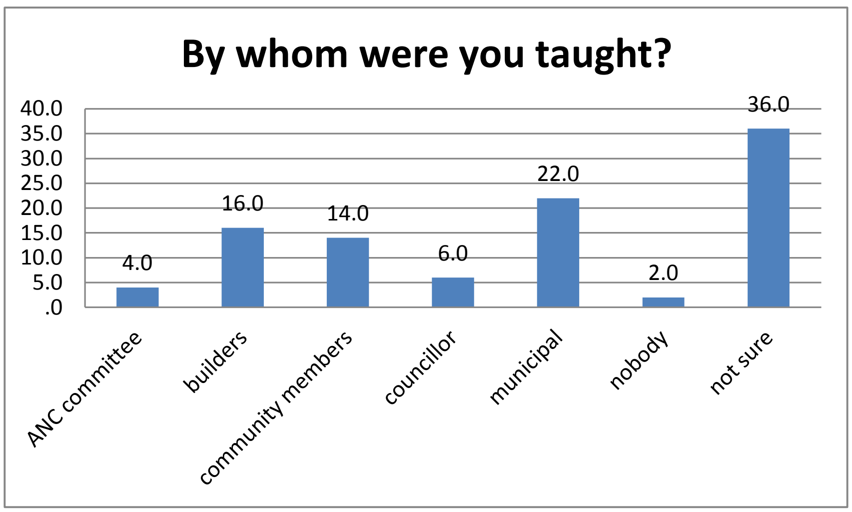
There is an element of comfort that is extremely important when assessing the use of this type of toilet. Eighty-two percent of the respondents surveyed were not comfortable with using a UDT. Sixty-two percent of the respondents, despite knowing how to properly use a UDT, were uncomfortable with using this type of toilet (Figure 4.10). Thus, a lack of knowledge on the proper use of this type of toilet is not the reason for the discomfort that many of the respondents feel when it comes to using this type of toilet.

Figure 4.11: Being taught vs. Understanding what was taught



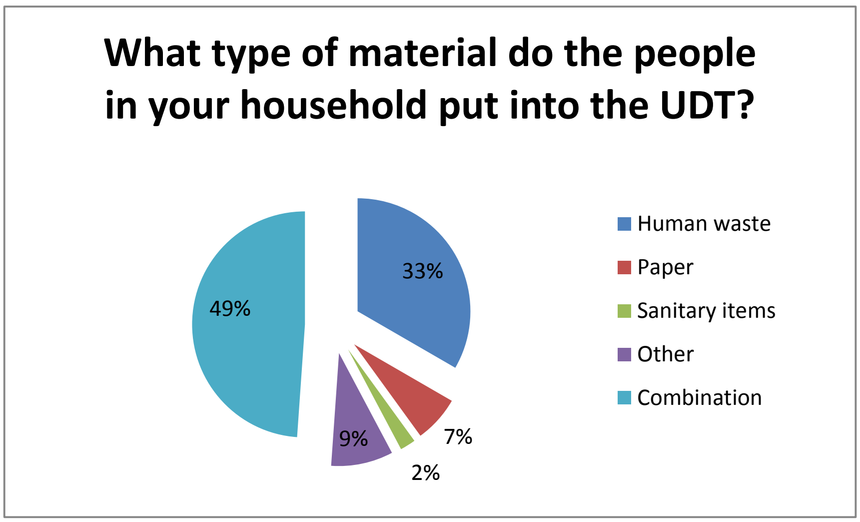
Upon installation of the UDT, each household was supposed to have been properly taught how to use the toilet, as it is completely different to using a flush toilet or a VIP. If the UDT toilets are used incorrectly, the entire system will fail. Out of the sample population, 74% (Figure 4.11) of the households were properly taught how to use a UDT, whilst 26% were not taught (Figure 4.11). Although 74% of the households indicated that they were properly taught how to use a UDT, 40% of these households did not understand what they were taught. It is possible that this discrepancy has been a leading factor which has led to the failure of this system in many households.

Figure 4.12: Instruction about UDT's



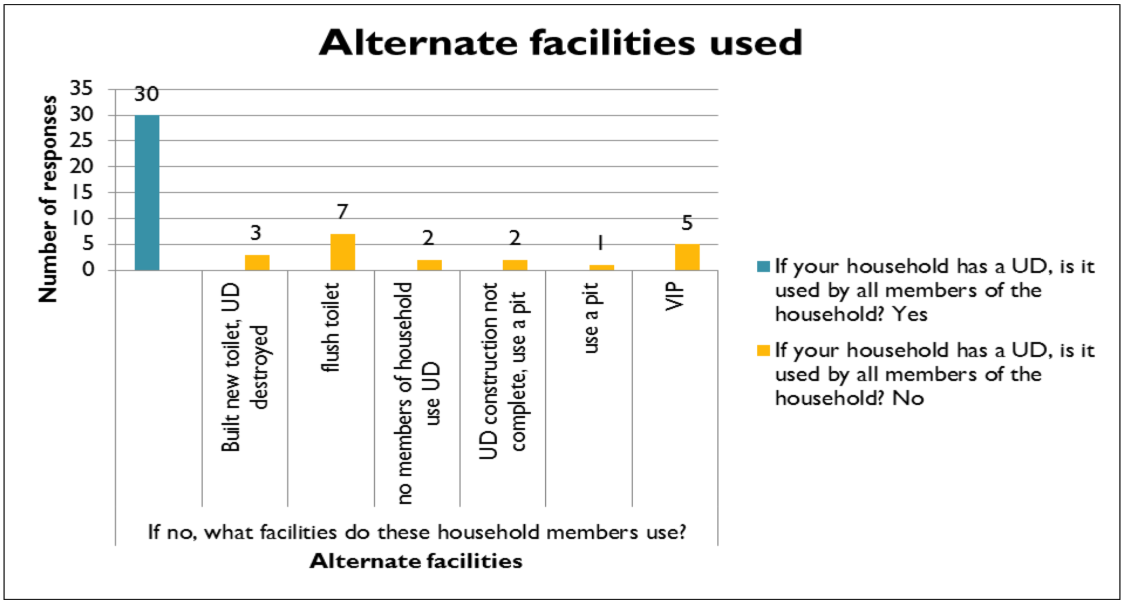
After UDT's were installed, household members were supposed to have been properly taught how to use this type of toilet. Thirty-six percent (Figure 4.12) of the respondents were unsure of who taught them. This leads to the question of whether these respondents were properly taught how to use a UDT if they didn't know who was teaching them. Installation of these UDT's was a municipal initiative. Therefore, one would expect municipal extension workers to have taught households how to use these toilets. However, only 22% (Figure 4.12) of respondents indicated that people associated with the municipality taught them. Builders, ANC committee members, community members, and the councillor were among the people who taught the respondents how to use the UDT. Education and training was crucial for the successful operation of this system. It is evident that much of the education provided to households seems to be informal; through community members trying to teach each other, to builders trying to educate households – a recipe for failure.

Figure 4.13: Materials added to UDT vaults



The UDT vault is meant to collect human waste, as well as other material such a toilet tissue and soak material such as sawdust to help absorb moisture and facilitate the composting process. The addition of other materials will disturb this process and lead to the malfunction of the process. Sanitary items, such as nappies, sanitary pads and condoms should not be deposited into the UDT vault. However, this was being done, according to the respondents. The UDT vault was being treated as a garbage bin for all disposables, not just human waste, and this severely impacted on the system. Forty-nine percent (Figure 4.13) of respondents were depositing a ‘combination’ of materials into the vault.

Figure 4.14: Alternate facilities used



Out of the sample size of 50 households, 40% of these households did not use UDT toilets. Six percent of the households indicated that they destroyed the UDT toilet that was built for them, and had built their own facility; whilst 14% of the households indicated that they modified their UDT toilets into a type of flush toilet (Figure 4.14). This defeats the aim of the UDT toilet, as it is a part of the dry sanitation movement. Introducing water into this system will not allow the waste to compost, and will result in the process becoming anaerobic. This, in turn, will result in unpleasant odours, and attract pests. Four percent of the households indicated that no members of the household use the UDT, despite having the facility. The remaining 10% of households used a pit or VIP, as they did not have a UDT in their household.

The following section will inspect the community's perception, knowledge and stance on compost and humanure, and their household agricultural activities.

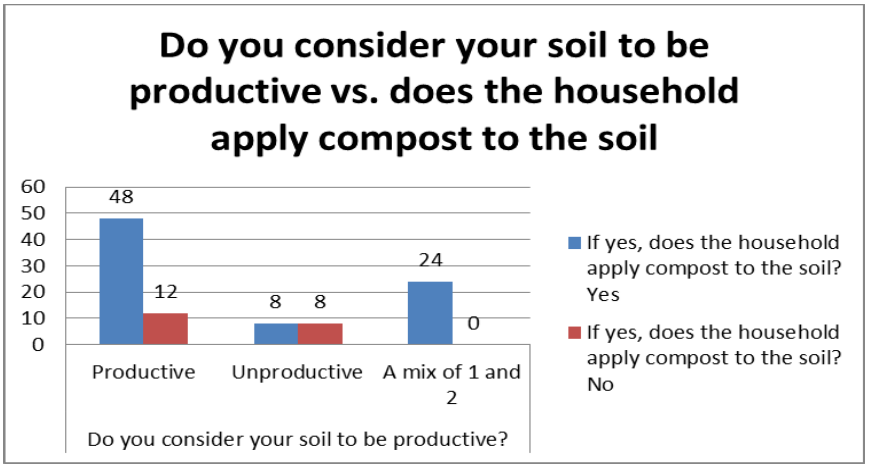
4.5. Compost, Humanure and Household Agriculture

Table 4.1: Household agricultural activities

Does your household grow its own vegetables? * If yes, does the household apply compost to the soil?				
		If yes, does the household apply compost to the soil?		Total
		Yes	No	
Does your household grow its own vegetables?	Yes	80	20	100
Total		80	20	100

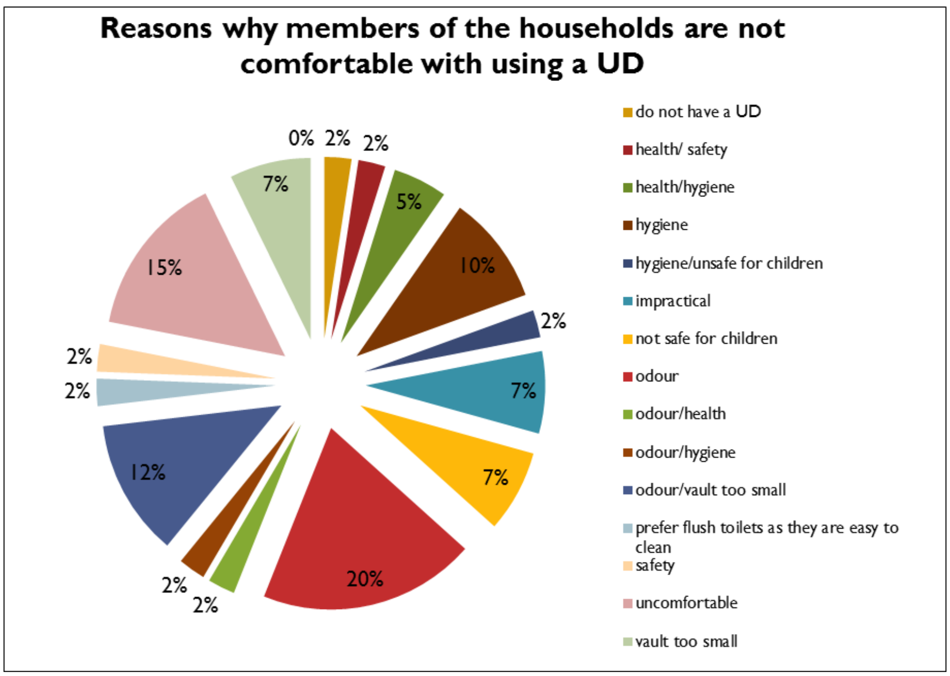
Out of the 100% of households that do grow their own vegetables, 80% of these households applied compost to the soil. Twenty percent of these households did not apply compost to the soil (Table 4.1). This may be indicative of the condition of their soil, or their limited knowledge about maintenance of soil health.

Figure 4.15: Soil productivity perception



The respondents classified their soil to be either ‘productive’, ‘unproductive’ or ‘a mix of 1 and 2’. Sixty percent of the households indicated that their soil was productive, 16% indicated that their soil was unproductive, and 24% indicated that their soil was a mix of both, with some areas being productive, and others being unproductive (Figure 4.15). Collectively, only 20% (Figure 4.15) of the households do not apply compost to the soil. This suggests that the majority of the population understand the importance of maintaining the good health of soil, and that extensive use of the soil without returning nutrients into the soil will lead to poor, unproductive soil.

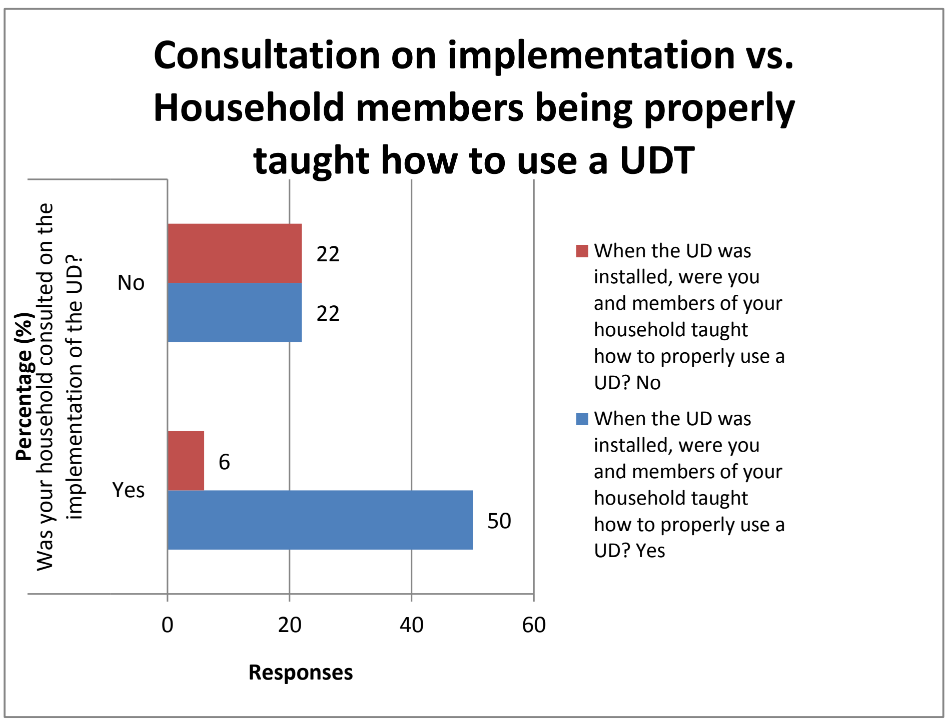
Figure 4.16: Reasons why members of the household are not comfortable with using a UDT



There were many reasons that were given by the respondents on why they felt uncomfortable with using this type of toilet. One of the most common reasons was the strong odour that was emitted by these toilets (20%). Fourteen percent of the respondents also cited odour as one of the causes of their extreme discomfort, with hygiene and health related issues playing a role as well (Figure 4.16). Additionally, the size of the vault is another reason that has been cited.

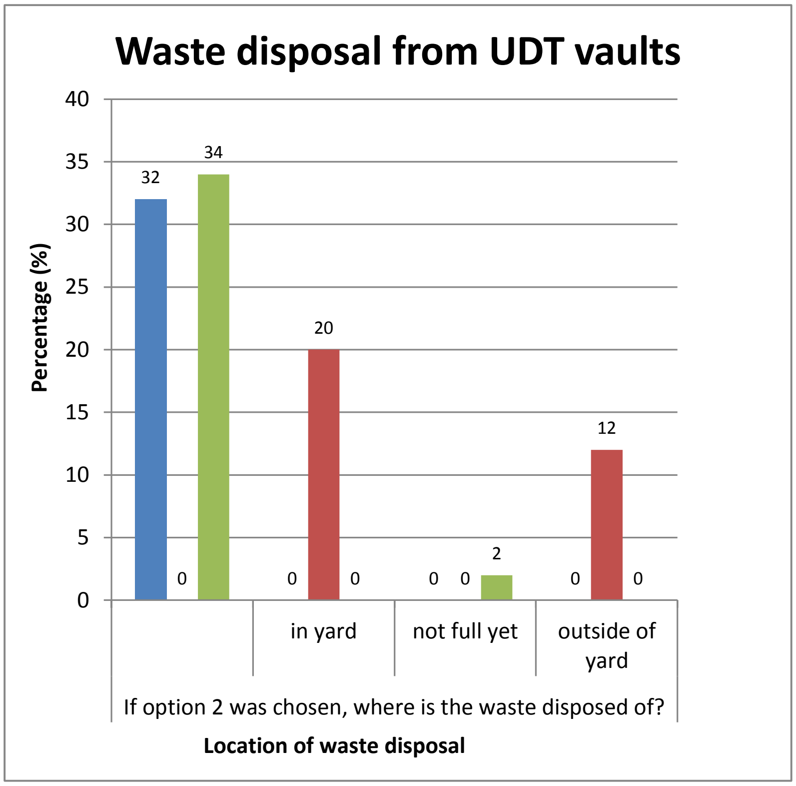
These vaults fill up too quickly, resulting in people having to deal with the raw sewage on a frequent basis. Twelve percent of the respondents were uncomfortable with the UDT system in general. Other reasons mentioned by the respondents were: that the UDT toilets were unsafe for children, impractical, and unsafe in terms of the toilet being away from the house (Figure 4.16). The partiality to the flush toilet is indicative of the preference of the population in general. It appears that if all the households that part took in this study were fitted with flush toilets, many of these issues will be alleviated. However, this may not be feasible, due to many reasons, such as cost, sustainability and geographical/topographical issues.

Figure 4.17: Consultation on implementation vs. Household members being properly taught how to use a UDT



Fifty-six percent of the households were consulted on the implementation of the UDT system, and 72% of these households were taught how to properly use the UDT (Figure 4.17). Those who were not consulted on the implementation of the system, were also not taught how to properly use the system.

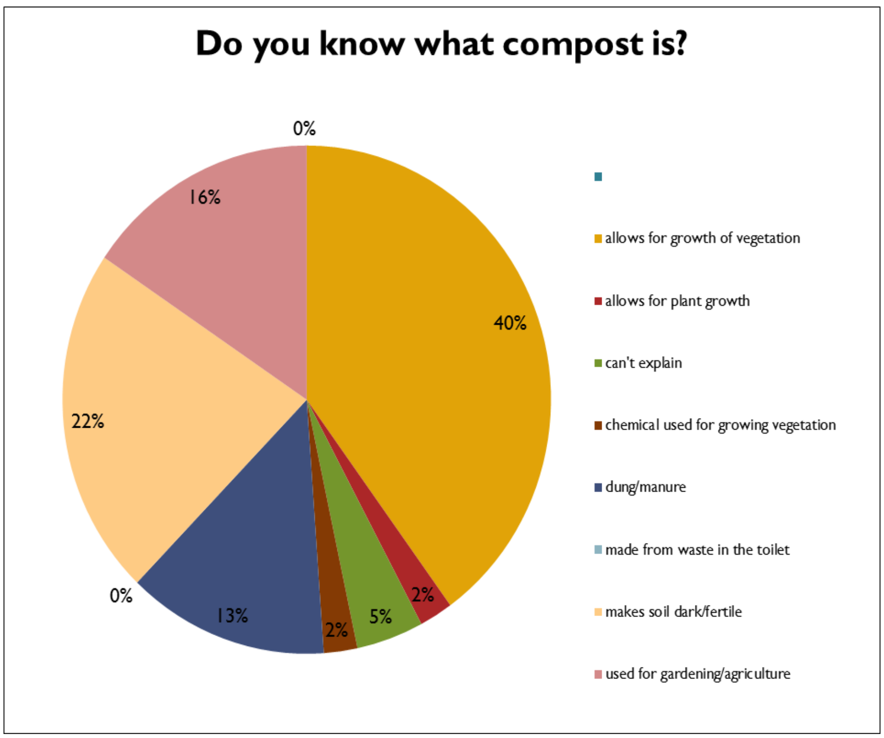
Figure 4.18: Waste disposal from UDT vaults



Each UDT toilet has two vaults, in which the waste is deposited. Thirty-two percent did nothing with the waste from the vaults, once they were full. Twenty percent and 12% disposed of the waste in their yard and out of their yard respectively. Out of the remaining 36% of respondents, 2% of the respondent's vaults were not yet full, and 34% of the respondents had modified their UDT so that the waste did not fill the vaults, but was rather rerouted via a pipe to the area behind the vaults (Figure 4.18). This is extremely dangerous and unhygienic, and may lead to severe health issues if the raw sewage comes into contact with people. Raw sewage contains many harmful pathogens that can be lethal to humans. Furthermore, if raw sewage is left untreated in soil, it could soak through and pollute ground water.

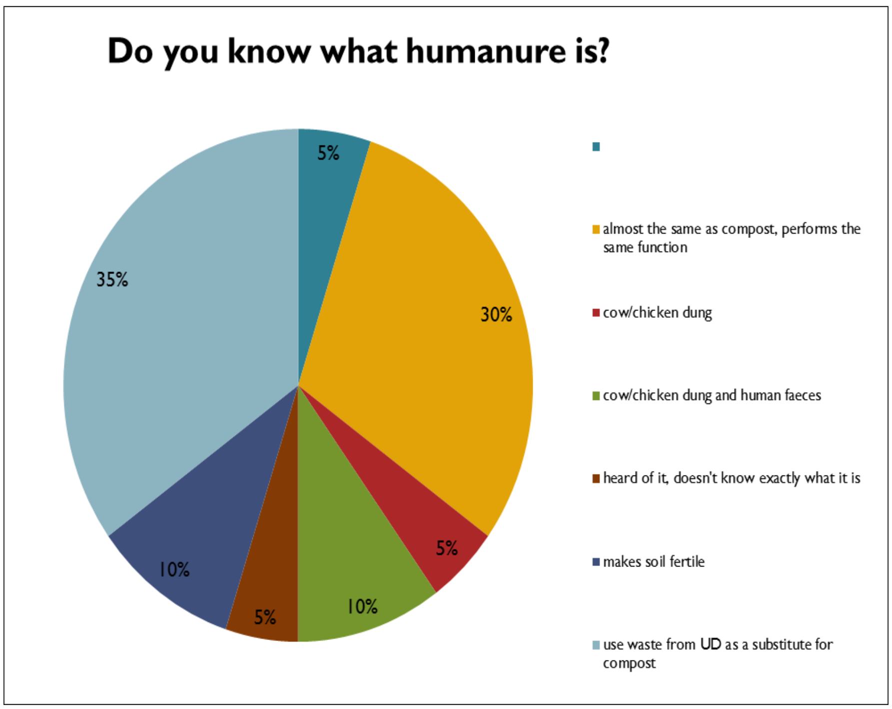
Agricultural activities such as rearing livestock and planting food gardens are an important part of the daily activities of households in the community. Compost is usually combined with soil to ensure that good health of soil is maintained and that maximum yield of crops is gained. The respondents were questioned on their agricultural activities, regarding their knowledge of compost and humanure and, their use of it.

Figure 4.19: Compost awareness



The majority (94%) of the respondents surveyed were aware of compost and its value. They knew that compost is a substance that supports plant growth, by making soil fertile (Figure 4.19). This illustrated that the majority of the sample population possessed some knowledge on soil health and upkeep and agricultural practices. It is interesting to note that 20% (Figure 4.19) of the respondents defined compost as a substance that made their soil dark and fertile, thus judging the fertility of the soil by colour. Only 2% (Figure 4.19) of the respondents indicated that compost was a chemical; which suggests that majority of households in this area do not rely on chemical additives in their agricultural activities.

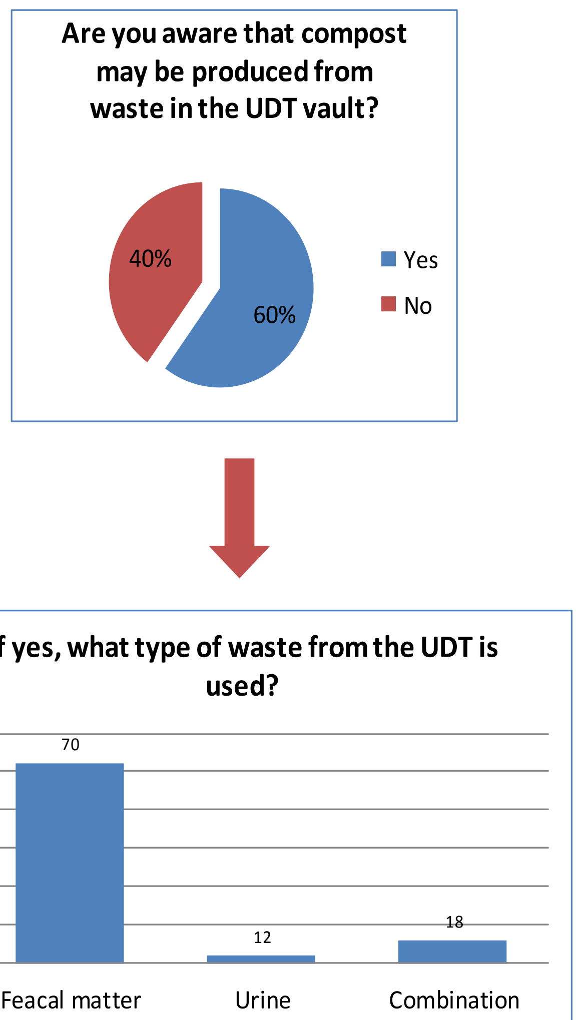
Figure 4.20: Humanure awareness



Humanure is a compost or soil conditioner that is made up of organic matter and human waste. This compost is nutrient rich, and contains the essential elements for vegetation growth, namely NPK (nitrogen, phosphorus and potassium) (Wilkonson *et al*, n.d.). There is a stigma attached to this type of compost, as the key ingredient is human waste. Many people are wary of this type of compost, and are unwilling to use it in their agricultural practices. Humanure has been used for many years, and can be dated back to the application of 'night soil'.

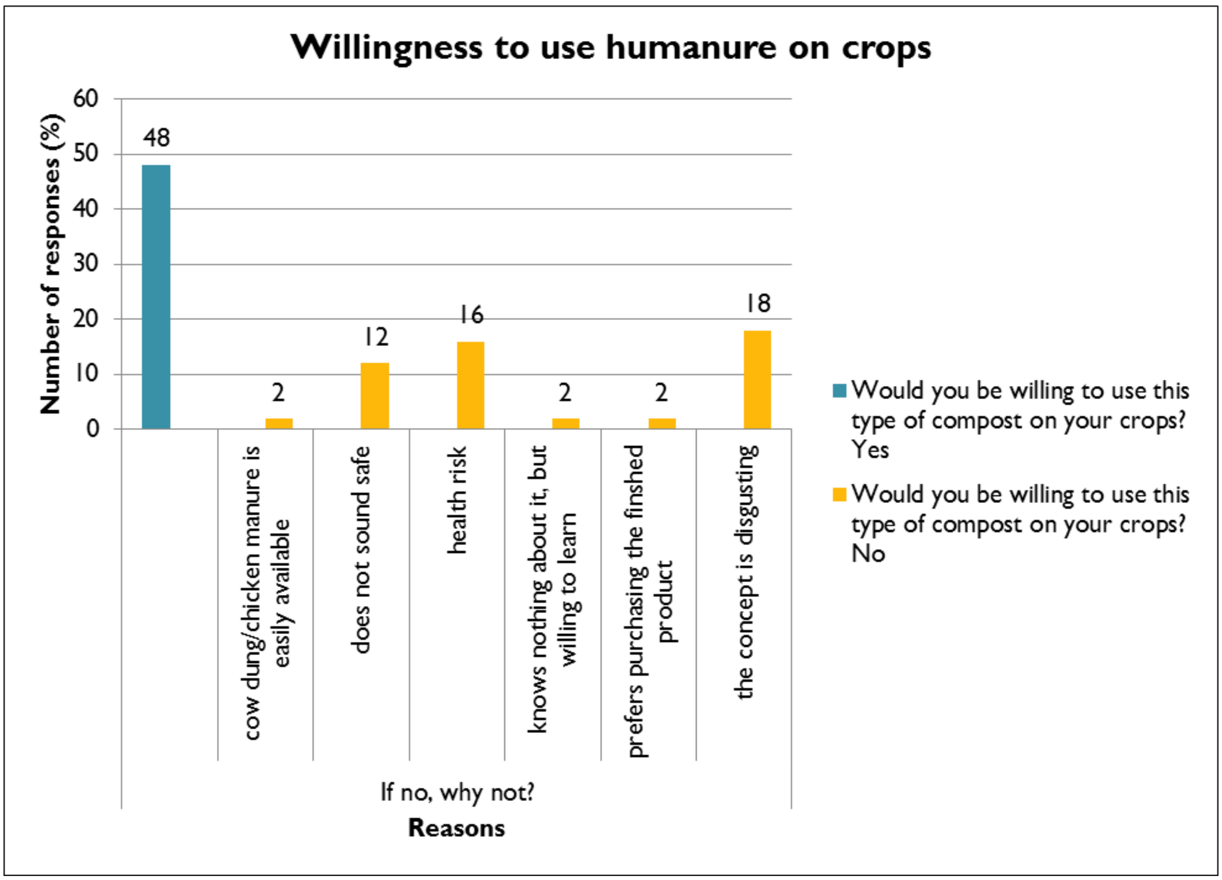
However, unlike night soil, humanure is treated human waste, which undergoes a process to eliminate all harmful pathogens and bacteria rendering it safe for use. Forty percent of the respondents surveyed had an inkling about what humanure was. The respondents referred to humanure being almost the same as compost/performing the same function, cow or chicken dung, a substance that makes soil fertile and using waste from the UDT vault as a substitute for compost (Figure 4.20). This suggests some awareness of the concept of using human waste to make compost, and that there was possibly room for acceptance of this idea.

Figure 4.21: UDT vault material and compost



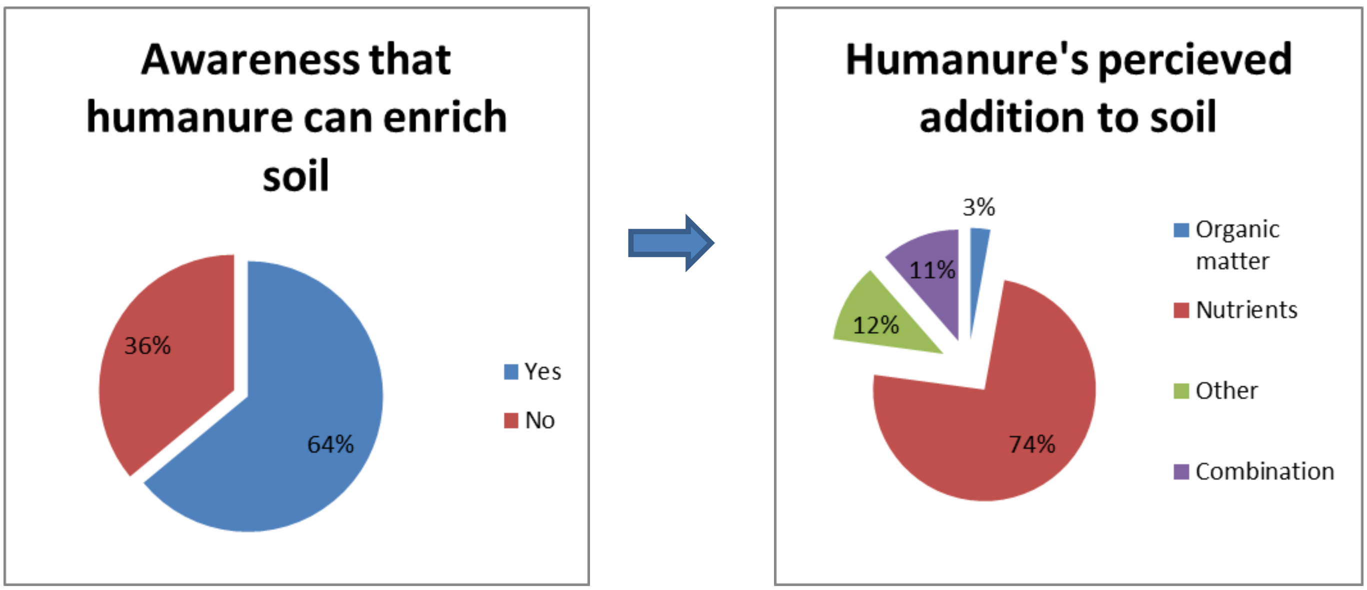
Sixty percent of the respondents were aware that humanure may be produced from waste in a UDT vault. Seventy percent in this category indicated that the faecal matter from the vaults was used in the process of making humanure. Eighteen percent of respondents indicated that a combination of all waste present in the UDT vaults was used in the production of humanure (Figure 4.21).

Figure 4.22: Willingness to use humanure on crops



As mentioned previously, there was a stigma attached to the use of humanure, as it is produced from human waste. Forty-eight percent of the households were willing to use humanure on their crops. The remaining 52% were severely opposed to the use of humanure. Some of the reasons that were being cited for this rejection are that it did not sound safe, posed a health risk, the concept was disgusting and that it was preferable to purchase the final composted product; as opposed to having to make it, using waste from the UDT toilet (Figure 4.22).

Figure 4.23: Humanure and soil



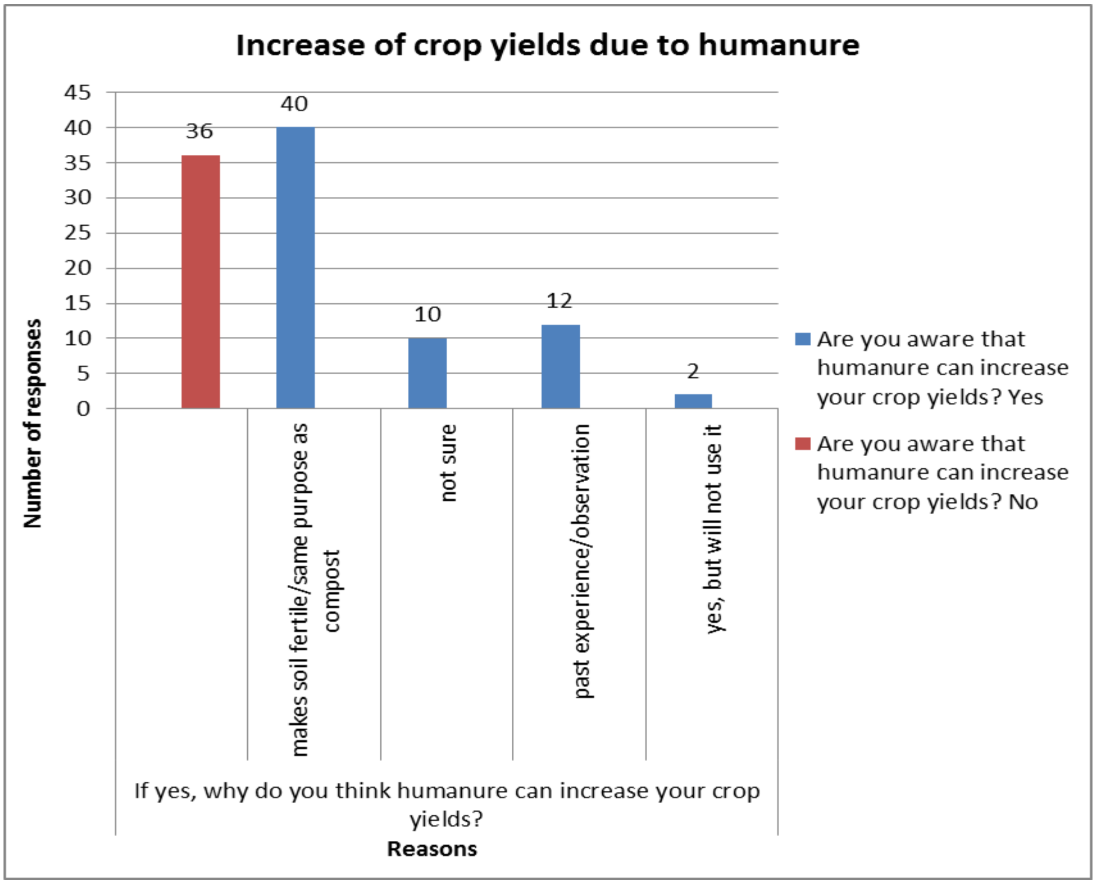
Humanure acts in the same way that compost would, adding valuable and essential nutrients to the soil for optimal plant and vegetation growth, thus enriching the soil. Sixty-four percent of the respondents, representing 32 households, were aware that humanure can enrich soil; with 74% of these respondents indicating that humanure adds nutrients to the soil, 3% indicating that organic matter is added to the soil and 11% indicating that a combination of the two (organic matter and nutrients) are added to the soil. Twelve percent of the respondents were aware of the fact that humanure can enrich soil, but were not sure about what it added specifically (Figure 4.23).

Table 4.2: Humanure's impact on soil and health perceptions

Are you aware that humanure can enrich your soil? * What health impacts do you think humanure could have on your health?				
		Are you aware that humanure can enrich your soil? (%)		Total
		Yes	No	
What health impacts do you think humanure could have on your health? (%)	Not sure	6	6	12
	No impact	18	10	28
	Other	40	20	60
Total		64	36	100

Sixty-four percent of the respondents surveyed indicated that they were of the opinion that humanure could enrich soil. However, 25% of the respondents also indicated that they believed that humanure could have impacts on human health, whilst 12% of the respondents were not sure (Table 4.2). The impacts that were indicated by these respondents, were different types of illnesses or diseases, such as cholera, nausea, vomiting and diarrhoea. Thirty percent of the respondents indicated that they were not aware that humanure could enrich the soil. However, they were of the opinion that humanure could impact on human health. Sixteen percent of these respondents indicated that humanure could have negative impacts on human health. Twenty-eight percent of the respondents stated that humanure had no impact on human health. This varied response with regard to the impact that humanure could have on human health, illustrates that education is needed to correctly inform people about the effects of humanure.

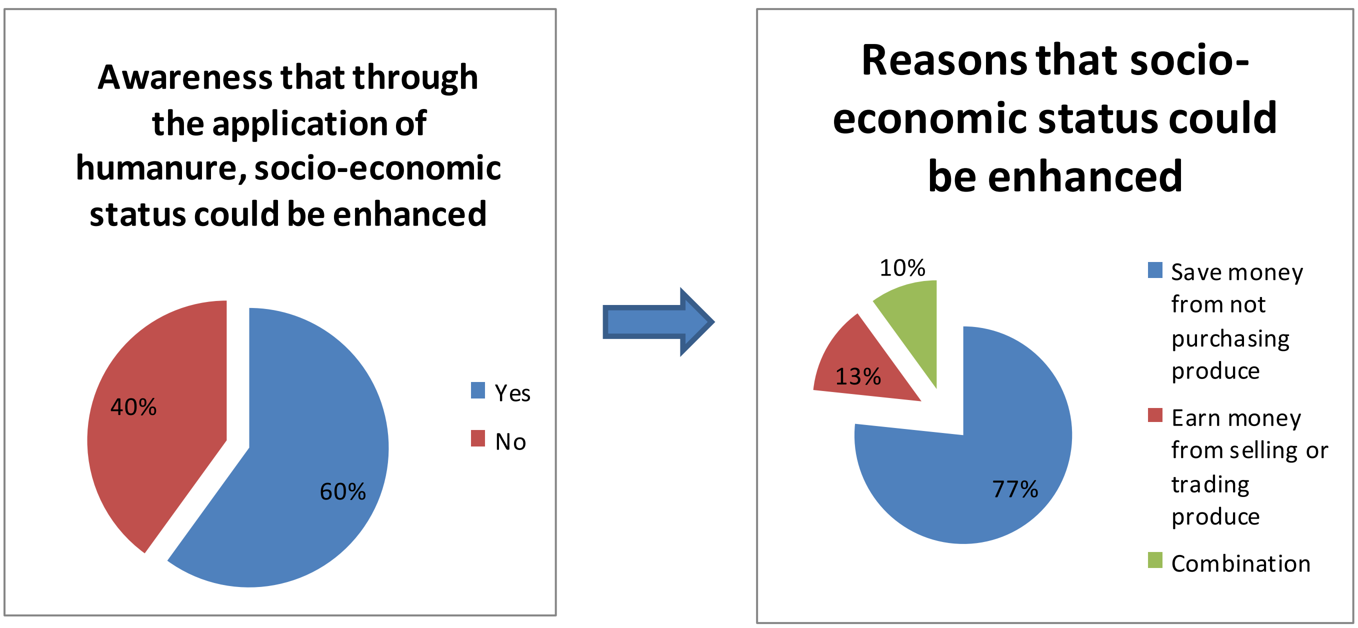
Figure 4.24: Increase of crop yields due to humanure



Thirty-six percent of the respondents were not aware that humanure could increase their crop yields. The remaining 64% of respondents were of the opinion that humanure could increase crop yields for the following reasons: humanure makes the soil fertile (40%), and serves the same purpose as compost; past experience/observation (12%). With regard to the past experience/observation, the respondents have witnessed crops grow where human waste was deposited.

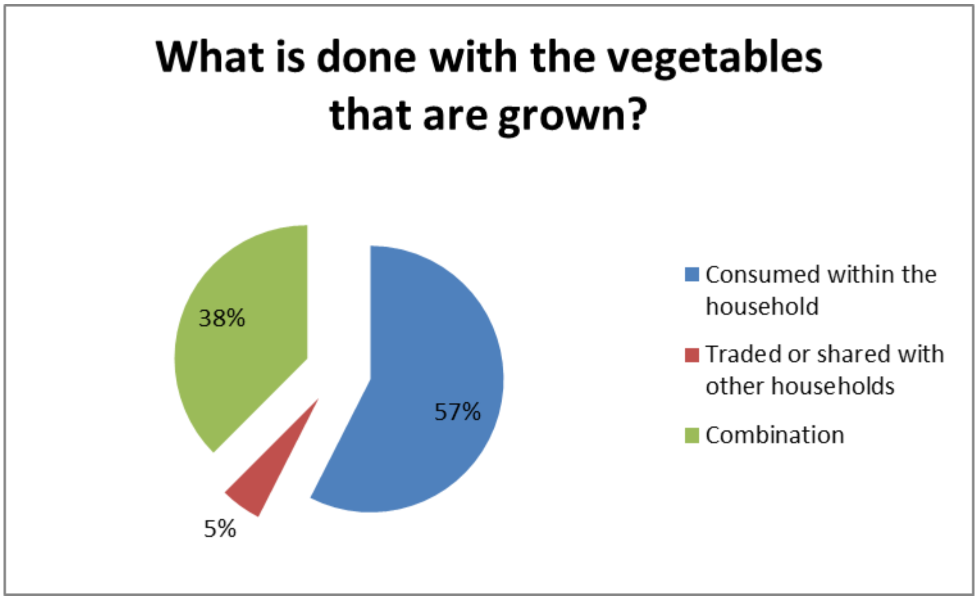
As indicated in Figure 4.18, many of the households that participated in this survey indicated that they had modified their UDT toilets so that none of the waste entered the vaults, which were redirected via a pipe to the area behind the UDT. It was in this area that respondents had observed crops of spinach grow, without the aid of any additive, or maintenance. Ten percent of the respondents indicated that they were unsure as to why humanure increased crop yields. This could be overcome with education and information. Two percent of the respondents indicated that despite the fact that they are aware that humanure could increase crop yields, they were unwilling to use it on their crops.

Figure 4.25: Humanure and socio-economic status



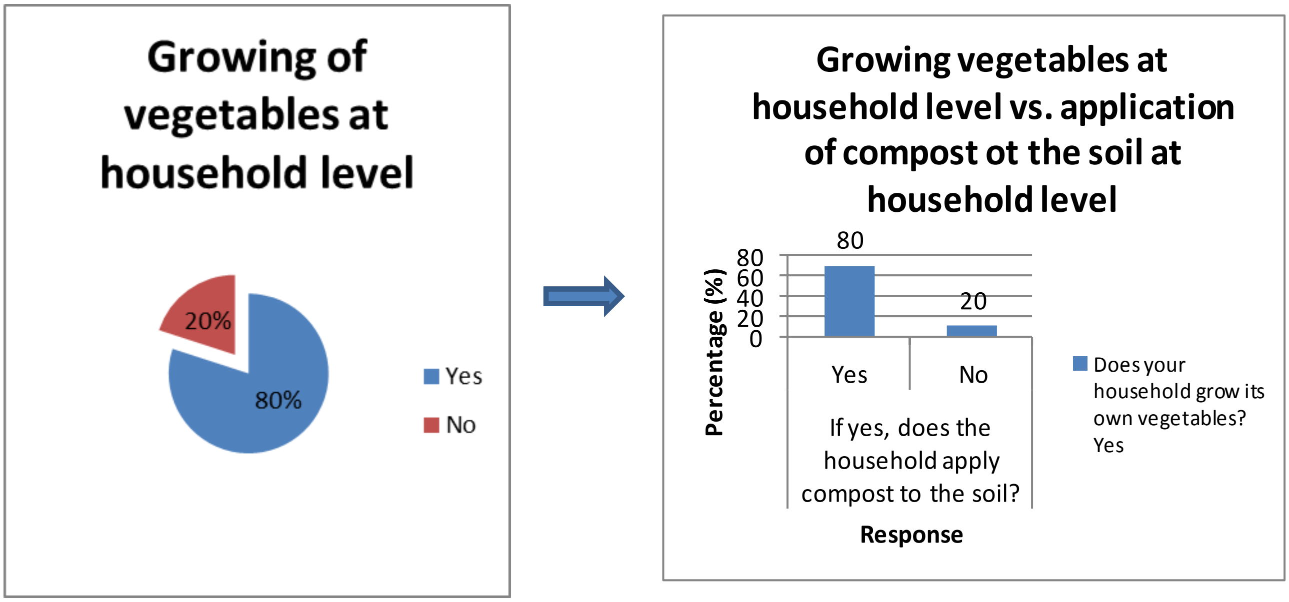
Sixty percent of the respondents surveyed indicated that they were aware that through the application of humanure, their socio-economic status could improve. Seventy-seven percent in this category stated that their socio-economic status could be enhanced through savings from not purchasing produce; 13% indicated that their household could earn money from the sale of produce grown with humanure, or from trading the produce for other material items (Figure 4.25). Ten percent of the respondents indicated that their socio-economic status could be enhanced as a result of a combination of abovementioned reasons.

Figure 4.26: Household produce norms



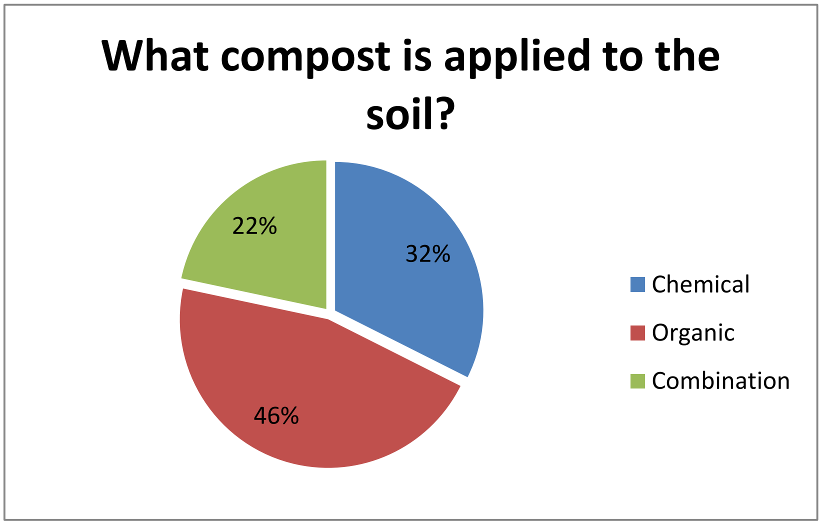
Many of the households in the community relied on household agriculture to achieve food security. As can be seen from Figure 4.26, 57% of households consumed the vegetables that they grew, whilst 9% of households traded or shared their vegetables with other households. Thirty-eight percent of households consumed some of what was grown, and shared or traded the remainder, either for different types of vegetables or cash. The amount of vegetables that the household was able to yield from each crop was dependent, to a large degree, on the condition of the soil. Poor soil will not produce abundant crop yields. Therefore, it is necessary for the good health of soil to be maintained.

Figure 4.27: Growing vegetables at household level



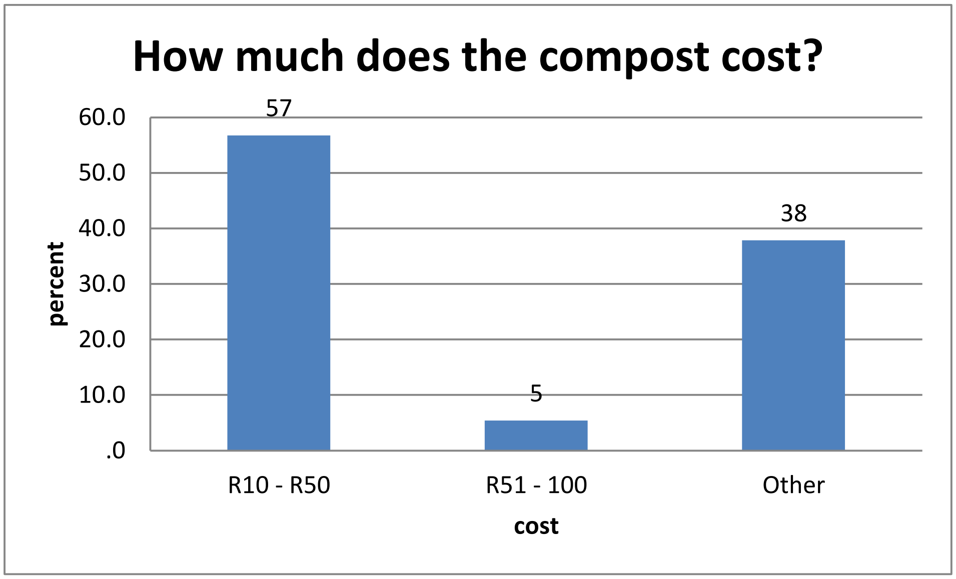
Eighty percent of the respondents surveyed did grow their own vegetables and the majority applied compost to the soil (Figure 4.27). As was mentioned previously, the yield from each crop that the respondents planted was dependant, to a large degree, on the condition of the soil. Degraded and fallow soil will not yield much, if anything at all. Therefore, it is essential that the good health of soil is maintained. The addition of organic based compost will aid in the upkeep of the soil. Continuous use of the soil without the addition of compost or a soil conditioner will be damaging in the long term. The majority of respondents were aware of this problem. The 20% of respondents who did not apply compost to the soil may not be able to afford commercial compost, thus humanure can be the alternative if the stigma attached to it is removed via education.

Figure 4.28: Type of compost applied to the soil



Those who applied compost to their soil, used organic compost (46%), chemical based compost (32%), and 22% a combination of both (Figure 4.28). With regard the chemical compost, respondents purchased this commercial product. The organic compost that respondents used was cow dung and other manures, as well as home-made compost, made out of kitchen waste and garden clippings.

Figure 4.29: Cost of compost



Despite the cost of compost being seemingly low, in comparison to the socio-economic status of the respondents, some of whom have a monthly income of less than R300, it was an expense that could be eliminated.

Overall, the perception of the respondents seemed to be evenly split. Approximately half of the respondents seemed to be open and willing to learn about the use of humanure in their household gardens. Those who did not seem as willing appeared to be against the notion due to preconceived ideas about human excrement and its intended use. Perceptions may be changed with education, which will help overcome stigma which has been rooted in a feaca-phobic society.

4.6. Humanure Analysis

There are many possible health risks and hazards associated with the use of any faecal matter, be it human or animal. Despite the source, faecal matter should undergo a process to eliminate harmful pathogens that may exist in the matter. Many of these pathogens give rise to illnesses and diseases in humans. Therefore, testing of the humanure for indicator bacteria and pathogens was done to determine the health and safety risks associated with the use of humanure. Table 4.3 details the bacteria that the humanure was tested for, and the results of the tests.

Table 4.3: Humanure microbiological test results

Bacteria		**Result**			**Minimal infective dose**
	Count	Humanure sample 1	Humanure sample 2	Humanure sample 1 + soil	
Total coliform bacteria	Per 100ml	>10000	>10000	>10000	* as E.coli
Faecal coliforms	Per 100ml	3800	>10000	>10000	* as E.coli
E.coli bacteria	Per 100ml	3800	>10000	>10000	1,000,000 – 100,000,000
Heterotrophic plate count	Per ml	>10000	>10000	>10000	* as E.coli
Clostridium Perfringens bacteria	Per 100ml	0	0	600	****0**
Streptococcus	Per 100ml	<10000	<10000	38900	10,000,000,000
Pseudominas Aeruginosa bacteria	Per 100ml	0	0	0	****0**
Helminth ova	Per 100ml	0	0	0	1 – 10 eggs (Ascaris)
Legionella	Per 1000ml	Not detected	Not detected	Not detected	****0**

*Source of "Minimal infective dose' column (Ascaris, E.coli, and Streptococcus only): Adapted from Jenkins (2005:128)

** Minimal infective dose assumed to be zero

4.6.1. Minimal Infective Doses

Minimal ineffective doses do not exist for most of the bacteria with respect to humanure. Consequently the researcher had to make assumptions in order to reach conclusions. The minimal infective doses of E.coli was applied to Total coliforms, Faecal coliforms and Heterotrophic Plate count, as E.coli is considered in each of these plate counts. In the case of Legionella, Clostridium Perfringens and Pseudomonas Aeruginosa, the minimal infective dose was assumed to be zero, erring on the side of caution.

Additional notes from the testing laboratory state:

- *Faecal coliforms: Indicator of unacceptable microbial water quality. Could be tested instead of E.coli but is not the preferred indicator of faecal pollution. Also provides information on treatment efficiency and after growth in distribution networks.*
- *E.coli: Definitive, preferred indicator of faecal pollution.*
- *Heterotrophic plate count: Process indicator that provides information on treatment efficiency and after growth in distribution networks*

4.6.2. Humanure Sample Analysis and Discussion

Sample one is the first batch of humanure made, Sample two is the second batch of humanure made, and Sample three is from the first batch of humanure and soil, taken from the trial garden plot three months after the application of the humanure. With regard to the results of the tests carried out on the humanure, the outcome is varied for the different indicators. Minimal infective dose values for each bacterium vary. The results have been separated on the basis of the level of risk posed (by the indicator tested).

All indicators can be classified as high risk, due to their disease causing ability. However, the levels of indicators present in the samples tested do eliminate some of the indicators from the high risk profile, due to their respective minimal infective doses. Therefore, the results of the humanure microbiological test results will be organised on a level of risk posed, based on the indicator's minimal infective dose and the presence in the sample tested. The levels of risk posed are 'High', 'Medium' and 'Low'. Indicators classified as 'High' are present in the sample tested and exceed the minimal infective dose; whilst indicators that are classified as 'Medium' are present in the sample and do not exceed the minimal infective dose. 'Low' risk indicators are those that tested negative or absent in the sample.

I. *LEVEL OF RISK POSED: HIGH*

- **Clostridium Perfringens** bacteria in sample three, with a level of 600 counts per 100 ml of sample. The minimal infective dose for this indicator is assumed to be zero, as discussed 4.4.1.

II. *LEVEL OF RISK POSED: MEDIUM*

- The test for **Total Coliforms** presented similar results, with more than 10 000 organisms per 100ml of sample. While total coliforms were initially thought to be an indicator of faecal contamination, other methods have emerged to test solely for E.coli bacteria, which is a more accurate indicator of faecal contamination. Furthermore, types of coliforms have been found to be naturally occurring in soils, water and plants (Payment *et al*, 2003). Therefore, despite the high total coliform count, it is uncertain whether this will impact negatively on crops grown with humanure. This will be confirmed by results from pathogen tests on produce from the garden trial.

- **Faecal coliforms** are a sub group of the total coliform group, with the most common indicator faecal coliform being **E.coli**. This is due to the fact that this type of bacteria is present in the intestine of humans and animals and is not found naturally occurring in the environment. Results for the faecal coliform and E.coli tests confirm a link between these coliforms, as the results for each sample correspond for the two tests. Sample one has a faecal coliform and E.coli count of 3800 organisms per 100ml of sample; while sample two and three have a count of more than 10 000 organisms per 100ml of sample. The difference in these results may be attributed to the time allowed for the humanure to moulder. The humanure used in sample one was allowed to moulder for a period of one year, the recommended time according to Jenkins (2005). Humanure used in sample two was allowed to moulder for a shortened period of three months, which could be the reason for the elevated E.coli count. With regard to sample three, a mix of sample one and soil from the garden trial plot, it should be noted that the faecal coliform and E.coli count could have been elevated due to the excrement of domestic animals.

- With regard to the **Heterotrophic Plate Count** test carried out, the results for all three samples indicate more than 10 000 organisms per ml of sample. Although this is a high count, the heterotrophic plate count is a count of all bacterial colonies present, not only harmful and pathogenic bacteria (Koch, 2003:2).

- Tests carried out for the presence of **Streptococcus** were positive, with less than 10 000 counts per 100ml detected in sample one and two, and 38 900 counts per 100ml detected in sample three. Although pathogens cause disease and illness, they each have varying degrees of virulence, which is "their potential for causing disease in humans" (Jenkins, 2005: 128). The minimal infective dose, which refers to the number of pathogens required to establish infection, is not the same for all pathogens.

  The minimal infective dose of Streptococcus as 10,000,000,000; which is considerably more than the amounts detected in the samples. It may be assumed from the above that while the presence of Streptococcus can pose a health risk, the danger is relatively low.

This will be confirmed by the results of the microbiological test results carried out on the raw vegetables grown in the trial gardens.

III. *LEVEL OF RISK POSED: LOW*

- One of the most difficult to eliminate and notorious pathogens, **Helminth ova**, were not detected in any of the three samples, having a zero count per 100ml. Helminth ova are excellent indicators due to their resilient nature to environmental conditions, owing to the thick outer layer of the ova (Jenkins, 2005).

- **Legionella**, which is the cause of Legionnaires' disease, was not detected in any of the samples either. Legionella bacteria may be transmitted by aerosols and aspiration of contaminated water, and may be hosted by humans (Public Health Agency of Canada, 2010). Legionnaires' disease causes a form of acute pneumonia in humans. It is a positive result that Legionella bacteria were found to be absent in the samples.

- **Clostridium Perfringens**, except for in sample three, and **Pseudomonas Aeruginosa** were also not detected, having a zero count per 100ml. Sample three, as mentioned above, is a mix of humanure and soil. Since sample one tested negative for Clostridium Perfringens, it may be assumed that the bacteria was present in the soil or was from another source other than the humanure.

Although the above test results indicate that there are bacteria present in the humanure, some strains and genera having higher counts than others, these results do not confirm that the use of humanure is either safe or unsafe for use in household agriculture. The following section, examining the results of food safety tests carried out on the crops grown in the trial gardens, will provide evidence on the viability and safety of using humanure for household agriculture; particularly in food gardens.

4.7. Food Safety tests

4.7.1. Food Safety - Results

As stated in Chapter three of this dissertation, four different bacteria and pathogens were tested for in the resultant produce from the trial gardens, both plot and tyre gardens. The plot and tyre garden each had applied and non-applied components, with the applied having humanure added to the soil and the non-applied having nothing added to the soil. The results of the microbiological food safety tests are shown below in a series of tables. There are four tables (one per bacteria/pathogen tested) per garden, and four gardens, namely:

- Plot without humanure
- Plot with humanure
- Tyre without humanure
- Tyre with humanure

Each sample was tested at different dilutions, as shown in the second row of each table. The Plate Count method was used to determine the level of contamination of the different bacteria being investigated. Briefly, the number of colonies formed on the plate, after the recommended incubation period, is counted. A formula to calculate colony forming units per ml is then used to determine the level of contamination of each individual sample. These levels will be compared to the recommended levels in Table 4.5 and 4.6. The results of the plate counts for *Listeria Monocytogenes, Salmonella, E.coli* and *Shigella* are detailed in tables 4.4.1 – 4.4.16.

Table 4.4.1: Plot without Humanure – Listeria Monocytogenes

Plot WITHOUT Humanure Listeria Monocytogenes	No. Of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**
BEETROOT	0															
BRINJAL	0															
SPINACH	2	8	10	x	x	x	TNTC	160	8	x	X					
OKRA	2	x	x	x	x	X	33	3	x	x	x					
TURNIP	3	X	x	x	x	x	8	x	x	x	X	x	x	x	x	X
RADISH	3	x	x	x	x	x	13	12	x	x	x	TNTC	69	x	x	x

Table 4.4.2: Plot without Humanure – Salmonella

Plot WITHOUT Humanure Salmonella	No. Of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	0															
SPINACH	2	x	x	x	x	x	x	x	x	x	x					
OKRA	2	x	x	x	x	x	x	x	x	x	x					
TURNIP	3	x	x	x	x	x	TNTC	x	x	x	x	x	x	x	x	x
RADISH	3	x	7	x	x	x	x	x	x	x	x	x	4	x	x	x

Table 4.4.3: Plot without Humanure – Shigella

Plot WITHOUT Humanure Shigella	No. Of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	0															
SPINACH	2	x	x	x	x	x	x	x	x	x	x					
OKRA	2	x	x	x	x	x	x	x	x	x	x					
TURNIP	3	TNTC	TNTC	x	x	x	TNTC	TNTC	x	x	x	x	x	x	x	x
RADISH	3	TNTC	x	x	x	x	TNTC	x	x	x	x	TNTC	TNTC	x	x	x

Table 4.4.4: Plot without Humanure – E.coli

Plot WITHOUT Humanure E.coli	No. Of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	0															
SPINACH	2	TNTC	80	x	x	x	TNTC	79	4	x	x					
OKRA	2	x	x	x	x	x	TNTC	16	x	x	x					
TURNIP	3	TNTC	TNTC	x	x	x	TNTC	16	x	x	x	TNTC	x	x	x	x
RADISH	3	TNTC	TNTC	7	X	x		46	x	x	x		TNTC	x	x	x

Table 4.4.5: Plot with Humanure: Listeria Monocytogenes

Plot WITH humanure Listeria Monocytogenes	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SPINACH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
OKRA	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TURNIP	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RADISH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 4.4.6: Plot with Humanure: Salmonella

Plot WITH humanure Salmonella	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SPINACH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
OKRA	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TURNIP	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RADISH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 4.4.7: Plot with Humanure: Shigella

Plot WITH humanure Shigella	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SPINACH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
OKRA	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TURNIP	3	132	x	x	x	x	x	x	x	x	x	63	x	x	x	x
RADISH	3	250	x	x	x	x	x	x	x	x	x	220	x	x	x	x

Table 4.4.8: Plot with Humanure: E.coli

Plot WITH humanure E.coli	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	0															
BRINJAL	3	8	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SPINACH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
OKRA	3	x	1	x	x	x	1	x	x	x	x	x	x	x	x	x
TURNIP	3	x	x	x	x	x	x	x	x	x	x	3	x	x	x	x
RADISH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 4.4.9: Tyre without Humanure: Listeria Monocytogenes

Tyre WITHOUT humanure Listeria Monocytogenes	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**
BEETROOT	2	x	x	x	x	x	x	x	x	x	x					
BRINJAL	1	x	x	x	x	x										
SPINACH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
OKRA	0															
TURNIP	0															
RADISH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 4.4.10: Tyre without Humanure: Salmonella

Tyre WITHOUT humanure Salmonella	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	2	x	x	x	x	x	x	x	x	x	x					
BRINJAL	1	x	x	x	x	x										
SPINACH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
OKRA	0															
TURNIP	0															
RADISH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 4.4.11: Tyre without Humanure: Shigella

Tyre WITHOUT humanure Shigella	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	2	x	x	x	x	x	x	x	x	x	x					
BRINJAL	1	x	x	x	x	x										
SPINACH	3	23	x	x	x	x	TNTC	x	x	x	x	x	x	x	x	x
OKRA	0															
TURNIP	0															
RADISH	3	TNTC	x	x	x	x	147	x	x	x	x	TNTC	x	x	x	x

Table 4.4.12: Tyre without Humanure: E.coli

Tyre WITHOUT humanure E.coli	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-5}**	**-VE**
BEETROOT	2	92	x	x	x	x	x	x	x	x	x					
BRINJAL	1	x	x	x	x	x										
SPINACH	3	TNTC	x	x	x	x	20	x	x	x	x	x	x	x	x	x
OKRA	0															
TURNIP	0															
RADISH	3	x	x	x	x	x	1	x	x	x	x	200	x	x	x	x

Table 4.4.13: Tyre with Humanure: Listeria Monocytogenes

Tyre WITH humanure Listeria Monocytogenes	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
BRINJAL	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SPINACH	2	x	x	1	x	x	x	x	x	x	x	x	x	x	x	x
OKRA	3	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TURNIP	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
RADISH	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 4.4.14: Tyre with Humanure: Salmonella

Tyre WITH humanure Salmonella	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BRINJAL	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
SPINACH	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
OKRA	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
TURNIP	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
RADISH	3	x	x	x	x	x	x	x	x	x	x	TN TC	x	x	x	x

Table 4.4.15: Tyre with Humanure: Shigella

Tyre WITH humanure Shigella	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	3	x	x	x	x	x	250	x	x	x	x	TN TC	x	x	x	X
BRINJAL	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
SPINACH	2	x	x	x	x	x	TNT C	TNT C	x	x	x	x	x	x	x	x
OKRA	3	x	x	x	x	x	x	x	x	x	x	TN TC	x	x	x	X
TURNIP	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
RADISH	3	TNT C	TNT C	116	x	x	x	x	x	x	x	TN CT	13	1	x	x

Table 4.4.16: Tyre with Humanure: E.coli

Tyre WITH humanure E.coli	No. of Samples	SAMPLE ONE COLONY COUNT					SAMPLE TWO COLONY COUNT					SAMPLE THREE COLONY COUNT				
		10^{-2}	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{--5}**	**-VE**
BEETROOT	3	x	x	x	x	x	x	x	x	x	x	11	x	x	x	X
BRINJAL	3	1	X	x	x	x	x	x	x	x	x	x	x	x	x	x
SPINACH	2	105	x	x	x	x	TNTC	1	x	x	x	5	x	x	x	X
OKRA	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TURNIP	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X
RADISH	3	x	x	x	x	x	TNTC	25	2	x	x	50	x	x	x	x

4.6.2. Food safety – Discussion

Food safety of minimally processed and ready to eat foods need to be carefully monitored, as many incidences of food-borne illness outbreaks have occurred in recent times. Minimally processed foods are food items that are mostly ready to consume and do not need to undergo many preparations in order to be 'ready to eat'. Raw fruits and vegetables, including fresh cut fruit or vegetable salads are included in the category of 'minimally processed' and 'ready to eat' foods. However, these food items need to be monitored to ensure microbial populations that may be present on the surface or within the item, are in accordance with recognised food safety standards and guidelines. Indicator bacteria and pathogens are usually tested for to ensure food safety. For the purpose of this study, *Listeria monocytogenes, Salmonella, Shigella and E.coli* were the indicator bacteria tested for in food samples from the trial gardens.

As a result of the garden trials carried out in this study using humanure, it was necessary to ensure that resultant produce was safe to eat – that it did not take up any pathogens that may have been lingering in the soil or were not destroyed during the composting process. The South African Department of Health (DoH) issued 'Guidelines for Environmental Health Officers on the Interpretation of Microbiological Analysis Data of Food'. These Guidelines detail proposed microbiological specification to be used as guidelines for foods. As detailed Table 4.5, the DoH guidelines specify proposed limits for two of the indicator bacteria tested for in this study, *E.coli* and *Salmonella*.

Table: 4.5: DoH food safety guidelines

FOOD TYPE	ANALYSIS	LIMITS
Raw vegetables and raw fruits, including fresh fruit salad, salad dressing and peanut butter	Coliform count	<200/g
	Yeast and mould count	<100 000/g
	E.coli	0/g
	Salmonella species	0/25g

Source: Table extracted from DoH Guidelines

The DoH proposals seem inadequate, as there are no guidelines with regard to the presence of *Shigella* and *Listeria monocytogenes* in fresh, raw vegetables. However, the limits of *Shigella* in other foodstuffs such as desiccated coconut, partly or uncooked sea or freshwater food, cooked freshwater and sea water food and cooked poultry, are all allocated limits of 0/gram or 0/20grams (DoH Guidelines, n.d). Therefore, it will be assumed that the limit for *Shigella* in fresh, raw vegetables is also 0/gram. Notes in the Guideline state that "in terms of foodborne pathogens, the rule of thumb is that processed food should ideally be free from pathogens" (DoH, n.d., 15). The Guideline further discusses criteria under which a 'zero tolerance' approach should be taken. One of the key criteria is that if the food item will undergo further processing (DoH, n.d.), which in the case of minimally processed foods such as fresh, raw vegetables is not the case, a 'zero tolerance' approach should be adopted.

Another guideline, 'Guidelines for the Microbiological Quality of some Ready-To-Eat Foods at Point of Sale', was consulted for microbiological limits of indicator bacteria and pathogens in fresh, raw vegetables. This Guide was published by the Food Safety Authority of Ireland and provides a more comprehensive and detailed guide of microbial limits in different food items. In the classification of different food items, 'fruit and vegetables (fresh)' were allocated the category 'E'. Table 4.6 details information extracted from this Guide.

Table 4.6: Guidelines for Microbiological Quality of ready to eat foods

Food category	**Criterion**	**Microbiological quality (cfu per gram unless otherwise stated)**			
		Satisfactory	**Acceptable**	**Unsatisfactory**	**Unacceptable/potentially hazardous**
A – E	*Escherichia coli (total)*	<20	20 - <100	>100	N/A
A – E	*Salmonella spp*	Not detected in 25g			Detected in 25g
A - E	*L. monocytogenes*	<20	20 - <100	N/A	>100

Source: Table adapted from Guidelines for the Microbiological Quality of some Ready-To-Eat Foods at Point of Sale (2001:8)

The levels of microbiological quality ('satisfactory, acceptable, unsatisfactory and unacceptable/potentially hazardous) are further explained in Table 4.7.

Table 4.7: Levels of Microbiological quality

Level	**Description**
Satisfactory	Test results indicating good microbiological quality
Acceptable	An index reflecting a borderline limit of microbiological quality
Unsatisfactory	Test results indicating that further sampling may be necessary and that environmental health officers may wish to undertake a further inspection of the premises concerned to determine whether hygiene practices for food production or handling are adequate or not
Unacceptable/potentially hazardous	Test results indicating that urgent attention is needed to locate the source of the problem; a detailed risk assessment is recommended. Such results may also form a basis for prosecution by environmental health departments, especially if they occur in more than one sample. Food examiners will wish to draw on their own experience and expertise in determining the advice and comments they wish to give and they will be required to do this if invited to give an expert opinion during legal proceedings

Source: Gilbert *et al*, 2000:165.

The results of the plate counts for *Listeria Monocytogenes*, *Salmonella*, *E.coli* and *Shigella* are detailed in the Tables 4.8 and 4.9, respectively.

Table 4.8: Number of Plant Samples Collected

	Plot Without Humanure	**Plot With Humanure**	**Tyre Without Humanure**	**Tyre With Humanure**
Beetroot	0	0	2	3
Brinjal	0	3	1	3
Spinach	2	3	3	3
Okra	2	3	0	3
Turnip	3	3	0	0
Radish	3	3	3	3
Total	10	15	9	15

It was decided that three samples of each plant type, from each sub-section of the entire trial was to be chosen for microbiological food testing. However, this was ultimately not possible, as certain plant types did not flourish, leaving no sample for collection. The turnips that were planted in the tyre gardens did not thrive, with no sample from both tyres being collected. The same may be said for the beetroot plants from the plot gardens. Additionally, brinjal's from the plot without humanure, as well as okra from the tyre without humanure did not grow well enough for samples to be collected. Overall, a greater number of samples were collected from the plots with humanure, than without humanure, indicating that humanure must have a basic, positive effect on plant growth and survival.

Table 4.9: Number of samples containing bacterial colonies

	Plot Without Humanure	**Plot With Humanure**	**Tyre Without Humanure**	**Tyre With Humanure**
Beetroot	-	-	1/2	2/3
Brinjal	-	1/3	0/1	1/3
Spinach	2/2	0/3	2/3	3/3
Okra	1/2	2/3	-	1/3
Turnip	3/3	2/3	-	-
Radish	3/3	2/3	3/3	3/3
Total	9/10 (90%)	7/15 (46.67%)	6/9 (66.67%)	10/15 66.67%)

Table 4.9 details the number of samples in each plot that was contaminated with bacterial colonies of either *Listeria Monocytogenes, Salmonella, E.coli* or *Shigella*. Contamination of the samples did not seem to follow any distinct pattern, with all types (root, leaf and fruiting) of crops being contaminated. The levels of contamination of the samples need to be examined before deciding whether or not the use of humanure for food production is safe for human health. Tables 4.8 and 4.9 detail the different levels of contamination of each sample for each bacteria type in comparison to the acceptable levels detailed by the aforementioned guidelines.

Comparison with the levels of microbial populations present in the tested samples and the consulted guidelines suggests that all the samples that tested positive for microbial populations of either E.coli, Salmonella, Shigella or Listeria Monocytogenes exceed the 'safe' zone of both guidelines consulted. Despite some of the samples testing negative, the samples that tested positive render all the produce unsafe for consumption as a minimally processed food.

If this produce is consumed as a minimally processed food, there is a definite risk of food borne illness. The safety of consumption of the produce after further processing, such as cooking using heat, is unknown. Although there is a possibility that further processing may render the produce safe to consume, further investigation is required to establish whether this is the case.

4.7. Plant Health

4.7.1. Visible Analysis - Results

PLANT HEALTH CRITERIA

4.7.1.1. Plot Garden WITHOUT Humanure

Table 4.9.1: Plot garden without Humanure: Brinjal

BRINJAL			
CATEGORY			
Visible, potential disease on plant leaves, roots or fruits	**YES**		**NO**
			x
Colour of plant leaves, roots or fruits	Plant still at bud stage, light green/grey buds forming.		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	<10	<10	
Image			

Table 4.9.2: Plot garden without Humanure: Okra

<table>
<tr><td colspan="4">OKRA</td></tr>
<tr><td>CATEGORY</td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Visible disease on plant leaves, roots or fruits</td><td>YES</td><td colspan="2">NO</td></tr>
<tr><td></td><td colspan="2">x</td></tr>
<tr><td>Colour of plant leaves, roots or fruits</td><td colspan="3">Light green fruit, black spot on sample three.</td></tr>
<tr><td rowspan="3">Weight of edible mass per plant (g)</td><td colspan="3">WEIGHT</td></tr>
<tr><td>SAMPLE ONE</td><td>SAMPLE TWO</td><td>SAMPLE THREE</td></tr>
<tr><td>22.17</td><td><10</td><td>24.94</td></tr>
<tr><td>Image</td><td></td><td></td><td></td></tr>
</table>

Table 4.9.3: Plot garden without Humanure: Radish

RADISH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**		**NO**
			x
Colour of plant leaves, roots or fruits	Red/dark brown with a course surface and dark spots on root.		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	35.29	55.06	37.4
Image			

Table 4.9.4: Plot garden without Humanure: Turnip

TURNIP			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**		**NO**
			x
Colour of plant leaves, roots or fruits	Purple/white root with light brown markings and a smooth surface		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	80.3	46.3	38.3
Image			

Table 4.9.5: Plot garden without Humanure: Spinach

SPINACH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**		**NO**
	x		
Colour of plant leaves, roots or fruits	Dark green leaves with a slight yellowing of the leaf in sample one; leaves eaten away in some areas		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	11.95	10.6	
Image			

4.7.1.2. Plot Garden WITH Humanure

Table 4.9.6: Plot garden with Humanure: Brinjal

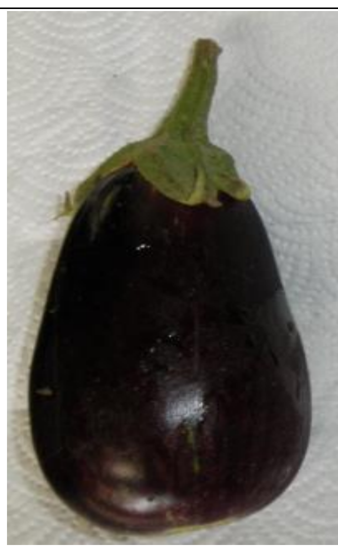
BRINJAL			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**		**NO**
			X
Colour of plant leaves, roots or fruits	Deep purple fruit with green stems		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	240	100.5	151.6
Image			

Table 4.9.7: Plot garden with Humanure: Turnip

<table>
<tr><td colspan="4">TURNIP</td></tr>
<tr><td>CATEGORY</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="2">Visible disease on plant leaves, roots or fruits</td><td colspan="2">YES</td><td>NO</td></tr>
<tr><td colspan="2"></td><td>x</td></tr>
<tr><td>Colour of plant leaves, roots or fruits</td><td colspan="3">White and purple roots with a slightly rough surface</td></tr>
<tr><td rowspan="3">Weight of edible mass per plant (g)</td><td colspan="3">WEIGHT</td></tr>
<tr><td>SAMPLE ONE</td><td>SAMPLE TWO</td><td>SAMPLE THREE</td></tr>
<tr><td>74</td><td>155.77</td><td>154.9</td></tr>
<tr><td>Image</td><td></td><td></td><td></td></tr>
</table>

Table 4.9.8: Plot garden with Humanure: Radish

RADISH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		X	
Colour of plant leaves, roots or fruits	Red/dark brown with a slightly rough, uneven surface		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	61.64	84.64	23
Image			

Table 4.9.9: Plot garden with Humanure: Spinach

SPINACH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**		**NO**
	x		
Colour of plant leaves, roots or fruits	Green leaves, yellowing with black/brown spots in areas		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	22.5	14.8	12.5
Image			

Table 4.9.10: Plot garden with Humanure: Okra

OKRA			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		x	
Colour of plant leaves, roots or fruits	Light green fruit with a smooth surface		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	24.2	39.7	39.21
Image			

4.7.1.3. Tyre Garden WITHOUT Humanure

Table 4.9.11: Plot garden without Humanure: Brinjal

BRINJAL			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		x	
Colour of plant leaves, roots or fruits	Deep purple fruit with a green stem		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	29.27		
Image			

Table 4.9.12: Plot garden without Humanure: Beetroot

<table>
<tr><td colspan="4">BEETROOT</td></tr>
<tr><td>CATEGORY</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="2">Visible disease on plant leaves, roots or fruits</td><td colspan="2">YES</td><td>NO</td></tr>
<tr><td colspan="2"></td><td>x</td></tr>
<tr><td>Colour of plant leaves, roots or fruits</td><td colspan="3">Dark pink/brown root with a rough skin</td></tr>
<tr><td rowspan="3">Weight of edible mass per plant (g)</td><td colspan="3">WEIGHT</td></tr>
<tr><td>SAMPLE ONE</td><td>SAMPLE TWO</td><td>SAMPLE THREE</td></tr>
<tr><td>28.5</td><td>77.1</td><td></td></tr>
<tr><td>Image</td><td></td><td></td><td></td></tr>
</table>

Table 4.9.13: Plot garden without Humanure: Spinach

SPINACH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
	x		
Colour of plant leaves, roots or fruits	Dark green with parts of leaves eaten; dark areas and yellowing patches visible on sample one		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	10.18	14.31	20.06
Image			

Table 4.9.14: Plot garden without Humanure: Okra

<table>
<tr><td colspan="4">OKRA</td></tr>
<tr><td>CATEGORY</td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Visible disease on plant leaves, roots or fruits</td><td>YES</td><td colspan="2">NO</td></tr>
<tr><td></td><td colspan="2">x</td></tr>
<tr><td>Colour of plant leaves, roots or fruits</td><td colspan="3">Light green fruit and buds</td></tr>
<tr><td rowspan="3">Weight of edible mass per plant (g)</td><td colspan="3">WEIGHT</td></tr>
<tr><td>SAMPLE ONE</td><td>SAMPLE TWO</td><td>SAMPLE THREE</td></tr>
<tr><td>1.37</td><td>2.1</td><td>4.3</td></tr>
<tr><td>Image</td><td></td><td></td><td></td></tr>
</table>

Table 4.9.15: Plot garden without Humanure: Radish

RADISH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		x	
Colour of plant leaves, roots or fruits	Red/dark brown coloured root with a slightly rough surface		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	18.6	27.0	13.5
Image			

4.7.1.4. Tyre Garden WITH Humanure

Table 4.9.16: Tyre garden with Humanure: Brinjal

BRINJAL			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		X	
Colour of plant leaves, roots or fruits	Deep purple with green stems; no lesions on fruit		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	165	75.1	205
Image			

Table 4.9.17: Tyre garden with Humanure: Okra

OKRA			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**		**NO**
			X
Colour of plant leaves, roots or fruits	Bright green; no lesions on fruit		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	28.7	33	20.8
Image			

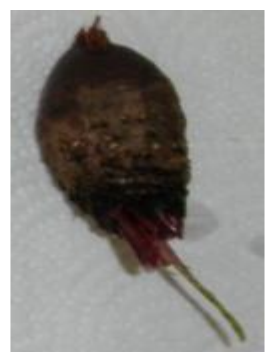
Table 4.9.18: Tyre garden with Humanure: Radish

RADISH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		X	
Colour of plant leaves, roots or fruits	Red/dark brown roots		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	21.9	18.7	14.3
Image			

Table 4.9.19: Tyre garden with Humanure: Spinach

SPINACH			
CATEGORY			
Visible disease on plant leaves, roots or fruits	**YES**	**NO**	
		X	
Colour of plant leaves, roots or fruits	Dark green leaves; evidence of leaves being partially eaten in areas		
Weight of edible mass per plant (g)	**WEIGHT**		
	SAMPLE ONE	**SAMPLE TWO**	**SAMPLE THREE**
	13.5	12.3	15.4
Image			

Table 4.9.20: Tyre garden with Humanure: Beetroot

<table>
<tr><td colspan="4">BEETROOT</td></tr>
<tr><td>CATEGORY</td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Visible disease on plant leaves, roots or fruits</td><td>YES</td><td colspan="2">NO</td></tr>
<tr><td></td><td colspan="2">X</td></tr>
<tr><td>Colour of plant leaves, roots or fruits</td><td colspan="3">Dark pink/brown roots; slightly rough skin</td></tr>
<tr><td rowspan="3">Weight of edible mass per plant (g)</td><td colspan="3">WEIGHT</td></tr>
<tr><td>SAMPLE ONE</td><td>SAMPLE TWO</td><td>SAMPLE THREE</td></tr>
<tr><td>74.1</td><td>97.8</td><td>34.9</td></tr>
<tr><td>Image</td><td></td><td></td><td></td></tr>
</table>

4.7.2. Visual Analysis - Discussion

Tables 4.9.1 – 4.9.20 each detail and illustrate the appearance of various samples of vegetables that were grown in the trial gardens, and tested for microbiological food safety. Based on the visuals, there is a marked difference between the crops grown with and without humanure. The crops grown without humanure appear to be smaller and more prone to disease and pests, as evidenced by the spinach leaves grown without humanure. Crops grown with humanure appear to have grown larger in size within the same amount of time. Furthermore, some of the crops grown without humanure did not produce the quality of vegetables compared to the crops grown with humanure. This is evidenced by the above visuals (Tables 4.9.1 – 4.9.20), with some of the leaf crops grown without humanure appearing diseased and sickly, whilst those grown with humanure appearing healthy and disease free.

Another point in favour of the use of humanure is that, although this research has not investigated ‘yield’ of each crop, it is shown that the trial crops grown with humanure appear to have produced a greater amount of fruits, roots and leaves as compared to those grown without humanure. Brinjal and okra grown in the plot trial garden without the addition of humanure did not reach a weight greater than 10 grams in the time frame, which is the amount of sample that was required for microbiological food safety tests. Comparatively, brinjal grown in the plot trial garden with humanure reached weights of greater than 100 grams each. The same may be said for okra grown in these trial plot gardens. Additionally, as mentioned above, the quality of the produce from the trial crops with humanure appear to be of a higher quality.

With regard to the presence of visible disease on the plants, all samples, with the exception of the spinach leaves seemed unaffected by any pest or disease. Three of the four spinach samples were visibly affected, excluding the spinach grown in the trial tyre garden with humanure. This may be indicative of a higher resistance to pests and diseases, without the application of pesticides, of plants grown with humanure, as opposed to those grown without humanure.

Visible analysis was carried out to determine the presence of diseases. Assistance in this regard was obtained from a professional horticulturist. Considering the community where the study was undertaken, it was important to inform them of this potential. Overall, there is a definite and noticeable difference in the plants grown with and without humanure. This difference favours humanure, with a greater amount and quality of produce being harvested.

4.8. Conclusion

This chapter has presented an analysis and discussion of the results of this study. Part one illustrated and discussed the social acceptability aspect of this study; whilst part two of this chapter dealt with results of humanure testing and food safety of the crops grown in the trial gardens. The food safety aspect of this research was further dealt with in two parts, namely, microbiological test results and a visual analysis. The following and final chapter of this research will outline overall conclusions drawn from this research, as well as recommendations and limitations of this study.

Chapter Five

Summary of Key Findings, Recommendations and Conclusion

5.1. Introduction

This study has explored the possibility of using human excrement to make humanure, to be used for household agriculture; eliminating the problem of safe disposal of the excrement. Research for this study was undertaken within the community of Cottonlands, whose perception on the use of humanure was determined. Humanure was produced with excrement sourced from UDT vaults, from households located within the community. The resultant humanure was used in garden trials to grow vegetable crops, including a root, leaf and fruiting crop. Samples from these plants were tested for certain indicator pathogens and bacteria to determine the food safety of crops grown with the addition of humanure. The key findings of this research will be presented in this chapter, with reference to relevant literature being made. Recommendations and an overall, final conclusion will follow.

5.2. Summary of Key Findings

The analysis and results of this research were organised in accordance of the research objectives of this study. Key findings may be divided into three sections, namely, 'social acceptability'; 'humanure' and 'food safety'.

5.2.1. Social Acceptability

I. *On the use of UDT's:*

People are uncomfortable with using this type of toilet, preferring ventilated improved pits (VIP's) or pit latrines to UDT's. This gives an indication of the level of dissatisfaction with UDT's, as VIP's and pit latrines are unpleasant types of sanitation systems. The most preferred and sought after type of toilet is the flush toilet, as people are most comfortable with this type of system. Many UDT's have been modified by people to create a flush toilet system, defeating the aim of the installation of the UDT's. UDT's form part of the dry sanitation movement (CSIR, 2000); where a waterless approach to sanitation management is adopted, within the context of the unsustainability of using potable water for sanitation disposal. There is a shortage of potable water; using this water is a wasteful and careless practice, contaminating what little of the resource remains (Binns *et al*, 2001; Friedrich *et al*, 2008). Furthermore, the issue of purifying this waste water arises.

There is a negative perception and stigma attached to the use of UDT's. People who have been given UDT's view this as a 'second class' treatment. This is especially prominent in the study area, as the landmark of the King Shaka International Airport is situated in close proximity to the study area, as well as the fully established towns of Verulam and Tongaat. This distinct difference in services offered to people within close proximity to one another is what gives rise to the sentiment of 'second class' treatment. Furthermore, many of the people who were allocated UDT's are unsure of how to properly use a UDT, resulting in incorrect usage.

A system such as this will only function optimally if used in the precise manner, with the correct materials being added to the vault. The addition of incorrect soak materials being added to the vault will result in the composting process being negatively affected, as well as result in material in the vault turning rancid, as opposed to desiccating. As Jenkins (2005:159) states, "The cover material acts as an organic lid or *biofilter* … Therefore, the choice of organic cover material is very important … ." He goes on to state that "cover materials prevent odour, absorb excess moisture, and balance the C/N ratio" (Jenkins, 2005:170). This was observed in many of the vaults in the study area.

II. On the use of Humanure:

There was almost a 50/50 split with regard to the willingness to use humanure in food gardens. The reluctance of those who disagree with its use in food gardens stem from societal perceptions on human excrement. There is an extremely negative connotation attached to human excrement, often referred to as human 'waste'. These perceptions may be altered with education, from a faecophobic to a faecaphilic view (Kelly, 2010), thus creating a new perception and attitude toward human excrement, and especially its potential value. This may be achieved through the adoption of the zero-waste management policy; changing the view of human excrement from a waste to a resource. As David Ferry noted, the benefits of adopting of a zero-waste framework are mainly environmental (Ferry, 2011).

5.2.2. Humanure Preparation

Drawing from the levels of contamination of vegetables grown in humanure left to moulder for different time periods, it may be noted that the period of mouldering has a definite and noticeable impact the microbiological state of humanure. Vegetables grown in humanure left to moulder for a period of 1 year had a distinctly lower level of bacterial contamination than those vegetables grown in humanure left to moulder for a period of 3 months. This is in line with the literature, which suggests that "a long curing period, such as a year after the thermophilic stage, adds a safety net for pathogen destruction" (Jenkins, 2005:43); and Golueke (1972) who notes that compost should be left for a period of time for mineralisation of the compost to occur and maximum benefit to be gained from the compost.

It is imperative that the method and technique of making and producing humanure is perfected, as incorrect methods could have negative impacts on the vegetable produce grown using the resultant humanure.

UDT waste has a huge impact on the process of making humanure. Waste that has been treated incorrectly and the addition of wrong cover materials have a negative impact on the process, not allowing optimal temperatures to be reached. This problem may be linked to the social acceptability study; which indicated that people are uncomfortable with or do not know how to properly use a UDT. If humanure is to be made within a community, it should be at a central point, after the method and technique have been perfected, and carried out by trained personnel. There is not much room for error, as incorrect methods may have negative knock-on effects on human health and lead to the outbreak of food-borne illness and disease, as evidenced by the case study of the German E.coli outbreak, discussed in Chapter two.

5.2.3. Food Safety

Vegetables were grown in trial gardens to gauge the difference between plants grown with and without humanure. The resultant produce was tested to certain bacteria and pathogens in order to assess the safety of the vegetables as minimally processed food. It is of extreme importance to test fresh vegetable produce for the presence indicator bacteria (WHO, n.d.). Many of the vegetables, from both the applied and control trials, tested positive for certain bacteria, all of which were more than the recommended microbiological limit for food safety, for minimally processed foods. According Abadias *et* al (2008:122), "fresh produce can be a vehicle for the transmission of bacterial, parasitic and viral pathogens capable of causing human illness and a number of reports refer to raw vegetables harbouring potential foodborne pathogens."

The implication of this is that humanure should not be used to grow minimally processed foods for human consumption, as food borne illnesses are a great risk. Food borne illnesses can potentially be devastating, and lead to death, as illustrated by the case study on E.coli contamination of fresh vegetable produce in Germany (Sample, 2011; Curta, 2011; Bronst, 2011, Sapa-AP, 2011), discussed in Chapter two of this study. Further research may be conducted to investigate the levels of indicator bacteria and pathogens in cooked or processed food.

Growing vegetables with humanure resulted in a definite and visible improvement in yield, plant health and appearance. Some of the plants grown without humanure wilted before bearing any fruit or growing any roots or leaves; whilst the same plants grown with humanure thrived in comparison. Humanure, if not made or prepared in accordance with recommended techniques can be dangerous for food production. It definitely has the ability to improve food security; however, much improvement in methods and techniques is needed. Alternatively, whilst these are being modified, humanure may be used to grow ornamentals, manure crops and cover crop, as there is definite proof that humanure improves plant growth.

5.3. Recommendations

This study has illustrated the potential of humanure to improve food security at a household level, dispose of human excrement in a non-hazardous manner, as well as conserve water. Further research needs to be done to perfect the method and technique of making humanure, in order to ensure that it is safe to grow food crops on it, and so that it will not lead to food-borne disease outbreaks. However, until such time, humanure may be used to grow ornamental plants and trees, for which there is a large demand; as well as manure or cover crops. Cover crops reduced the rate of soil erosion, and as a result, land degradation, adding another positive to the use of humanure.

The negative attitude towards any type of sanitation system other than flush toilets needs to be addressed. Flush toilets are viewed as a preferential amenity, thus reflecting treatment as either a ‘first’ or ‘second’ class citizen. This is problematic, especially when viewed within the context of South Africa’s past. People have been made to feel inferior based on their race group. It seems that people continue to feel this way, only now due to their socio-economic standing. This issue needs to be addressed as it is not a case of one system being reserved for a certain group of people. Topography, infrastructure, water availability and cost are deciding factors.

Gauging from the social acceptability study, UDT's do not seem to be the preferred sanitation system. This may be attributed to the lack of understanding on how to properly use these toilets, associated negative perceptions and general dislike of the system. Incorrect use of the UDT will result in unpleasant odours emanating from the vault. Ensuring that people are taught how to properly use and manage a UDT system should alleviate many of the problems that are associated with the system.

The taboo that society has attached to human excrement is a definite limiting factor to the UDT system, as well as the use of humanure. People do not want to deal with their excrement, it is viewed as dirty and of no value; a highly sensitive issue that should not be handled. Unfortunately, this approach is not realistic. As Jenkins (2005) states:

> "It is ironic that humans have ignored one waste issue that all of us contribute to each and every day — an environmental problem that has stalked our species from our genesis, and which will accompany us to our extinction. Perhaps one reason we have taken such a head-in-the-sand approach to the recycling of human excrement is because we can't even talk about it."

Efforts should be made to change the status of human excrement from 'taboo' to acceptable, especially since it is an issue that every single person contributes to on this earth.

The period of time that humanure is allowed to moulder for is an important factor which influences the quality and safety of the end product. This was evident in the two batches of humanure that were produced, and the resultant levels of bacteria and pathogen present in vegetable samples grown in each batch. It is strongly recommended that humanure be allowed to moulder for a minimum period of 1 year. The longer, the better.

This study tested the safety of minimally processed foods only. Further research should be conducted on the effect of processing the vegetable samples, through cooking, in order to determine food safety as not all vegetables grown with humanure are consumed as minimally processed or raw food.

The perceptions and attitudes of people may only be altered once they have been properly made aware of the benefits of alternate sanitation systems. If people are schooled on the proper method of operating and maintaining a UDT system, many problems and negative views associated with the system may be alleviated. Furthermore, the process of making humanure could drastically improve, as human excrement will be treated in the correct manner, with appropriate materials only being added to the vault.

5.4. Conclusion

This dissertation has assessed the sustainability and viability of the use of humanure for household agriculture. The focus of the study was to determine community perception about the use of humanure; the process of making humanure; food safety status of crops grown with humanure and an overall assessment of whether growing crops with humanure resulted in a marked difference in plant health and growth.

Through investigation of the above objectives, it was determined that the community perception of the use of humanure was not collectively negative, with a significant percentage of the community displaying either acceptance or willingness to accept humanure as compost for their home gardens. This was a definite positive in favour of this research, as negative perceptions may be altered through education.

The process of making humanure was explored, with two separate batches of humanure being made, using the aerobic, thermophilic method. This method of composting allowed heat cycles to occur within the compost pile, with temperatures reaching thermophilic levels, which are ideal conditions for the activation of essential microbes and the elimination of most harmful bacteria and pathogens. Furthermore, with the use of aerobic composting as opposed to anaerobic composting systems, the emission of green-house gases such as methane was eliminated. Each batch of humanure was left to moulder and mineralise for different time periods, to investigate the value and necessity of a mouldering period. Results indicate that the longer humanure is left to moulder, the safer the humanure is for use in food gardens. A minimum mouldering time period of more than 12 months must be observed for a superior end product. Results indicate a higher level of produce contamination in produce grown with the addition of humanure with a reduced mouldering period. This is indicative of a need for a significant mouldering period.

The determined safety levels of food crops grown with the addition of humanure were the crux of this research. Food crops need to be grown in clean and safe conditions, to ensure that human health is not compromised in any way. Food borne illnesses and diseases are easily contracted through the ingestion of contaminated food, and can prove to be fatal, as has been the case previously. It is a matter that cannot be taken lightly, with a zero risk attitude being adopted. It is for this reason, despite there being evidence of the beneficial use of humanure, that the recommendation of this study is that humanure should not be used for food crops until its safety is confirmed beyond doubt.

Although there is great potential for humanure to increase food security in peri-urban and rural areas whilst targeting the problem of sanitation and waste disposal, the system needs to be researched and refined. The garden trial that was conducted as part of this research demonstrated two ways of having and maintaining food gardens in a limited space. This targeted one of the main issues regarding food security, as people and households do not have ample place to develop gardens. Through the use of tyres, space is maximised and gardens may be grown.

This research has the potential to target many of the key issues society faces, but further and more intensive investigation needs to be conducted to refine processes and help educate people on alternative practices that will aid in improving their quality of life and lead to socio-economic improvement.

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Appendix

SCHOOL OF AGRICULTURAL, EARTH AND ENVIRONMENTAL SCIENCES

UNIVERSITY OF KWAZULU-NATAL

COMMUNITY PERCEPTION OF COMPOSTING HUMAN WASTE FOR AGRICULTURAL PURPOSES SURVEY

1. FAMILY MEMBER CHARACTERISTICS

Family Members	**Relation to household head**	**Age**	**Gender**	**Marital Status**	**Monthly income**	**Employment Status**	**Place of Employment**	**Education**
Person 1	Head							
Person 2								
Person 3								
Person 4								
Person 5								
Person 6								

Codes:

1.Relation to Head
1. Head
2. Spouse of Head
3. Married Child
4. Spouse of Married Child
5. Unmarried Child
6. Grandchild
7. Father
8. Mother
9. Father-in-law
10.Mother-in-law
11.Sister-in-law
12.Brother-in-law
13.Other relative

2.Age
1.5-14
2.15-24
3.25-34
4.35-44
5.45-54
6.55-64
7.65-74
8.75+

3.Gender
1.Male
2.Female

4.Marital Status
1.Currently Married
2.Single (Never married)
3.Widowed
4.Divorced
5.Separated
6.Abandoned
7.SingleParent

5.Income
1. <300
2. 300-499
3. 500-699
4. 700-899
5. 900-1099
6. 1100-1299
7. 1300-1499
8. 1500-1699
9. 1700-1899
10.1900-2099
11.Other (state)

6.Employment Status

1.Professional
2.Technical
3.Managerial
4.Clerical
5.Sales
6.Crafsman
7.Labourer
8.Retired/pensioner
9.Housewife
10.Unemployed
11.Selfemployed
12.Other (specify)

7. Highest Education

1.No formal education
2.Nursery
3.Pre-school
4.Primary
5.Secondary
6.Tertiary

2. DWELLING

2.1. Type	1) Brick & tile	2) Informal	3) Other
2.2. Living Space	1) Room	2) Rooms	3) Other
2.3. Housing Condition	1) Good	2)Satisfactory	3) Poor
2.4. Housing Environment	1) Clean	2) Moderate	3) Dirty
2.5. Is dwelling convenient for needs?	**YES**		**NO**
2.5.1. If no, what would you change if given the choice?			
2.6. Is dwelling convenient for all weather?	**YES**		**NO**
2.6.1. If no, what problems do you experience?			

3. WATER

3.1. Source of Drinking Water	1)Tap (public/private)	2) Tank	3) River/stream	4) Other
3.2.Water Storage	1) No Applicable	2) Tank	3) Other	
3.3. Distance to nearest water source	1)Not Applicable		2) (Metre)	
3.4. Persons carrying water to home	1) Not Applicable		2)	

4. SANITATION - Household Level:

4.1. Toilet Type	1) Flush	2) Urine Diversion (UD)	3) Ventilated Improved Pit (VIP)	4) Other
4.2. Availability of Public Toilet	**YES**		**NO**	

<table>
<tr><td>4.3. If yes, above give distance per toilet (metre)</td><td colspan="30"></td></tr>
<tr><td rowspan="2">4.4. If your household has a UD, is it used by all members of your household?</td><td colspan="15">YES</td><td colspan="15">NO</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td>4.4.1. If no, what facilities do these household members use?</td><td colspan="30"></td></tr>
<tr><td rowspan="2">4.5. Do all the members of your household know how to properly use a UD?</td><td colspan="15">YES</td><td colspan="15">NO</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td rowspan="2">4.6. Are all the members of you household comfortable with using a UD?</td><td colspan="15">YES</td><td colspan="15">NO</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td>4.6.1. If no, why not?</td><td colspan="30"></td></tr>
<tr><td rowspan="2">4.6.2. Was your household consulted on the implementation of the UD system?</td><td colspan="15">YES</td><td colspan="15">NO</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td rowspan="2">4.7. When the UD was installed, were you and members of your household taught how to properly use a UD?</td><td colspan="15">YES</td><td colspan="15">NO</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td rowspan="2">4.7.1. If yes, did you understand what you were taught?</td><td colspan="15">YES</td><td colspan="15">NO</td></tr>
<tr><td colspan="15"></td><td colspan="15"></td></tr>
<tr><td>4.7.2. By who were you taught and</td><td colspan="30"></td></tr>
<tr><td>4.8. What type of material do the people in your household put into the UD?</td><td colspan="6">1) Human waste</td><td colspan="6">2) Paper</td><td colspan="6">3) Plastic</td><td colspan="6">4) Sanitary items</td><td colspan="6">5) Other</td></tr>
<tr><td>4.9. What does your household do with the waste from the vaults once they are full?</td><td colspan="10">1) Nothing</td><td colspan="10">2) Dispose of the waste</td><td colspan="10">3) Other</td></tr>
<tr><td>4.9.1. If option b was chosen, where is the waste disposed of?</td><td colspan="30"></td></tr>
</table>

5. HOUSEHOLD KNOWLEDGE

	YES	NO
5.1. Do you know what compost is?		
5.1.1. If Yes, what is it?		
5.2. Do you know what humanure is?	**YES**	**NO**
5.2.1. If Yes, what is it?		

6. **HOUSEHOLD SUBSISTENCE AGRICLUTURAL ACTIVITIES**

6.1. Does your household grow its own vegetables?	**YES**		**NO**	
6.1.1. If yes, does the household apply compost to the soil?	**YES**		**NO**	
6.1.2. If yes, what types of vegetables does your household grow?				
6.2. What is done with the vegetables that are grown?	1) Consumed within the household	2) Traded or shared with other households	3) Sold for cash	4) Other
6.3. What compost is applied to the soil?	1) Chemical fertilizer	2) Organic fertilizer	3) Other	
6.4. How much does the compost used cost?	1) R10 – R50	2) R51 – R100	3) R101 – R150	4) Other
6.5. What is the condition of your soil?	1) Productive (fertile)	2) Unproductive	3) A mix of 'a' and 'b'	4) Other

7. **HOUSEHOLD PERCEPTIONS**

7.1. Are you aware that compost may be produced from the waste in the UD vaults?	**YES**		**NO**	
7.1.1. If yes, what type of waste from the UD is used?	1) Urine	2) Faeces	3) Tissue paper	4) Other
7.2. Would you be willing to use this type of compost on your crops?	**YES**		**NO**	
7.2.1.If no, why not?				
7.3. Are you aware that humanure could impact negatively on your health, if not produced properly?	**YES**		**NO**	
7.3.1. What health impacts do you think humanure could have on your health	1)Vomiting	2) Diarrhea	3) No impact	4) Other
7.4. Are you aware that humanure can enrich your soil?	**YES**		**NO**	
7.4.1. If yes, what do you think humanure adds to your soil?	1) Organic matter	2) Nutrients	3) Increase water holding capaeThekwini Municipality	4) Other
7.5. Are you aware that humanure can increase your crop yields?	**YES**		**NO**	
7.5.1. If yes, why do you think humanure can increase your crop yields?				
7.6. Are you aware that through the application of humanure, your socio-economic status can be enhanced?	**YES**		**NO**	
7.6.1. How do you think your socio-economic status can be enhanced?	1) Save money from not purchasing produce	2) Earn money from selling or trading produce	3) Other	

Ethical Clearance Letter

UNIVERSITY OF
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7 October 2011

Ms V Harilal (207504882)
School of Environmental Science

Dear Ms Harilal

PROTOCOL REFERENCE NUMBER: HSS/0958/011M
PROJECT TITLE: An assessment of the viability and sustainability of the use of humanure for household and agricultural practices. A Case Study in Cottonlands, eThekwini Municipality.

In response to your application dated 4 October 2011, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.
PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Professor Steven Collings (Chair)
Humanities & Social Science Research Ethics Committee

cc Supervisor – Mr J Lutchmiah
cc Mrs. S van der Westhuizen

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