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SUSTAINABLE DISPOSAL AND POTENTIAL REUSE OF GREYWATER PRODUCED AT HOUSEHOLDS IN INFORMAL SETTLEMENTS: A CASE STUDY OF MONWABISI PARK, CAPE TOWN, SOUTH AFRICA

BY

SIMAMNKELE LUVO MAGABA

(2017034721)

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Supervisor: Dr Ntokozo M. Malaza

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DECLARATION

I, Simamnkele Luvo Magaba, hereby declare that the content of this thesis for the Master of Environmental Management represents my own work unless otherwise stated or acknowledged. This dissertation/research project and report has not previously been submitted for assessment or completion to another University or for other postgraduate qualification.

Signature:  **Date: June 2020**

Simamnkele Luvo Magaba

ABSTRACT

The disposal of greywater is a challenge for informal settlements that do not have a reticulation system to collect the wastewater stream. However, studies have proved that there are some benefits associated with the reuse of greywater. The reuse of greywater around the household is a benefit because the demand for fresh water is reduced and also there is a necessity associated with sustainable disposal of greywater which will prevent environmental health risks. The former is attached to the protection of clean water resources while the latter acts as a preventive mechanism in sustainable water resource management. Greywater effluent can provide a platform as a resource in household uses that do not necessary require the use of freshwater. The term, sustainability in the context of the current study, not only incorporates the minimal use of scarce drinking water resources, but considering recent drought conditions, lowering the use of clean water also entails having to properly dispose wastewater (greywater) to prevent environmental health conditions. This is associated with the accumulation of wastewater effluent and the protection of aquifers/ underground water resources from being contaminated by greywater effluent that infiltrates the ground. Hence, it is by far a crucial topic that needs to be investigated in the absence of proper management mechanisms and facilities when it comes to informal settlements compared to its counterpart, being the formal settlements.

The study has administered semi-structured survey questionnaires to the residents of Monwabisi Park community through an interview process during the field visits. A total number of 69 questionnaires were administered and the respondents of the ages between 18 to 70 years. From this sample population, 51 % were female and 49 % were male. This process has also allowed the research to be able to get a deeper meaning behind the responses of the respondents. Apart from covering matters pertaining to water access, sanitation, and deducing the sources of greywater effluent in the households of informal settlements, the questionnaire has addressed greywater management in which the perceptions towards reused, recycling and sustainable disposal of greywater effluent were investigated. The disadvantages of greywater reuse from the community were also investigated and matters concerning environmental health implications, especially those concerning children in which grey water pondering may results in nuisance and diseases. The data collected was then analysed in which statistical and graphical representations were performed.

The data analysed also included the perceptions of the community towards the sustainable disposal and potential reuse of greywater produced in each household were elucidated. The analysis of the data have revealed an unstable and multifaceted relationship between unemployment and educational levels. Both unemployed and less educated respondents demonstrated lack of knowledge and interest in the reuse and sustainable disposal of greywater effluent. Though other respondents revealed that they do use greywater, there is a huge deal of environmental education that is necessary in changing the communities' perceptions.

The study has found that the community's perceptions need to be changed through educational initiatives that will make the community realize these benefits which will provide positive feedback in the promotion of greywater reuse and sustainable disposal aspects for informal settlements. The community of informal settlements are high risks in that they must be aware of not only the benefits, but also the disadvantages of unmanaged greywater and its implications to their health and surrounding environment. The residents who currently use greywater need to be well informed about which types of greywater to use and to what extent they can use it. Thus, this current research presents the findings and the assessment of the objectives set for the study pertaining the sustainable disposal and potential reuse of greywater produced in the households of Monwabisi Park informal settlement.

Key words: *Greywater*[1]*, Households, Reuse, Sustainable disposal, Informal Settlements.*

[1] The words, wastewater, domestic wastewater and greywater are used interchangeably.

DEDICATION

To my late father, Mzikayise Patrick Kakana.

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To God, be the Glory.

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ABBREVIATION	EXPLANATION
AIDS	Acquired Immunodeficiency Syndrome
BOD	Biochemical oxygen demand (5 day)
CoCT	City of Cape Town
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
GAC	Granular Activated Carbon
HIV	Human Immunodeficiency Virus
IS	Informal Settlement
ODTP	Organisational Development and Transformation Plan
SA	South Africa
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UV	Ultraviolet
VPUU	Violence Prevention through Urban Upgrading
HH	Household(s)
PFTs	Portable flush toilets

CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1 Introduction

One of the most crucial aspects of a democratic South African government is the provision of basic services as highlighted by the constitutions, 'everyone has the right to have access to sufficient food and water (Republic of South Africa, 1996). This is through the National Water Act (Republic of South Africa, 1998) which promotes the provision of water as a basic service, including providing equitable access to water resources. The Water Service Act (Act No. 108 of 1997) also provides for the rights of access to basic water supply and basic sanitation. Hence, there are extensive laws and legislations that caters for the provision of water as a constitutional right. Much focus and resources still have been invested to provide water to a number of areas that still lack access to clean drinking water. Local authorities are still faced with the challenge of meeting targets in terms of providing water services to disadvantaged communities, especially informal settlements. However, what is lacking though is the development of laws pertaining to greywater management in these types of settlements. There is no provision from a legislative perspective that gives strategic guidance on how to deal with greywater challenges. Owing to this, the research has established a theoretical context that will assist in ways to solving the problem at hand.

The lack of laws with regards to the disposal and reuse (management) of greywater has resulted in a number of challenges faced predominantly by rural communities and informal settlements residents. There is a need to find sustainable greywater disposal ways and reuse options in informal settlements that lack water based engineering services. Informal settlements are areas where residents have illegally invaded vacant land in which there are shortages of basic engineering services particularly to provide a connection into the reticulation system (Carden *et al.,* 2007b). Thus, the greywater generated is often disposed-off by just throwing the water outside their houses. The greywater management issue in most densely populated informal settlements of South Africa is a challenge, which pose significant health and environmental risks to its residents (Carden *et al.,* 2007b).

The informal settlement of Monwabisi park is what Carden *et al*. (2007c), refer to as a 'non-sewered area' due to the absence of water based sanitation facilities in the area. It is for this reason that the starting point for this research is to classify the sources of greywater in the household for domestic use. The greywater from households predominantly comes from the kitchen, baths, laundry and washing basins. The quality of greywater is further characterised by chemical, physical, biological, nutrients, ground elements and heavy metal properties (Edwin *et al.,* 2014). Such aspects require that the greywater be disposed of properly and to explore any possible treatment options that can facilitate reuse which can be adopted to reduce water demand, health and environmental challenges.

In brief, for every clean drinking water provided per household has several wastewater outcomes which includes greywater as a result of daily domestic use. According to Ludwig (1997), greywater is the wastewater that is produced from household processes (e.g. washing kitchen utensils, laundry and bathing) excluding any input from toilets. Thus, the definition of greywater and various sources of greywater generated through domestic use in households has been highlighted. These are of importance so as to establish a baseline for the potential reuse of greywater sources in the study. Greywater management options is dependent on the amount of greywater effluent in the study produced by each household. The physical or locational settings also the type of settlement, because dense settlements need to dispose of greywater to a designated disposal facility away from the settlement as there are high health and environmental risks associate with greywater effluent.

The classification of greywater will also help to deduce the least contaminated greywater source found in the household which can be reused immediately without treatment. Greywater has several benefits around the household which includes irrigation of gardens, and the flushing of toilets. Ultimately the reuse of greywater benefits the environment in that there is less pressure put on providing clean drinking water and thus, this narrative supports sustainable development thinking. This case study has provided baseline information to come up with suitable ways of disposing greywater and also provided ways in which greywater can be reused in and around the household thus, implementing an effective greywater management baseline system that speaks to a household in the area is important. In literature, studies have demonstrated a number of other ways that the reuse of greywater has in the household with particular applications in cleaning, flushing, domestic gardens and smallholding farming, which has the benefits of nutrient recovery when greywater is used for irrigation purposes in a controlled environment.

1.2 Defining Greywater

There are a number of words in literature that are synonyms to greywater which are greywater, sullage and light wastewater all referring to the same thing. Household level greywater consists of water sourced from bathing in: bathtubs and showers; handwashing basins; laundry basins, machines and tubs; and floor cleaning wastewater but excludes water from the toilet (Jordan, 2006). In some countries they exclude wastewater that originates from the kitchens (Rodda *et al.,* 2010). The word "greywater" refers to untreated household wastewater, which doesn't consist of any contaminations of toilet waste (Jordan, 2006). Domestic wastewater is usually divided into two categories which are black water and greywater, and Rodda *et al.,* (2010), added a third category which is yellow water.

Black water is the water that originates from the toilet which has been contaminated by faecal waste coliform and possesses several high organic content. This water consists of potentially pathogenic microorganisms with a blackish colour and a foul smell (Al-Joyyousi, 2003). On the other hand, greywater is wastewater which is a result of daily household activities which is collected from hand basins, showers, baths, washing machines and kitchen sinks but it excludes water collected from toilets, thus any wash water that has been used in a household is greywater (Ludwing, 1997).

From a broader perspective of domestic wastewater, greywater is characterised by low concentrations of organic matter and nutrients compared to the former, although the rate of heavy metals has been found to be in the same scale (Carden *et al.,* 2007c). Consequently, the greywater generated that is of better quality can be used appropriately for purposes that do not necessary require clean drinking water within the household such as flushing a toilet (Ilemobade *et al.,* 2010).

Yellow water is a waste streams that consist of urine. Though it is not collected separately from black water unless a separate collection system has been installed, usually where a form of urine diversion system is in place. This wastewater system is characteriesd by high concentrations of nitrogen and phosphorus, but low concentrations of micro organisms as it is consists of urine. In the event that there is suitably system which collected the wastewater separate from black water, the yellow water collected can then be utilized as a nutient suppliment for agricultural purposed (Ilemobade *et al.,* 2010).

1.3 Problem Statement

The disposal of greywater is a serious issue for non-sewed informal settlements. The greywater generated needs to be classified first, as there are a variety of sources in informal settlements. This is because such areas are normally characterized by poor or low levels of water based engineering services. The absence of water based engineering services makes greywater disposal a critical issue. This is because, it is subjected to health and environmental degradation challenges associated with lack of proper ways to manage and dispose this kind of effluent waste stream, as there aren't sustainable ways of managing of any wastewater. As it stands, there are few facilities that can collect the majority of wastewater in particular greywater effluent from daily household activities in the area. Thus, the types of greywater around the household needs to be classified to find suitable greywater effluent that have a potential to be reused while the other unsuitable ones can be safely disposed. Furthermore, an innovative and costs effective treatment technologies for greywater produced in household in informal settlements needs to be investigated and thus proposed. Presently, there is no clear solution that could be used but nonetheless, it needs to be developed and to get buy-in by the community, thus involvement of them is crucial. Consequently, the study seeks to determine sustainable ways for the disposal of greywater effluent while reusing some of it. This will in turn reduce the pressure put on the provision of clean water while promoting water conservation especially with Cape Town having experienced severe drought conditions recently.

1.4 Research Questions

The main research questions in this study are:

1. What are the main sources of greywater generated at households in the informal settlement?
2. What is the volume of greywater produced per household?
3. How does the residents dispose of the greywater type generated within the household?
4. How can greywater be sustainably reused in the households of informal settlements for domestic purposes?

5. What are the potential impacts of unmanaged greywater disposal on the surrounding environment?

1.5 Research Aim

The aim of this project is to investigate the sustainable disposal and potential reuse of greywater produced at households in informal settlements in Monwabisi Park, Cape Town, South Africa.

1.6 Specific Objectives

The specific objectives are:

- To classify greywater produced from the different domestic purposes around the household.
- To assess sustainable disposal of each type of greywater by identifying the least contaminated greywater source around the household.
- To determine potential reuse of greywater in and around the household to prevent environmental health hazards while promoting water conservation.

1.7 Location of the Study

The study area for the current research project is the Monwabisi Park informal settlement formerly known as Endlovini. This area is located at the greater Khayelitsha, a peri-urban township found in the Southern East part in the City of Cape Town. Khayelitsha was formed in 1984 when apartheid laws were slowly losing power in which subsequently allowed for a huge number of black migrant workers to the urban landscape (Herries *et al.,* 2009). Monwabisi Park is one of the 215 (with 379 pockets) informal settlements out of the 534 areas of informality found in the City of Cape Town. This shanty town is found in area 2 of the organisational development and transformation plan (ODTP)/ area-based service delivery model in Sub council 10. This settlement has been further divided into four sections namely section A, B, C and M.

According to the 2011 census, the area can be divided into the following population groups and percentages: Black African amounts for 97.99%; Coloured amounts for 0.67%; Indian/Asian are 0.09%; and other is 1.19% (Statistics South Africa, 2011). Furthermore, the Monwabisi Park informal settlement has an estimated roof count of around 7 700 individual shacks which covers an area of 66.32 Ha (CoCT). Violence Prevention through Urban Upgrading (VPUU NPC), has maintained that Monwabisi Park has about 25 000 people of which 11% are children which is a bit higher than the estimated population (VPUU, 2006) of 19 253 people from the City's Human Settlement Directorate matrix (Social Justice Coalition, 2016).

To-date the area has been provided with 174 standpipes with 307 taps. The sanitation facilities of the area include predominantly about 360 pour flush, 866 portable flush toilets in individual households to 1361 distributed to crèches and few container toilets. This informal settlement is highly congested and pose a challenge when it comes to the provision of engineering services which will first require de-densification.

The provision of water services as a basic service is faced with several challenges which are centred around sustainable use and disposal of wastewater particularly for informal settlements. The current study area has very minimum reticulation connection for sewer as the toilets that are present in the area are pour flush, PFTs and Container which are not connected to a reticulation system. Though there are standpipes to provide water in the settlement, there are very few wastewater collection systems like gullies/drains which feeds into a reticulation system. These standpipes are installed at a communal basis where they are distributed throughout the settlement where 1 tap has a ratio of 25 households, the sanitation facilities distributed for this area has a pour flash toilet type as top structures which has conservancy tanks where the faecal matter is flushed to. These conservancy tanks are pumped over planned periodic time frame which is at best, 3 times a week.

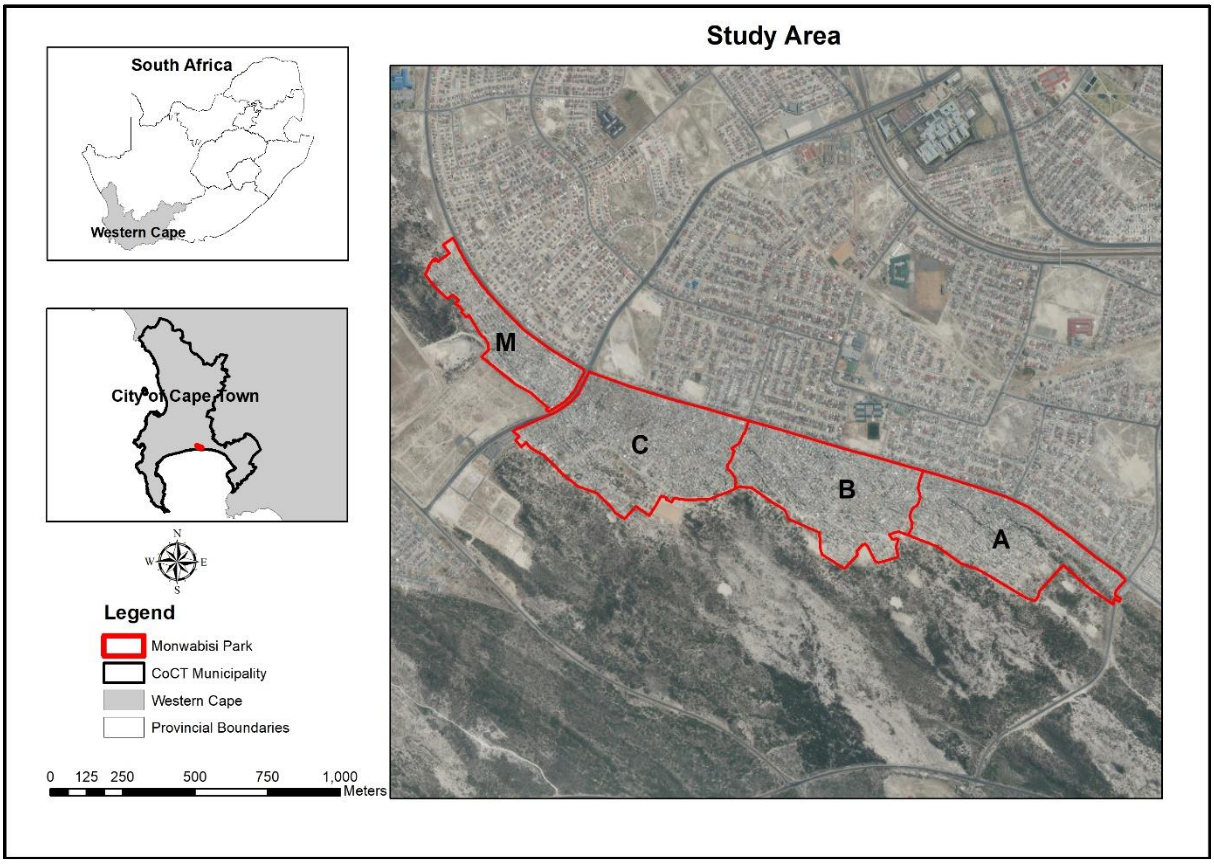

Figure 1:1: Monwabisi Park informal settlements located in Khayelitsha township, Cape Town.

1.8 Climate and Weather

Generally, climatic conditions of the City of Cape Town are considered to be of a Mediterranean climate that is characterised by winter rainfall and hot dry summers which are influenced by the cold Benguela Current and coastal winds. The City is also characterised by uneven temperatures due to surrounding mountains causing microclimates where some parts receive severely more rainfall than others. In general, the winter rainfalls are driven by cold fronts from the North-West Atlantic bearing heavy rain and strong winds (South African Weather Services, 2017).

The annual average rainfall is approximately 39 mm during June/July winter month. The lowest recorded temperatures are experiences during June (falling approximately below 10 degrees Celsius) for winter, while summer highest temperatures are recorded during January/February to up to 40 degrees Celsius (approximately an average of 25 to 28 degrees Celsius) in the January month. The average amount of annual precipitation is: 520.0 mm. Wind is unavoidable in the City of Cape Town as the period from November to April during the summer season gale force winds are usually recorded which can last up to 100 days each year particular in the ever-recorded Cape Peninsula region.

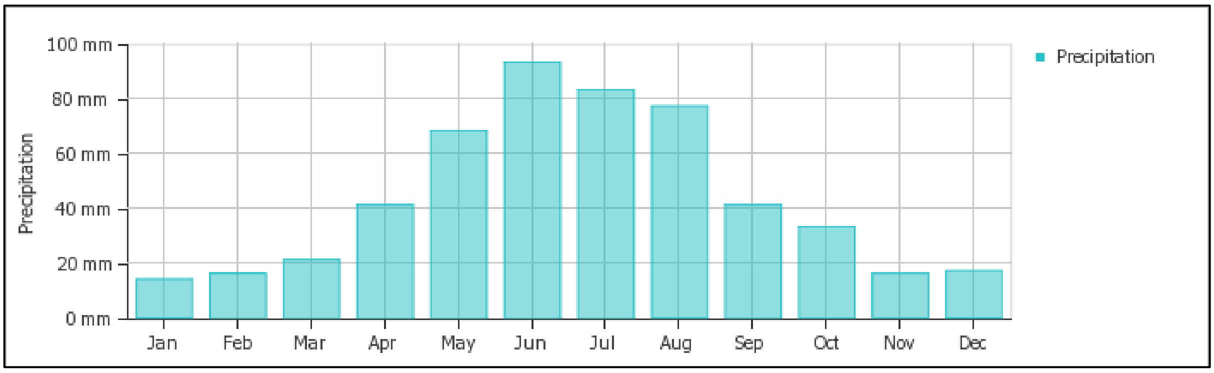

Figure 1:2: Average precipitation (rain/snow) vs months throughout the year in Cape Town, South Africa.

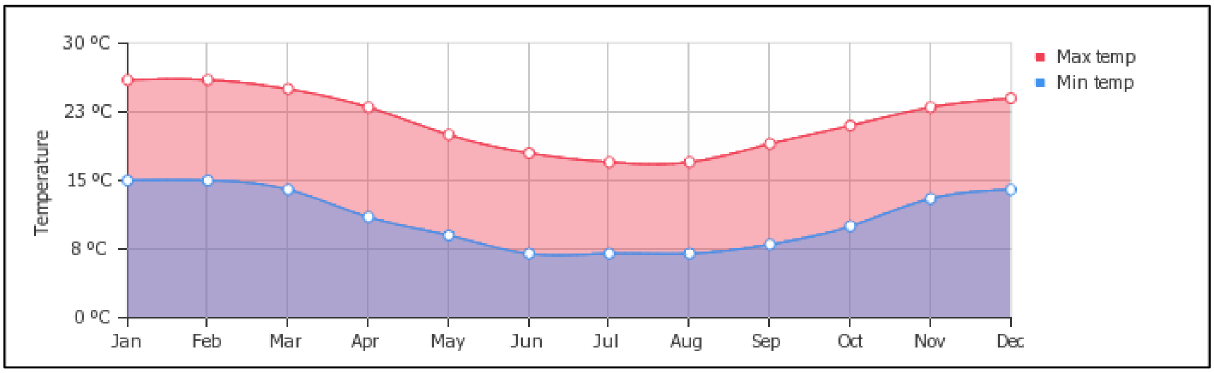

Figure 1:3: Average minimum and maximum temperature vs months throughout the year in Cape Town, South Africa.

1.9 Delineation of the Research

This research is limited to Monwabisi Park informal settlement which is located at Khayelitsha a peri-urban township found in the South Eastern part of the City of Cape Town Municipal region, in the Western Cape. The basic entity of this research was to investigate sustainable disposal and potential reuse of greywater produced at households for Monwabisi Park Informal Settlement which will reduce health and environmental risks.

1.10 Significance of the Research

The approach of this case study is to build up on the literature that exist in SA with regards to sustainable disposal and potential reuse of greywater effluent in informal settlements. Moreover, there are a few benefits that are associated with this project and they are:

- To provide sustainable disposal of greywater effluent.
- To provide guidelines for the disposal and reuse of greywater effluent.
- To reduce the possibility of water borne disease.
- To reduce environmental health risks and environmental degradation.

1.11 Research Limitations

The research has assessed sustainable disposal mechanism and potential reuse of greywater for Monwabisi Park informal settlement. This has presented concrete solutions to safely dispose greywater effluent for households including the reuse options for the greywater found in the area. The research did not include any sewer waste related matters. Furthermore, stormwater, soil texture and soil analysis related substances were also not dealt.

1.12 Summary

In this research, the general background of the study and literature, the problem statement and the research aims and objectives have been highlighted and research question have been stated. Furthermore, the significance of the study has also been highlighted and the research limitations have been indicated.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter review the literature outlining the background of relevant legislations pertaining to water, wastewater and thus greywater. Then the characteristics of greywater in terms of their general quality, the physical, chemical and microbial quality parameter will be reviewed. In line with the topic of the current study, the literature also covers aspects about the sustainable reuse of greywater in the household and its benefits, various sustainable greywater disposal mechanisms and treatment options. The topic of the reuse and treatment of greywater cannot be isolated from health and environmental considerations which the general ideas when it comes to such water will be covered in this chapter. Lastly this chapter end with the review of greywater management options.

2.2 Legislative Framework for Greywater in South Africa

Post-apartheid South Africa brought about the Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996). The Constitution of the Republic of South Africa is the basis of all laws in the country including environmental legislation and developmental social welfare. By virtue of this, it was adopted as the supreme law of the Republic and any other laws must be consistent with the constitution and those that are not are therefore simply invalid. The obligations imposed by it must be fulfilled. It is inclusive of the Bill of Rights, as chapter two and it provides a framework for government structures, roles and responsibilities. In the Bill of Rights, chapter two of the constitution, section 24 provides the duty of '*environmental'* protection, and stipulates that "Everyone has the right (a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that – I. Prevent pollution and ecological degradation; II. Promote conservation; and III. Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development". While section 27 provides the right to access to basic services 'health care, food, *water* and social security' and it stipulates that "(1) Everyone has the right to have access to (a) health care services, including reproductive health care; (b) sufficient food and water; and (c) social security, including, if they are unable to support themselves and their dependents, appropriate social assistance. (2) The state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of each of these rights. (3) No one may be refused emergency medical treatment" (RSA, 1996).

The two sections mentioned above gave effect to the Water Service Act (Act No 108 of 1997) and the National Water Act (Act No. 36 of 1998). Both of these acts are responsible for regulating matters pertaining to domestic water and sanitation services in the country in which they provide the legislative framework regarding water supply, sanitation services and water use (DWAF, 2005). In government structures the ministry of the Department of Water and Sanitation, is mandated by the constitution to allocate the management of water resources and reform of water laws from a national government standpoint through the National Water Act (36 of 1998). While the provision and management of water and sanitation services for everyone is given to local government through the Water Service Act (108 of 1997). Both acts are regulated by the Minister of Water and Sanitation (Republic of South Africa (RSA), 1998). At this point there is no distinct policy or act that specifically deals with greywater management. Mofokeng (2008), maintained that greywater is probably dealt with as part of general sewage and thus covered as such by policy, legislation and strategy. Consequently, such a standing is inadequate as only the City of Cape Town specifically has draft guidelines and Durban's EThekwini municipality has included greywater disposal as part of its business plan when it comes to the delivery of basic sanitation services as stated by Carden *et al*., (2007).

2.2.1 The National Water Act (Act No. 36 of 1998) (NWA)

The National Water Act (Act 36 of 1998) is the overall act that deals with regulating water use and disposal of water. Particularly from this act, there is no direct reference to greywater matters but its general principles mention 'waste[2] discharge, or water containing waste and disposal of waste' into a water resource. The use and disposal of such is subjected to controlled activities that requires an authorisation as listed in the act which is through issuing of a licence. The National Water Act of 1998, provides for the management of the natural water resources by ensuring that the nations' water resource base is protected, used, developed, conserved, managed and controlled in a sustainable manner to benefit all though,

[2] The National Water Act defines "waste" – 'includes any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted'.

- Meeting the basic human needs of present and future generations;
- Promoting equitable access to water;
- Promoting the efficient, sustainable and beneficial use of water in the public interest;
- Facilitating social and economic development;
- Providing for growing demand for water use;
- Reducing and preventing pollution and degradation of water resources;

This act recognises the need to protect the quality of water resources as a necessity to ensure sustainability of the nation's water resource. Chapter 3 of this act provides for the protection of water resources from pollution by taking all reasonable measures to cease, modify or control any act or process causing pollution and fosters compliance with waste standards or management practices. The Department of Water and Sanitation does endorse the reuse of greywater as indicated in section 3(1) which states that everyone has a right of access to basic water supply and basic sanitation. The strategic overview of the water sector promotes safe greywater reused in household level particularly with regards to irrigating food gardens, flowers and lawns as this will act as a water conservation aspect on the demand for portable/drinking water, provided that caution is exercised in preventing zero health and environmental pollution risks (DWA, 2013).

2.2.2 The Water Service Act (Act No. 108 of 1997)

The main objective of the Water Services Act (Act No 108 of 1997) in section 2(a) of the act is 'to provide for the right to access to basic water supply and the right to basic sanitation necessary to secure sufficient water and an environmental not harmful to human health or well-being. Moreover, this act basically focuses on the provision and/or distribution of water services (means water supply services and sanitation services) which have been provided by municipalities to individual households or communities and other municipal water users. Furthermore, the act contains rules about how municipalities should provide water supply and sanitation services. According to the act, sanitation services means 'the collection, removal, disposal or purification of human excreta, *domestic wastewater*, sewage and effluent resulting from the use of water'. Also, when this act defines basic sanitation "it means the prescribed minimum standard of services necessary for the safe, hygienic and adequate collection, removal, disposal or purification of human excreta, *domestic wastewater* and sewage from households, including informal households)". This includes domestic wastewater and sewage from households but not specific reference to greywater, therefore for this reason the aspect of greywater is considered to be within the context of this. Section 9 (1) of the act gives the minister of Water and Sanitation to prescribe compulsory national standards for (a) the provision of water services; (b) the quality of water taken from or discharged into any water services or water resource system; (c) the effective and sustainable use of water resources for water services; (d) the nature, operation, sustainability, operational efficiency and economic viability of water services; (e) requirements for persons who install and operate water services works; and (f) the construction and functioning of water services works and consumer installations.

2.2.3 Other Relevant Legislation, Policies and Strategies

With regards to special application to the issue of greywater, apart from there two acts there are other documents that have had the spirit of dealing with the greywater attributes in the country. These documents consist of the White Paper on Water Supply and Sanitation (1994), the White Paper on a National Water Policy of South Africa (1997); the White Paper on Basic Household Sanitation (2001); the Strategic Framework for Water services (2003), but to name a few. According to the White Paper on Water Supply and Sanitation (1994), basic adequate services are defined as portable water supply of 25 l/person/day within 200 m cartage distance, and a ventilated improved pit latrine.

The overall legislative requirements for water and sanitation services in South Africa are:

- White Paper on Water Supply and Sanitation (1994)
- The Constitution of the Republic of South Africa (Act No. 108 of 1996)
- White Paper on a National Water Policy of South Africa (1997)
- National Development Plan (NDP)
- National Environmental Management Act (Act No. 107 of 1998)
- The Housing Act (Act No. 107 of 1997)
- Water Service Act (Act No. 108 of 1997)
- National Water Act (Act No. 36 of 1998) and its amendment (Act No. 27 of 2014)
- Municipal Structures Act (Act No. 117 of 1998)

- Municipal Systems Act (Act No. 32 of 2000)
- National Water and Sanitation Act Amendment Bill
- White Paper on Basic Household Sanitation (2001)
- Compulsory National Standards for the Quality of Potable Water (2001)
- Strategic Framework for Water Services (2003)
- National Health Act (Act No. 61 of 2003)
- National Water Resources Strategy (2004)
- Framework for Drinking Water Quality in South Africa (2005)

2.3 Greywater Generation

2.3.1 Greywater Quantity (Volumes)

The amount of greywater that is produced by each household in terms of quantity will not be the same. This can be location based in that for informal settlement that uses communal taps/standpipes, a household near the tap will use more water than one that is further away from it (Hardy and Whittington-Jones, 2017). Furthermore, the number of people living in a household, the age structure of those occupants, their lifestyle characteristics, water-usage patterns (etc.) (Jordan, 2006) has an influence on the amount of water they use.

The amount of greywater generated in low-income communities per household is between 20 to 30 litres per person per day and if the tap is nearby or inside the house, this ratio increases and about 90 – 120 per person per day in sewered households (Morel and Diener, 2006). While Carden *et al.,* (2007c), conducted on-site surveys about water usage in informal settlements and found that they used about 4.7*l* to 28*l* per capita per day (*l*/c/d).

According to Carden *et al.,* (2007b), 75% of the total households water is disposed in some matter thus being greywater generated and the remaining 25% is entirely used for drinking and cooking in non-sewered settlement in South Africa. In the absence of water meter readers', surveys about water usage are necessary to account for the estimated amount of water used by households in an area for a case study research, although this cannot accurately reflect the total water drawn from the reticulation system including leaks, which are not being accounted for in this case.

The amount of greywater generated will also inform ways that the water can be sustainably disposed and reuse option that can be explored. Carden *et al*., (2007c) stated that it could be assumed that the greywater generated in households is from all water usages especially in a non-sewered informal settlement/ area except water lost to drinking and cooking purposes. Thus, the only water lost is the one used for cooking and drinking and the rest is wastewater in form of greywater effluent from informal settlements that do not have a reticulation system (Carden *et al.,* 2007c). Wood *et al*., (2001) noted that 'there is a general absence of data on the quantification of greywater effluent in dense informal settlements because generally lacks proper measurement of water services in these areas, and assumptions based on population estimates are indicative at best'.

2.3.2 Greywater Sources

Greywater is wastewater which is coming from everyday household activities from the bathroom, kitchen and laundry. Such greywater origins can also be further divided into two groups or classes (i.e. light greywater and dark greywater), which is based on the organic strength and levels of contaminants that are found in such water. *Dark greywater* is a combination of laundry first wash and wastewater from kitchen sinks. While *light greywater* generally includes laundry rinse wash, showers, hand basins and bath. The light greywater has lower concentrations of contaminants than black water and dark greywater (Jordan, 2006).

2.3.2.1 **Bathroom Greywater** (Hand Basin, shower, and bathtub)

The bathroom produces about 38% of the household wastewater flow, with the greywater volumes that are less contaminated accounting for an estimated 55% (may vary) amount of the total amount of greywater produced in a household. Many have supported that bathroom greywater is considered to be the least contaminated of all the greywater streams (Al-Joyyousi, 2003; Carden *et al*., 2007c; Abu Ghunmi, 2009). Particularly the water of bathrooms and showers greywater contains small amounts of soaps and shampoo as well as hair, skin, oil, faecal matter and urine, but can also contain residues of cleaning products. While wash basin greywater for brushing teeth, hand washing, and shaving may contain soap, toothpaste, mouthwash, hair and shaving cream as well as residues of cleaning products. Microbiologically, there are thermotolerant coliform concentrations that can be found in shower and bathwater as a result of people who urinated in them with a range of 10ˆ4 - 10ˆ6 cfu/100m/ which then increases the possibility of health-related disease especially when there are the traits of inappropriate disposal. The thermotolerant (or faecal) coliform levels of both showers and baths greywater which have been assessed has indicated that there is existence of pathogens and microorganisms though their amount is insignificant compared to black water and dark greywater. In general, this water is suitable for irrigation use although food items may need to be washed before cooking or consumption (Ng, 2004; Morel and Diener, 2006; Carden *et al.,* 2007c; Ilemobade *et al,.* 2010; Rodda *et al*., 2010;).

2.3.2.2 Laundry Greywater

The second largest amount of domestic wastewater is laundry effluent that accounts for 23% of household wastewater an estimated 34% of the total portion of greywater which may vary. The laundry water is from clothing washing basins or washing machines which contains traces of soaps, detergents, bleaches, fabric softeners, lint, dirt and small amounts of skin or faecal matter from clothes. This consists of high levels of chemicals from soaps, soap powders (which include high sodium content, phosphorus, nitrogen, boron and surfactants), bleaches (Chlorine etc.), suspended solids, non-biodegradable fibres from clothes, and possibly oils, paints, soil, and other solvents and thus making the chemical oxygen demand (COD) to be very high. Also, there may be faecal pathogens in households with infants when washing nappies, thus having possible bacteria, including thermotolerant coliforms, making the microbial load to be high. However, in certain households this may not be present of the laundry being done at the point in time, thus vary with the nature of the items being washed.

Greywater from the laundry is of two-fold as it consists of the first wash water usually considered as dark greywater and rinse wash which is considered as light greywater. The former may not be suitable for long term reuse for activities like irrigating small scale agriculture/ gardens as in consists of high level of suspended solids that are able to alter the composition of soil (Perret, 2002; Rodda *et al.,* 2010). The latter is considered to be light strength and can be used for a variety of reuse applications. Nevertheless, recently there are many detergents produced that have become biodegradable and safe to the environment. In a controlled environment, this water is suitable for irrigation use if the detergent used in that household is biodegradable (Ng, 2004; Morel and Diener, 2006; Rodda *et al.,* 2010).

2.3.2.3 Kitchen Greywater

The third portion of greywater that originates from the kitchen is said to be an estimated 11% of the total wastewater volume that is being produced in household. The kitchen greywater from sink or dishwasher greywater is heavily polluted physically than black water or raw sewage as it supports the growth of micro-organisms coming from food particles, oil and fats. Generally, this water may contain soap, detergents, grease, oils, blood, small traces of pesticides and food scraps. The food particles and other materials can solidify causing blockages and clogging in the collection systems as we all know sinks in sewered households often gets blocked and thus such water needs to be treated or removed from mixing with other greywater sources. This greywater is very high in nutrients level and suspended solids and may also contain bacteria from food sources.

Microbiologically, this wastewater is extremely high in the level of thermotolerant coliform which can result in the transmission of diseases. As a result, this water waste stream needs to be managed effectively and preferable separately too. Furthermore, this wastewater is high also in chemical pollutants from detergents and cleaning agents as in dishwashers there is high pH value and high levels of suspended solids and salts. Clearly, it can be deduced that this wastewater sources can be harmful to soils and the natural environment as such elements have the capacity to change soil characteristics in a long term. Consequently, such wastewater should not be used for irrigation unless the water does not contain grease, blood, pesticides or oils (Ng, 2004; Morel and Diener, 2006; Carden *et al*., 2007c; Rodda *et al.,* 2010). Due to such reasons the kitchen greywater cannot be reused in poor settlements and informal settlements, it is sometimes not diverted to the sewer reticulation as there are high health and environmental risks including causing a foul smell when it is retained. Thus, kitchen water can never be reused without first being treated and can only be used after treatment. Fortunately, as it is produced in small quantities than the above greywater sources, it is recommented not to reuse it (Mofokeng, 2008).

Table 2.1 Domestic greywater generation in l/p/d in selected countries.

Sources	**Busser (2006)**	**Fiedler (2004)**	**Helvetas (2005)**	**www.greenhouse.gov.za.au**	**Martin (2005)**	**Wheatley and Surendran (2008)**		**Shrestha (1999)**	**Faruqui and Al-Jayyousi (2002)**
Country	Vietnam	Israel	Switzerland	Australia	Malaysia	UK		Nepal	Jordan
						University Hall	Domestic household		
Water source	**In-house taps**	**In-house taps**	**In-house taps**	**In-house taps**	**In-house taps**	**In-house taps**	**In-house taps**	**In-house taps**	**In-house taps**
Kitchen	15-20	30	28	17	-	-	-	-	-
Bath & Shower	30-60	55	52	62	-	46	34	-	-
Laundry	15-30	13	30	34	-	14	26	-	-
Wash basin	-	-	-	-	-	44	24	-	-
Total	80-110	98	110	113	225	104	84	72	30-50

Source: Ilemobade, et al., *2010.*

2.4 Greywater Characteristics

2.4.1 General Quality

The characteristics of greywater in households can vary over time and space. Moreover, Eriksson *et al.,* (2002) and Carden *et al.,* (2007c), maintained that the composition of greywater is affected by three significant factors: water supply quality, the use of the water for household activities and the condition of the mechanisms in which greywater is being carried from point of discharge. The quality of water that is required for irrigation and other nondrinking applications does not have to be the same quality as tap clean drinking water. The quality of greywater generated by each and every household is not the same, it is dependent of the activities of that particular household. In addition to this, the quality of greywater is determined by the source of the water (Table 2.1). The greywater from household sources consist of toothpaste, hair particles, bathing soaps, body oils, shaving gel and creams, body and hair shampoos contents, oils and grease, washing detergents, lint particles, dirt and dust particles, various materials of fats, the chemical substances of cosmetics, soaps, urine and faecal material from nappies (Jordan, 2006). The important pollutants to take noted in these are coming from laundry detergents which usually have high content of phosphorus, chloride and sodium. Moreover, greywater also can contain viruses, parasites, dead skin and coliform bacteria, washed from the body and clothes (i.e. underwear) (Health Department of Western Australia, 2012).

Table 2.2: Composition of quality determinants usually found on greywater.

Parameter	**Unit**	**Greywater range**
Suspended solids	mg/L	45-330
Turbidity	NTU	22-200
BOD5	mg/L	90-290
Nitrite	mg/L	< 0.1-0.8
Ammonia	mg/L	< 0.1-25.4
Total Kjeldahl nitrogen	mg/L	2.1-31.5
Total phosphorus	mg/L	0.6-27.3
Sulfate	mg/L	7.9-110
pH	-	6.6-8.7
Conductivity	mS/cm	325-1140
Sodium	mg/L	29-230

Source: Jordan, (2006).

Ludwing (1997) maintained that water quality is informed by physical, chemical and biological components. Physical quality includes turbidity (clarity of the water), temperature and the total suspended solids in the water. While, chemical quality includes pH (acidity or alkalinity of the water), chlorine (found in disinfectants in cleaning products), the amount of dissolved oxygen in the water and chemical oxygen demand (COD) – a measure of the amount of organic material in the water. And lastly, biological quality mainly relates to the presence of bacteria and viruses, and the presence of E. coli, which indicates the presence of faecal contamination and thus biological water quality (Ludwing, 1997).

Table 2.3: Possible constituents of greywater from various household sources.

Sources of greywater	Potential contents
Automatic clothes washer	Phosphates and nitrates (from detergent), suspended solids (dirt, lint), oil and grease, sodium, increased salinity and pH, bleach, and organic material.
Automatic dishwashers	Increase in salinity and pH, oil and grease, organic material and suspended solids (from food), detergent, bacteria, fat.
Bathtubs and showers, washing bath basins	Soap, organic material and suspended solids (skin, particles, lint), bacteria, oil and grease, hair and detergent residue.
Sinks, including kitchen	Detergent residue, grease and oil, soap material, bacteria, fats, organic matter and suspended solids (food particles).

Adopted from Jorden, 2016.

2.4.1.1 Physical Characteristics of Greywater

2.4.1.1.1 Turbidity

Greywater turbidity is produced as a result of the sources other than laundry sourced greywater which is generally between the range of 15.3 to 240 NTU (Erikson *et al.,* 2002). The values of turbidity that can be observed from laundry greywater are not always the same. They tend to vary extensively, where there is washing greywater consists of very high values of turbidity of around 39 – 296 compared to the low values of turbidity during rinse wash water of around 14 – 29 NTU (Erikson *et al.,* 2002). Moreover, the high turbidity values of the greywater basically reflect that there is also high concentration of suspended matter which is not suitable for long term irrigation as it may cause clogging to both the soil and the greywater conveying system (Weston, 1998). In a nutshell, the laundry greywater has been observed to have the highest values of turbidity amongst other greywater sources (Jefferson, 2008).

2.4.1.1.2 Temperature

The temperature of greywater effluent is not constant as it can range from 18 – 30 °C. The higher temperatures of greywater are associated with the use of warm water for personal hygiene and water discharged when cooking. For biological treatment to take place, the greywater does not need to have the high temperatures, although such temperatures increase microbiological growth and lower the decrease of CaCO3 solubility. This then can result in precipitation inside the storage tanks or the piping systems used (Eriksson *et al.,* 2002; Morel and Diener, 2006).

2.4.1.1.3 Total Suspended Solids

All greywater sources are bound to have suspended sources depending on their source. For kitchen greywater, there are particles from food, oil and soil particles, while in the laundry greywater there is hair or fibres from clothing and residues from soap powders, soaps, and other laundry detergents which can lead to an elevated amount of suspended solids in the greywater effluent. These contents of suspended solids in the greywater can lead to clogging of pipes, filters and pumps that are used in the collection of greywater for treatment purposes. The amount of suspended solids in the greywater also depends on the source of the water and has a range of 50 – 300 mg/l, which can increase up to 1 500 mg/l in isolated cases (Morel and Diener, 2006). It has been found that kitchen wastewater accounts for very high concentrations of suspended solids followed by laundry water (Jefferson, 2008), which explains why the former is often excluded as greywater in other countries as it will require extensive treatment techniques. The SS found in greywater can provide a surface area to which micro-organisms can attach, particularly in the case of organic solids such as food particles, this then may produce high strength wastewater that can have a foul smell when stored longer without any treatment.

2.4.1.2 Chemical Quality of Greywater

These are many different nutrients that are found in greywater which predominantly consists of nitrogen and phosphorus. According to Jordan (2006), a volume of 356 Litres per day of greywater will produce an estimated 45g of nitrogen and a 3g of phosphorus per day. Such nutrients found in the greywater can be of benefit for watering lawns and gardens around the household, which can reduce the need for fertilizers thus cutting costs. The chemical contaminants that are found in the greywater that originates from bathroom is due to shampoo, hair dyes, toothpastes and detergents. While the greywater that originates form laundry contains higher chemical concentrations from washing powders, soaps, jik and bleaches (laundry detergents) and clothes with mud and soil particles (ammonia, nitrogen, phosphate, sodium and boron); and the water can also be high on lint, chemical oxygen demand, suspend solids and turbidity. If this water is applied directly to some plants and the natural environment without being treated, it would result in a number of serious environmental damages that may have negative impacts on the general public health and welfare matters especially in poor communities such as informal settlements (Jordan, 2006).

In a study conducted by Jefferson, *et al.,* (2004), greywater collected from showers, baths and hand basins displayed similar biodegradable content as demonstrated by BOD5 levels of 146 ± 55, 129 ± 57 and 155 ± 49 mg/l respectively at a 76% confidence. Moreover, a lot of variability was also observed in terms of the non-biodegradable fractions as observed by the total COD levels of the same sources which accounted for 420 ± 245, 367 ± 246 and 587 ±370 mg/l. When comparing the two COD: BOD ratio which were generated were lower in the bathrooms' greywater with (2.9±1.3) and for shower samples the value was (2.8±1.0) and then 3.6±1.6) for hand basin. Thus, greywater is found to have very high concentrations of biodegradable organic materials, such as fats and oil from cooking, and also xenobiotic compounds and other residues that originates from soaps and detergents (Edwin *et al.,* 2014).

2.4.1.3 Microbial Quality of Greywater

The greywater content when it comes to the characteristics of microbial quality and composition is associated with the presence of faecal contaminants. This means that the water has hazardous conditions that can be introduced by cross-contamination of microbial content or organisms. Since toilet wastewater is not included as it is not greywater, the faecal contamination in this instance is reduced to activities such as the washing of clothes especially infants diapers or nappies which can have some level of faecal contamination and also bathing and showering (Jordan, 2006). Thus, greywater from households with children tend to consist of a high concentration of coliforms compared to homes without children (Edwin *et al.,* 2014). Common indicator organisms is one of the things that is used to measure the faecal contamination of greywater for instance the presence of bacterial coliforms and enterococci species (Ottoson and Stenstrom, 2003). The presence of *Eschericia coli*, *Salmonella* and other enteric organism in the water is directed to faecal contamination, the possible presence of intestinal pathogens or viruses, respectively. Faecal coliforms show pollution presences in the greywater effluent and may be used to assess the relative safety of reusing such water (Rose *et al.,* 1991; Ottosson, 2003).

Jorden (2006), maintained that the wastewater that originates from showers, handwashing basins and washing bath basins is usually known to be the least contaminated sources of greywater. Moreover, the thermotolerant bacterial levels in such water have been observed and found that they range from 10^2 to 10ˆ5 cfu/100 m*l* (Jordan, 2006). In general, the elevated portion of faecal content and matter is not wanted, and it also implies high risks and chances for causing and spreading human related illness that can develop as a result of being in contact with greywater reuse.

2.5 Greywater Reuse

2.5.1 Suitability of Greywater use within the Household

In a nutshell, greywater is wastewater generated from domestic activities around the household, excluding wastewater from the toilet. The greywater from the bathroom hand basin, shower and bath water have been noted to be most suitable to be used for irrigation purposes as it is considered to be the least contaminated. It is estimated that the reuse of greywater that originates from the bathroom alone is sufficient to meet onsite reuse requirements because of the light strength quality as it has low pollution load because most materials found in such laundry detergents can have high concentrations of biodegradable organic material. Considering this, there is about 28.5% reduced demand on portable water consumption (Edwin *et al.,* 2014). Moreover, the use of natural systems of treatment such as constructed wetlands are also recommended considering the low costs associated with less maintenance costs of this technology. The kitchen sink water may not be suitable for irrigation if it consists of grease, blood, pesticides or oils and thus has high concentration of pollution load. Such greywater source will require extensive treatment before being used. Any water content from the toilet is called black water and therefore it is not suitable for any reuse in or around the household (Rand water and van Staden, 2017). Thus, in order to alleviate the stress, put on clean water in developing countries, the least contaminated sources of household greywater should be prioritized for reuse (Edwin *et al.,* 2014)

2.5.2 Benefits of Greywater Reuse

There are various ways into which greywater can benefit occupants in a community such as the watering of vegetable or food gardens, lawn irrigation, washing cars, flushing of toilets, ornamental uses in fountains but to name a few (Wood *et al*., 2001; Uveges *et al.,* 2013). The greywater effluent in general for settlements is wasted as residents dispose it by just throwing it away because there is little knowledge about the reuse option open for it. Moreover, having to use greywater offset clean drinking water that would be used for these functions, thus conserving water as a precious scare resource (Ludwing, 1997). Consequently, water will remain in a balance state on our ecosystems. The benefits of using greywater should be stressed that they depend on the source, as greywater may contain small and varying amounts of nitrogen and phosphorus, which are potential sources of plant nutrients. The soapy nature of greywater can sometimes act as a pest repellent whereby it is reused in suitable plants. In essence greywater reuse saves portable water, thus recycling and reuse can make a significant contribution to the sustainability of available water resources (Parsons *et al.,* 2000; Jordan, 2006).

Jordan (2016) further elaborated that, 'the reuse of greywater as a resource can help in saving money spent by water bodies and authorities, lower the flow of sewage also significantly limits the demand on clean drinking water. To achieve this, the community will have to practice greywater reuse, which can also reduce the load on wastewater disposal systems. The lifespan of wastewater management and disposal plants which can be prolonged and the budget for both operational and capital funds in municipalities that is required for the upgrades and development of new systems is delayed. Thus, recycling and reuse can make a contribution to the sustainability of available water resources (Parsons *et al.,* 2000).

2.6 Greywater Disposal and Treatment

Particularly in informal settlements they are noted by ever increasing population growth which in turn increases water consumption and thus increases greywater production which results in environmental and health issues. Thus, the lack of a comprehensive system for the collection and the disposal of wastewater with the combined increase of water consumption has created widespread pollution related scenarios due to inadequate disposal of the greywater effluent. The only way wastewater is disposed locally in informal settlements is onto open grounds which then creates ponding of foul-smelling stagnant water (Parkinson and Tayler, 2003). Treated wastewater and/or greywater can also be used for firefighting, toilet flushing, cooling systems, street cleaning, dust control and a variety of applications that do not require portable water (Carden *et al.,* 2007c; Department of Water Affairs, 2013).

2.6.1 Low-cost options for Greywater Treatment

The treatment of any wastewater is important before the water can be disposed or reused. Greywater is no different as there needs to be prior treatment in order to reduce the content of pathogens. The level of treatment is determined by the disposal and the re-used options to be adopted for the greywater effluent. This is important in that, it provides for the protection against adverse impacts on the health of informal settlements residents, especially children and people with compromised immune systems and protects the natural environment (Parkinson and Tayler, 2003).

2.6.1.1 Simple Greywater Treatment Systems

Simple treatment systems are also known as systems that use primary diversion such as screen filters with coarse structures or sedimentation to remove oil matters, grease particles and other solids before they can be discharged or re-used (Jordan, 2006). The simple greywater treatment technologies are usually of two-fold. These are the coarse filtration or sedimentation stage that is used to removed larger solids from the greywater and then the disinfection process follows. Pidou *et al.*, (2007), maintained that these two systems are usually used to treat low strength greywater effluent collected form baths, showers and hand basin bacause of the limited treament they can achieve and subsequently, the water from this can be used to flush toilets and for garden watering. Coarse filteration only provides limited treatment of the greywater in terms of removing organics and solids system. It is most often prefered and selected to be the most viable in economic terms for filtering greywater to be reuse and its maintenance can be carried out at household level which can be used for watering gardens (Jordan, 2006). The disinfection process of inactivation of greywater pathogenic microorganisms is involved. This provides houselholds with the opportunity to reuse the treated greywater effluent for other domestic purposes that include flushing toilets and car washing and so on. There are various ways and protocols that shape the disinfection of greywater which can be handled and they are: bromine, hypochlorite, chloride, calcium, chlorine, ultraviolet and ozone radiation treatment (Darby *et al*., 1993; Jordan, 2006).

2.6.1.2 Physical Greywater Treatment

The physical systems for the treatment of greywater also known as secondary treatment systems, can be categorised into two sub-categories which are sand filters and membranes (Pidou *et al.,* 2007). Sand filters are a common filtration technique which is cost-efficient in that it is simple to operate and has low maintenance costs. The greywater is dosed onto the surface of the sand through a distribution network and is allowed to percolate through the sand to the underdrain system. This underdrain system then collects the filtrate for further processing, recycling, or discharging (USEPA, 2002). In a nutshell, this system basically consists of bed of sand or other media that treats greywater through physical filtration of contents found in the greywater or through bio-filtration which encompasses physical particulate separation, and the absorption and bio-degradation of soluble and particulate organic contaminants from the greywater (Edwin *et al*., 2014).

To prevent clogging, firstly the greywater must pass through a grease trap and sedimentation tank before passing through the sand filter. However, it must be noted that these types of filters do not totally eliminate the pathogens at this stage. Jefferson *et al*., (1999), pointed out that physical treatment processes such as sand filters, coagulation and flocculation processes produce an effluent quality better than primary sedimentation or storage tanks. Nevertheless, the previous approach "simple GW treatment" and the physical GW treatment requires a periodic discharge of primary sludge in order to stabilize and to prevent deterioration of the effluent quality with time (Abu Ghunmi, 2009), and both of these two types of systems achieve limited treatment of the different fractions present in the greywater (Pidou *et al.,* 2007).

On the other hand, Pidou *et al*., (2007), mentioned that treatment done though membranes provides very limited removal of organics; however, it provides for an excellent removal of the dissolved and suspended solids. The main issue when it comes to the operation of a system with membranes is fouling, which directly influences the operation of the entire system itself and the costs for maintenance as the membrane will require cleaning 'servicing'. Other measures to prevent fouling will be to pre-treat greywater through a sand filter. In a study done by Ward (2000) that provided a hybrid system of incorporating sand filtration, membrane and disinfection stages in the treatment of low strength greywater can produce good result with the outcome meeting the minimum / strictest standards for reuse (Pidou *et al.,* 2007).

2.6.1.3 Extensive Greywater treatment technologies

2.6.1.3.1 Waste Stabilization Ponds

Waste stabilization ponds are large, shallow basins designed to treat raw sewerage through natural processes that involve algae and bacteria. They are a combination of anaerobic ponds, facultative ponds that are a mixture of aerobic and anaerobic process and purely aerobic maturation ponds. This is a conducive, beneficial and simplest system which is also has a long retention time in treating wastewater and thus, reducing pathogens level (Kalombo *et al.,* 2004). They basically represent one of the most dependable, cost-effective, and are easy to operate when treating domestic wastewater. Once the pond reaches its maturation stages, it can be able to grow fish such as tilapia, thus it also provides some economic benefits (Parkinson and Tayler, 2003). The water from ponds facilitate the growth of algae and such water can be a good source for irrigation purposes. However, it must be mentioned that to be able to have such a system there needs to be sufficient land or space availability. The wastewater stabilization ponds are conducive to be integrated in a re-use system in that there is sufficient water for irrigation, thus good for plant production hence benefiting or making room for agricultural activities (Wood *et al.,* 2001).

2.6.1.3.2 Constructed Wetlands

According to Hammer (1990), constructed wetlands are defined as a designed, manmade complex of saturated substrate, emergent and submerged vegetation, animal life, and water that simulate wetlands for human uses and benefits (Kalombo *et al*., 2004). Constructed wetlands also called 'reedbeds', they are planned systems designed and constructed to employ wetlands vegetation in order to help in the treatment of wastewater in a controlled fashion than the naturally occurring ones. These can also provide low-cost and appropriate technology for treating domestic wastewater and faecal sludges, but such firstly requires pre-treatment and thus can be considered as a second stage in the system of treating domestic wastewater (Parkinson and Tayler, 2003; Kalombo *et al*., 2004). These are also very good at removing pathogens, although the facilities must be designed and operated in a way that controls diseases vectors, especially mosquitoes, and odours to prevent adding to other issues especially mosquitoes relate disease like malaria (Parkinson and Tayler, 2003). Moreover, constructed wetlands can remove other pollutants which include organic materials, suspended solids, nutrients, pathogens, heavy metals and other toxic or hazardous pollutants. When applied by municipal systems, such a technology can be integrated to their wastewater treatment processes in which these wetlands can be grouped into stages to treat primary, secondary and tertiary wastewater as a system keeping in mind that the wastewater was pre-treated thus not raw. Therefore, constructed wetlands can be used as an alternative for the treatment of wastewater compared to conventional methods of treating domestic wastewater (Kalombo *et al.,* 2004).

2.6.1.4 Biological Greywater Treatment

Biological treatments of greywater followed by disinfection to guarantee risk-free effluent are recommended in which such a system can be optimized for a minimum energy and maintenance (Ghunmi, 2009).

2.6.1.4.1 Aerobic Treatment

Aerobic systems are similar to septic systems in that both of these systems use natural processes in treating wastewater, and it requires oxygen. In an aerobic system oxygen is injected and circulated so that oxygen dependant bacteria can thrive. The bacteria then break down organic matter, reduces pathogens and transforms nutrients (e.g., ammonia to nitrate) (National Environmental Services Center, 2005; Septic Smart, 2010). The Aerobic treatment system also requires electricity / energy to be in operation, thus this process can have high operational costs and will require regular maintenance than anaerobic biological treatment processes (National Environmental Services Center, 2005). Aerobic treatment is designed to oxidize both organic material and ammonium-nitrogen, which then decreases the concentration of suspended solids and reduces the concentration of pathogens.

2.6.1.4.2 Anaerobic Biological Treatment Process

This technology is the most appropriate technology when it comes to the treatment of wastewater especially black water and water with faecal matter. This treatment is also cost-effective compared to aerobic treatment processes as it produces energy and therefore does not require external sources of power (Parkinson and Tayler, 2003). This requires minimum land areas and can produce a well stabilized sludge in less quantities than aerobic treatment. Anaerobic treatments are cheaper in that they produce energy which makes it less reliant on external power sources. A septic tank is the simplest form of anaerobic treatment which both settles suspended solids and achieve some anaerobic digestion of those settled solids. Septic tanks can remove about 60% or more of organic loads during hot temperatures, but they can only remove very little pathogens. Other forms of anaerobic technologies include anaerobic waste stabilization ponds, anaerobic filters and upward-flow anaerobic sludge blanket reactors (UASBs) (Parkinson and Tayler, 2003). The drawback from such technologies especially for UASBs is that it requires careful management by personnel with technical skills and where such skills and organization systems for effective management lack, may not be well developed. Thus, such a system requires adequate attention during its operations and maintenance.

2.6.1.5 Chemical Treatment

It is difficult to treat greywater as there is a variation of the quality of greywater observed over short timescales, because various households use various cleaning agents that consist of varying elements (Parsons *et al.,* 2000). As a result, many treatment schemes propose only the use of physical and biological treatment processes since they usually have problems with adjusting to the shock loading or organic matter and chemicals. One of the types of chemical treatments for greywater that exists consists of coagulation/ flocculation to remove solids and TOC, advanced oxidation using titanium dioxide and UV to Remove TOC, (Parsons *et al.,* 2000), sand filter and granular activated carbon (GAC) for treating laundry greywater, electro-coagulation with disinfection for the treatment of a low strength greywater and photocatalytic oxidation with titanium dioxide and UV (Pidou *et al.,* 2007), and so on.

2.6.1.5.1 Chlorination as a Chemical Treatment

Chlorination is the most used and common methods of wastewater disinfection and it is used all over the world for the disinfection of pathogens before the wastewater can be discharged into the receiving environment. Chlorine is a powerful oxidizing agent which has been used to effectively disinfect wastewater materials, as it is effective in destroying many types of bacteria, viruses and protozoa including *Salmenella*, *Shigella* and *Vibrio cholera* (American Chemistry Council, 2005 - 2018). This can be added to the systems as either a gas (CL2) or as a liquid in the form of sodium or calcium hypochlorite, respectively. The chlorine is highly corrosives and is not recommended for onsite treatment because it highly presents safety hazards risks (USEPA, 2002). The sodium form of chlorine is usually the most favoured for onsite applications. Chlorination of wastewater is widely practised across the world in reducing microbial contamination and the potential disease risks that may be exposed to humans and living organisms in the natural environment.

2.7 Health and Environmental Considerations

There are a number of health and environmental risks associated with greywater. Firstly, greywater may be mixed with surface water which obviously will contaminate them and also this has deterioration in environmental and health conditions. This is particularly because, greywater can be contaminated with human excretion from bathing and laundry which is not suitable to be reused and should immediately be disposed and treated as a sanitation issue as it pose a potential risk to human health from the microbial and chemical contaminants (Jordan, 2006). It must be noted that greywater effluent is not 100% safe as it does have the possible factor of transmitting diseases specifically for children and residents with compromised defence system such as HIV/AIDS patients (Carden *et al.,* 2007b).

Secondly, the greywater with high sodium, chloride and other components have effect on plants in that they reduce plant growth (Jordan, 2006). This is due to some laundry washing detergents and soaps which in particular may make use of a diverse range of chemicals materials that can inhibit specific plant growth and can be harmful to edible fruits against and by extension, humans. It has been found that the increased presence of sodium ions can result in also the discoloration and burning out of plant leaves, which can increase the levels of alkalinity on the soil. Adding to this, the increased sodium ion presence is bad for certain plants as it can hinder the possibility of calcium ion materials from reaching the important parts of a plant (Jordan, 2016).

Thirdly, the key effects of greywater on soil texture is that it has a potential in increasing the level of salts (salinity) and also alkalinity of the soil. This is because there is a decrease factor produced on the ability of certin soils textures in the absorbtion and retainment of water levels within the plant. When the alkalinity of the soil increases it is usually because of the presence of calcium salts, potassium ions and sodium on the greywater source, particularly from laundry detergents. The retention of water is also influenced some what by the forms of sodium which is a consequence measured by a parameter known as the sodium adsorption ratio (SAR). When it comes to a sandy, well-drained soil, it is deemed to be less affected by greywater applications than on a poorly-drained soil dominated by clay particles (Jordan, 2016).

Forthly, environmental risks that are associated with the reuse of greywater effluent that are impoartant to note is the contamination of both groundsource and underground water resources. There is a chance that some of the material and substances that reside in greywater effleunt may find their way into both surface and underground water reserves where the water table is close to the surface underlying the area. Pondered greywater and reuse of greywater in large volumes or where there is ponding/storage of greywater in ponds which may end up being mixed with surface water is another negetive enviromental risks that can affect biological species. In order to eliminate any negetive environmental effects that can be as a result of greywater reuse on groundwater contaminated and in order to guarantee that the greywater system are safeguarded and used effectively, there is a need to analyse and study the nutrients required by those specific plants and the conditions of that soil (Wilson *et al.,* 1995).

Lastly but not least, sustainable development is very crucial and thus it cannot be overemphasized at any particular point. When the development is considered sustainable it is when there is assurance on the uses, to conserve and enhance community resources so that biological ecosystems processes, on which life depend on, are maintained, and the total welfare quality and life for now and in the future can be improved. Greywater effluent reuse of is an example of sustainable development in practice as the wastewate is viewed as a resource that can assist in clean drinking water demand conservation (Jordan, 2006). It goes with out saying that one of the most impartant benefit for the topic of greywater reuse as a resource is also clean water conservation. Occupants who practise reuse for their greywater effluent will assist the natural environment by limiting the need to use clean water thus reducing demand on clean water needed as a resource.

2.8 Greywater Management options

Greywater management options should be designed in a way that will be able to help communities and the local authorities in determining how greywater can safely be disposed in their areas. An area with no reticulation network to collect this wastewater should identify or develop systems that are conducive for the area. Such a system would then incorporate disposal on-site or off site. It can be reused for home-based gardens through irrigation of vegetable or flowers. Moreover, disposal off-site can be through bulk collection for the water to receive some form of treatment and be disposed the same manner as in formal areas (Carden *et al.,* 2007c). The idea behind this in ultimate sense would be to reduce health and environmental impacts associated with the unsafe disposal and storage of greywater. To prevent health and environmental risks that will result from greywater disposal in a settlement, there are significant parameters that must be safeguarded which are:

- There must be no saturation/ ponding of greywater.
- The greywater must not be allowed to be retained in a manner that will cause pollution to surface water.
- The greywater is also not allowed to accumulate and infiltrate in the soil to the extent that it contaminates the soil and groundwater resources.

The local authority and government need to provide some form of guidance in the development of ways or guidelines on how to safely dispose and reuse greywater generated and the potential impacts associated with them (Carden *et al.,* 2007a). The option of choice then is required to help occupants and municipality authorities in determining the amount of greywater that can be safely controlled in the settlement. There are factors that need to be identified in a specific settlement that are beneficial in considering greywater management which are limited to beneficial reuse either on-site or off-site through irrigation, disposal on-site or off-site with or without treatment. The idea behind the on-site and off-site approaches is a reminiscent factor of reuse and decision leading to treatment and finally disposal and these are identified below.

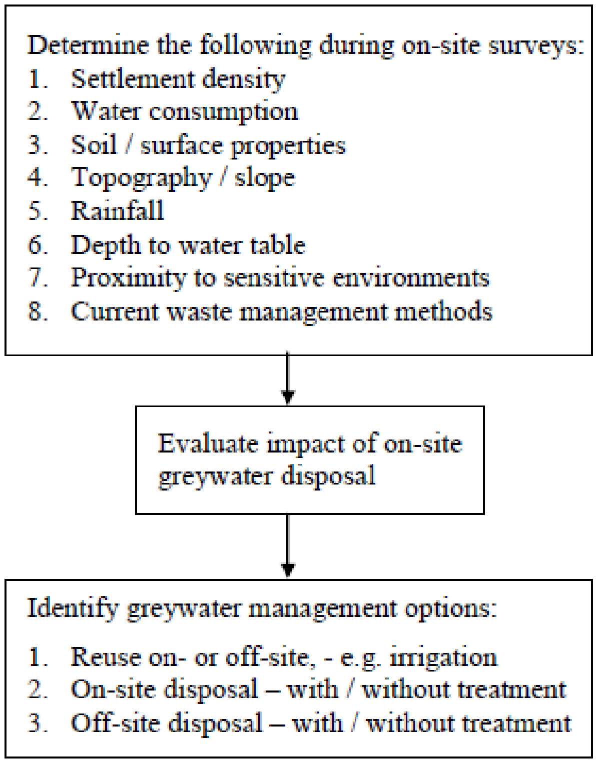

Figure 2:1: Greywater management flowchart.

2.9 Summary

This chapter has provided an overall review and position of the literature that is associated with the research project. The study began with reviewing the literature associated with legislation that guide water, wastewater and thus greywater in which it was highlighted that there currently is no exact act that speaks to greywater management only guiding documents. The study further provided a definition of what greywater effluent specifically refers to. This was then followed by the introduction to greywater sources, notion of quantifying greywater, characteristics/ quality of greywater, sustainable disposal, reuse, treatment and its management in informal settlements. Although there are research studies in the subject matter particularly greywater management, there is still more that needs to be studied particularly with regards to informal settlements. Greywater management for informal settlement is crucial in that it has close relations with sustainable development and the prevention of water based diseases, groundwater contamination and prevention environmental degradation in a long term. It is thus from this view that the sustainable disposal and reuse of greywater effluent in settlements that do not have water based (non-sewer) services must be investigated. This will assist to provide mechanisms to effectively manage the problem of greywater disposal and thus provide solutions for other settlements thereafter. In an attempt to provide a solution and studying the problem at hand in more detail, the next chapter will provide the basis for the research methodology adopted and its instruments.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter discusses the research design and methodology that were employed in collecting data that aims at achieving the objectives and addressing the research questions of the study. The chapter further provides a detailed explanation of the methodology techniques, sampling and data collection methods that were adopted during the study. This chapter focuses on the tools used for primary data collection, which are, questionnaires and interviews. Basically, the chapter focuses on how the information gathered was analysed. The collection of data using survey questionnaires will serve as a guiding protocol for the researcher on the measures followed when interacting with the participants.

3.2 Site selection

One of the first and most important tasks of this study was to determine the project study area. This research aims at using both primary and secondary data in addressing the aims of the study. The study area was selected on basis of a work-based project the researcher was involved in, which was identified as one of the informal settlements in the City of Cape Town that faces major greywater disposal and management issues.

3.3 Research Design and Methodology

Generally, a research design mainly refers to the generic approach that a researcher adopts to integrate various methods of study in a systematic and comprehensive manner that ensures addressing the research problem and research objectives in an effective and efficient way (Creswell and Creswell, 2018). This study uses both qualitative and quantitative methods, in which the qualitative research methods will be focusing on the participant's views in light of the objectives. Anderson (2010) maintains that qualitative research mainly entails the collection, analysis and interpretation of data which is not easily reduced to numbers. This approach will be the primary method of data collection that aims at understanding and looking at perceptions, habits and standing point of the community into how they construct ideas and how they react to social dynamics (May, 2005; Dooley, 1995). This is an important data collection instrument that obtains community values, assumptions, believes and knowledge (Curtis *et al.,* 2000). This method also focuses on providing data about uncertain interpretation for what is happening in context and thus, it is crucial to concede the information in providing a deeper meaning and purpose for the participants (Sharma, 2010). In a nutshell, qualitative data relates to the studying of social parameters and the concepts and behaviours of people within their environment (Anderson, 2010).

On the other hand, quantitative research methods provide a descriptive numerical and analytical basis of validating data collected from the survey (Yeasmin and Rahman, 2012). The quantitative methods traditionally deal with numerical basis of data representation by utilising statistical data analysis to try and infer a meaning that lies within hidden data and that may also show some certain potentials which may have further investigation (Leed, 1993; May, 2005). This conceptualizes the reality in terms of the variables and the relationship between them as it measures and restructures data, research questions and the design.

Both quantitative and qualitative research approaches are very useful in answering research questions and thus, understanding real world issues in which mitigation and management guidelines can be devised. Both of these methods are used in the current study in which qualitative research has been used to collect information required to understand the research problem while quantitative research methods were used to make arguments, look for trends and thus provide recommendations. Against this background, both quantitative and qualitative research techniques were employed in the implementation of the present study. The data that has been acquired and the types of instruments were constructed before time and they have been applied in a standardized approach. The measurements in the questionnaire aims at specific variables which have been quantified in a rating scale, timeframes and frequency for water collection and usage on specific things within the household. The use of a questionnaire having to be a quantitative research method consists of descriptive measures in the data required from the respondents and explanatory designs. Thus this was meant to answer certain research questions and determine desired outcome as per specific objectives set.

3.4 Research Approach

This speaks to how respondents during the surveying process were sampled and how that information was obtained. The current research has adopted a case study approach method which is focusing on Monwabisi Park informal settlement only. The settlement itself is further divided into four sections namely section A, B, C and M as shown in Figure 1.1. These four sections are where various number of survey questionnaires 69 which were collected in Monwabisi Park informal settlement and thus distributed for individual households amongst the different sections. Respondents had to have a representation in all four sections of the study area that was surveyed for the collection of primary data from the community. The current study has focused on collecting primary data using survey questionnaires, interviews and secondary data was collected through the reviewing of literature. Moreover, during the site visits, field observations were conducted in the informal settlement to assess the situations and the current status of the area with regards to greywater disposal and usage. A total of 69 survey questionnaires were distributed equally amongst the 4 sections on Monwabisi Park's residents on water access and use, greywater generation, disposal, possible use and management thereof.

3.4.1 Population and Sampling

The population of this study comprises the residents of Monwabisi Park informal settlement situated in the greater Khayelitsha Township. The research questions of this study suggest that there is no specific target group, but the whole Monwabisi Park informal settlement itself was used as a case study. The study drew respondents from any of these sections in Monwabisi Park informal settlement which all of them are affected by the same issue under study. The available population is said to be a subset of the target population which is also known to be the study population. Any member can be the target respondent as they meet the criteria for the research. The population in this regard consists of all the individuals in which the researcher had an interest in for the study. Sampling can be distinguished to be field testing or the collection of samples for further testing in a laboratory. Sampling has been defined as the process of selecting a manageable group in order to determine the characteristics of a larger group (Brynard and Hanekom, 2006). In this regard, sampling refers to the selection of a specific number of respondents who have the capacity to fulfil the objectives of the study, in which, it is relatively a small number of people selected from a larger population for the investigation purpose of the research (Alvi, 2016).

3.4.2 Sampling procedures

The people who were sampled for this research are called participants or respondents. These individuals can produce accurate generalized results about the population. One of the most important aspects of social research in the selection of subjects who will participate in the study as it is difficult, time consuming and at times impossible to examine an entire population. Sampling criteria thus provides an opportunity to study the entire population using a representative "sample" of that population in which generalization is made. Thus, it is necessary to consider only a small portion of people as a sample to represent the entire population.

There are mainly two types of sampling techniques that have been identified for sampling individuals from a larger population and they are namely: probability and non-probability sampling. Probability samples are mainly used for quantitative research designs and non-probability samples in qualitative designs (Alvi, 2016).

In the current study, the non-probability sampling and stratified random sampling were adopted. Stratified random sampling was applied in all the sections as each element of that population has an equal chance of being selected as a sample. Participants from the four sections in Monwabisi Park are randomly selected to ensure that there is representation which has equal chances (Alvi, 2016). Secondly, within these strata, purposive-sampling was employed in which the researcher attempted to obtain a representative of the population. The samples with in the strata were randomly selected. Purposive sampling is very common in qualitative research in which individual participants are chosen with characteristics relevant to the study who are thought to be most informative to the current study (Anderson, 2010). Also, this sampling technique may be employed to yield maximum variations within a sample.

3.5 Data Collection Methods and Instruments

One of the advantages of qualitative research paradigm is the collection of rich amounts of data that can further assist the researcher in developing a hypothesis for quantitative investigations (Yeasmin and Rahman, 2012). Within the context of qualitative research methods, data can be collected through a variety of ways. This may also include observations, interviews and the analysis of literature. The data must also correlate with the data source. The current study has used both primary and secondary data. The primary data collection methods are administered using questionnaires, face-to-face interviews and field observations. On the other hand, secondary data was collected through literature review for referencing arguments made from various types of reports including documents, books, articles (etc.). If repetition of stories occurs among participants and no new information awarded to the researchers by any new participants, then the data is said to reach a saturation point. Then, the researchers can stop selecting new participants for their study' (Ishak and Bakar, 2013).

3.5.1 Primary Data

3.5.1.1 Interviews

It is important to note that the conduction of face-to-face interviews has both advantages and disadvantages. The most important advantages of this approach of collection data is that, it yields a very high response rate in getting adequate information and there is high control for the interviewer. Bell (2010), has noted that the advantage of this approach is its adaptability as a skilful interviewer can follow up ideas, probe responses and investigate deeper feelings in a social based research. The disadvantage however include that the process has proved to be time-consuming, can have high costly and also it brings intimidation to the respondents as some may require anonymity (May, 2005; Bell 2010). There were 69 Interviews conducted between January to February 2019 after ethical clearance was obtained in December 2018. Each interview took 20 to 30 minutes.

3.5.1.2 Survey Procedures (Self-administered questionnaires)

A semi-structured self-administered questionnaire was used to collect data directly from the respondents. The semi-structured interviews using survey questionnaires together with observations were conducted. The semi-structured questionnaire was administered to individuals at an interview basis to gain individual response which was accompanied by emotions or feelings and thoughts. The sample size from the study would provide a quantitative basis too and the patterns and perceptions of the sample should complement the qualitative data produced by the participants. The questionnaires were structured in the following context:

1. Particulars of the Respondent – settlement sections, employment, education level, number of the household etc.
2. (A) Water Access – distance from water sources, type of water sources, daily water use, main usage of the water etc.
   (B) Sanitation – type of sanitation used, distance from it, day and night usability, amount of water used for, handwashing facilities etc.
   (C) Particular water usage for domestic activities (kitchen, house cleaning, bathroom, laundry etc.) – frequency for the specific activity, amount of water used by each respondent, and how it is disposed.
3. Greywater management – current greywater reuse activities, perceptions of the community about greywater effects on health and the environment.

4. General site observations – checking existing greywater reuse and disposal mechanisms, existing greywater management mechanisms, topography, vegetation, soil etc.

The questionnaire consisted of closed, open-end and open questions. The questions were structured in a way that allows categories of distinction. The main language was English but due to the fact that most residents speak IsiXhosa, during the face-to-face interview process the researcher did an in-text translation. This also helped in making respondents more comfortable. The survey was conducted on a random door-to-door visit.

3.5.1.3 Field Observation Method

In qualitative data collection methods, field observations are carried out to observe the naturally occurring behaviour of the people in their natural environment with regard to the generation, and usage of greywater. Basically, field observation is a method of data collection whereby the researcher observes people in ‘real’ locations and situations, such as workplaces, homes, etc. (Bryant, nd). During the data collected process the researcher was able to understand and capture information in the context within the people who are affected and have interacted with. The immediate experience with the settings basically permits the researcher to open up to discoveries and inductive, rather than probing what the context is like. It is also important to note that the researcher may observe the routines that may escape the awareness of the participants using a different method. This may provide the chance to observe what other people may be unwilling to discuss in an interview. During data collection, observations were made about the complexities of the study. The data can be collected in different ways which is not limited to videos, pictures (etc.). In the present study, pictures were taken in this regard.

3.5.2 Secondary Data Collection

Secondary data was used in this research through a number of ways so as to address the research questions and aim of the study. The main one was through literature review of journal articles, government reports, internet pages and scholarly thesis and research papers. Secondary data has been obtained through a number of formats which was through the internet from journal articles; web portals; software analysis of the data collected through the interviews and questionnaires was plotted on an excel spreadsheet; reports; newspaper; municipality documents; and government policy documents. Additional data on access to clean and safe water was collected from pieces of legislations such as the National Water Act (Republic of South Africa (RSA), 1998) and The Water Service Act (Act No. 108 of 1997). The information collected assisted to adequately study the problem and to formulate theoretical contexts for this research. Consequently, in the current research, secondary data guided the researcher in making arguments, addressing aims and objectives and answering the research questions formulated.

3.6 Data Analysis

The current study combines both qualitative and quantitative based research methods. The data analysis stage also entailed quantitative methods. Consequently, it is subjected to a variety of data analysis procedures. The household data has been collected through semi-structured survey questionnaires in which they have been analysed using Microsoft excel. Qualitative research concentrates on studying social life issues (biographical data), their socio-environmental patterns and/or behavioural traits and the perceptions of the people in those surroundings.

Qualitative research must be open when it comes to data analysis and it must provide evidence of the researchers thinking (e.g.) were alternative explanations for the data considered and dismissed and if so, why were they dismissed? (Anderson, 2010). Glesne and Peshkin (1992) maintained that 'the number of participants for a qualitative study could be determined by looking at the data during data analysis.

When the researcher is done with data collection, the next step is to organise data into manageable format. This allows the researcher to prepare the data for analysis. The data was analysed through the use of Microsoft excel software, which has produced results that reflects the objectives of the study. From the results presented in the preceding chapter, they are displayed through data analysis procedures through the use of graphs, tables and chart which has helped in conveying a message in line with objectives. The results that has been displayed on the graphs will provide further information that can be used to make arguments. This information can then be used in all other stages thereafter. There are various ways in which the data has been represented and these include: tables, bar graphs, pie charts, maps and histograms. The main reason in this research for reducing and displaying data in this manner is to assist in drawing up conclusions and recommendations where needed (Curtis *et al.,* 2000). Such conclusions are meant to summarise the main findings from the study and to emphasize what the study adds to the body of knowledge in the area being studied

(Anderson, 2010). After the results chapter, a discussion and conclusion chapter will follow in discussing in detail the findings of the study and thus provide recommendations before drawing conclusions.

3.7 Ethical Considerations

When conducting a research based on qualitative research methods in which the researcher has undertaken using surveys questionnaires and interviews. It was mandatory for the researcher to first get approvals from the City of Cape Town and an ethical letter from the university for ethical considerations. Ethics are codes and procedures that guide a researcher about aspects to consider when dealing with research that entails people. Such ethical considerations are there to provide not only guidelines but also safety and privacy for the participants in which they have a choice to remain anonymous to protect themselves. Such procedures were followed and during data collection, it was explained to the respondents for them to be aware that their participation was not mandatory but a choice (Bell, 2005). The researcher considered the informed consent when dealing with the participants in order to establish if they were willing to take part in the study after they have been informed of all aspects of the research that might influence their decision. Consequently, an ethical clearance certificate was obtained, with reference no: 217034721/08/2019.

Participants were made fully aware of the purpose of the research and they also understood their rights. When collecting data, participants need to be aware that they have rights in that, they are not forced to participate, and their participation is voluntary. The researcher had explained that should the participants feel uncomfortable they would be able to withdraw and they also had a choice to remain anonymous. During the data collection process the researcher has invited the respondents to participate in the study in the form of a written letter in which the letter of the consent for the participants to participate in the questionnaire/ interview.

Thus, ethical considerations are there to protect respondent by making them aware of their part in the research and stating that they have a choice to remain anonymous. In this case study research, participant of Monwabisi Park was being dealt with according to the research ethics as stated above. The collection of data through surveys was subjected to the institutions approval of the questionnaire developed, which had to meet the standards of the institution. From there onwards, the use of secondary data had to begin once the proposal was approved, as well as the interviews of the informants. All necessary paperwork such as letters were directed to the relevant stakeholders in order to obtain the required information in this case, a letter of approval to conduct research was obtained from the City of Cape Town. The Consequently, all research ethics guidelines communicated were upheld by the researcher to comply with all relevant laws and procedures of the institution.

3.8 Summary

This chapter explain all the steps and processes that were employed as part of the methodology to conduct the current study. This basically entails the methodology employed that consisted of the target population and sampling procedures, data collection methods, analysis of such data and ethical considerations. The methodology of the current study has enabled the researcher to establish a series of procedures and phases on how the whole research project should be carried out. This was done to give out credibility to the current study. The next chapter entails data analysis and there after findings, discussions, conclusion and recommendations.

CHAPTER FOUR: ANALYSIS OF RESULTS

4.1 Introduction

The purpose of this chapter is to display the results based on the data collected during site visits. The area is a non-sewer informal settlement situated in the greater Khayelitsha area. The researcher has conducted qualitative research method type of interviews and semi-structured survey questionnaires with the respondents who are residents of Monwabisi Park informal settlement. This process was in-line with the objectives set out in Chapter 1. The first objective aimed at getting an idea of the main sources of greywater generated in each household in the study area. The second objective was to get the volumes of greywater generated. The third objective focuses on how the residents/respondents dispose their greywater effluent. Thus, a formal data collection process was conducted to ensure that the data collected is both defined and accurate. The purpose of this study specifically is, to investigate the sustainable disposal and potential reuse of greywater effluent that has been produced by households in the Monwabisi Park informal settlement. The structure of this chapter is guided by the structure of the questionnaire and interviews.

4.2 Data and Methods of Analysis applied

In Chapter 3, it has been stated that the questionnaire used in the study was divided into four sections. These sections are (1) Particulars of the respondents; section (2) (a) Water Access (b) Sanitation (c) Particular water usage for domestic activities (kitchen, house cleaning, bathroom, laundry and others; section (3) Greywater management and section (4) General site observations (Existing greywater reuse and disposal mechanisms). Therefore, this chapter will follow the sequence of this questionnaire. This data was analysed using Microsoft Excel software. Different types of graphs have been used. This consists of bar graphs, line graphs, scatter plots, pie charts and histograms. These types of graphs are useful in showing various types of data from frequencies, normal, ordinal, intervals and ratios to show various data scale measurements.

4.3 Presentation of Findings from the Questionnaire used

The response that has been obtained from the respondents will be first analysed in accordance with the objectives set in chapter one and answering the research questions. The objectives that apply in the context of the questionnaire are: (1) to classify greywater produced in the different domestic purposes around the household;

(2) to assess sustainable disposal of each source of greywater by deducing the least contaminated greywater source around the household; (3) to determine potential reuse of greywater in and around the households so as to prevent environmental health hazards while promoting water conservation, with which its information will first be analysed.

4.4 Biographical data of the Respondent (Demographic Aspects)

4.4.1 Gender

Table 4.1 below shows the observed composition of gender for the respondents that were interviewed during the data collection phases, while Table 4.2 shows the expected gender. In the data collected 51 % of the respondents were females, while 49 % were males. The table below (Table 4.1) shows the number of each gender that were interviewed in all the different sections of the Monwabisi Park informal settlement. Ethnic background was not part of this questionnaire; however, it should be noted that all respondents interviewed were of Black African (Xhosa) origin. Following this, Figure 4.1 shows the breakdown of the number of respondents per section for both males and females in a graphical manner

Table 4.1 Observed gender of respondents in the study area.

Gender	Sections				Totals
	A	B	C	M	
Male	8	9	9	8	34
Female	9	8	9	9	35
Totals Per Section	17	17	18	17	69

Table 4.2: Expected gender of respondents in the study area.

Gender	Sections				Totals
	A	B	C	M	
Male	8.38	8.38	8.87	8.38	34
Female	8.62	8.62	9.13	8.62	35
Totals Per Section	17	17	18	17	69

The statically analysis of observed and expected values was calculated for the population of Monwabisi Park. The chi-square test value of P= 0.98348 was observed which is greater than the Alfa of 0.5 and shows that there is no significant finding. It is too likely that these results are due to chance. Thus, the values in the tables above (Table 4.1 and 4.2) has shown that there is no significant difference between the observed and expected frequencies.

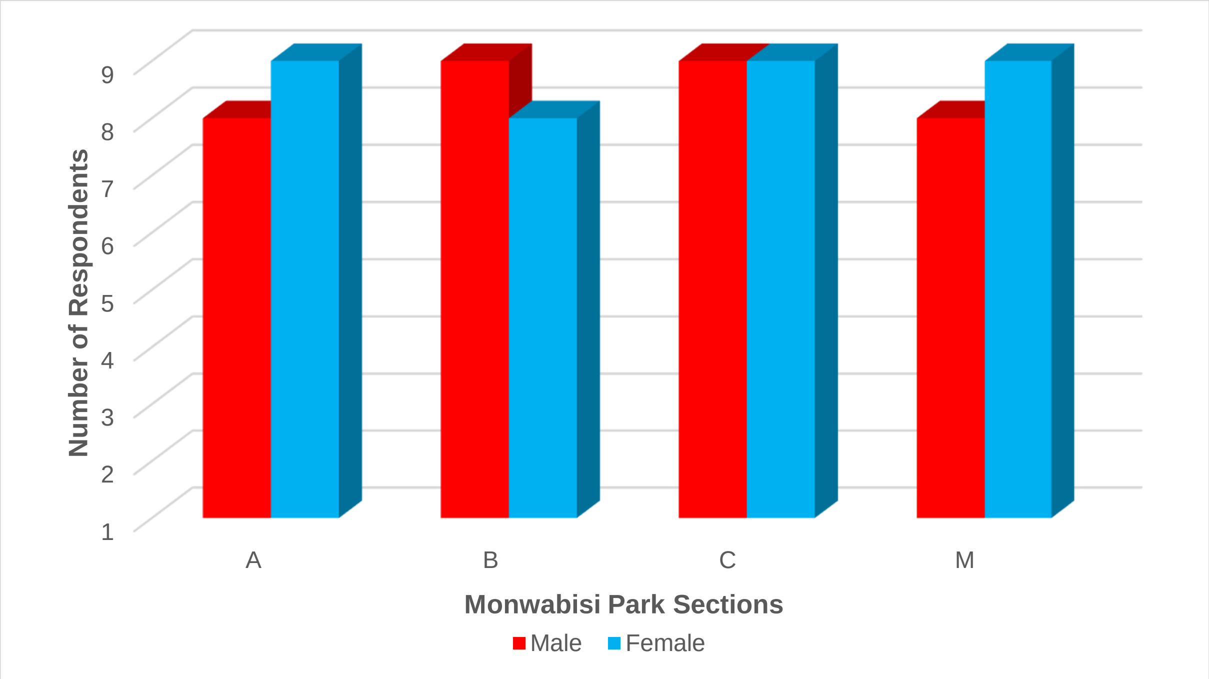

Figure 4:1: Gender composition of the respondents.

4.4.2 Age Distribution

As reflected in Table 4.1, there were 69 respondents that participated in the study. Figure 4.1 provides a breakdown of the respondents for both males and females per section in Monwabisi Park informal settlement. The majority of which were female. In both genders of the sample population they are of African origin. Then Figure 4.2 shows the percentages of respondents per age group as a representation of participants, while Figure 4.3 further breaks down the age distribution per gender of the participants.

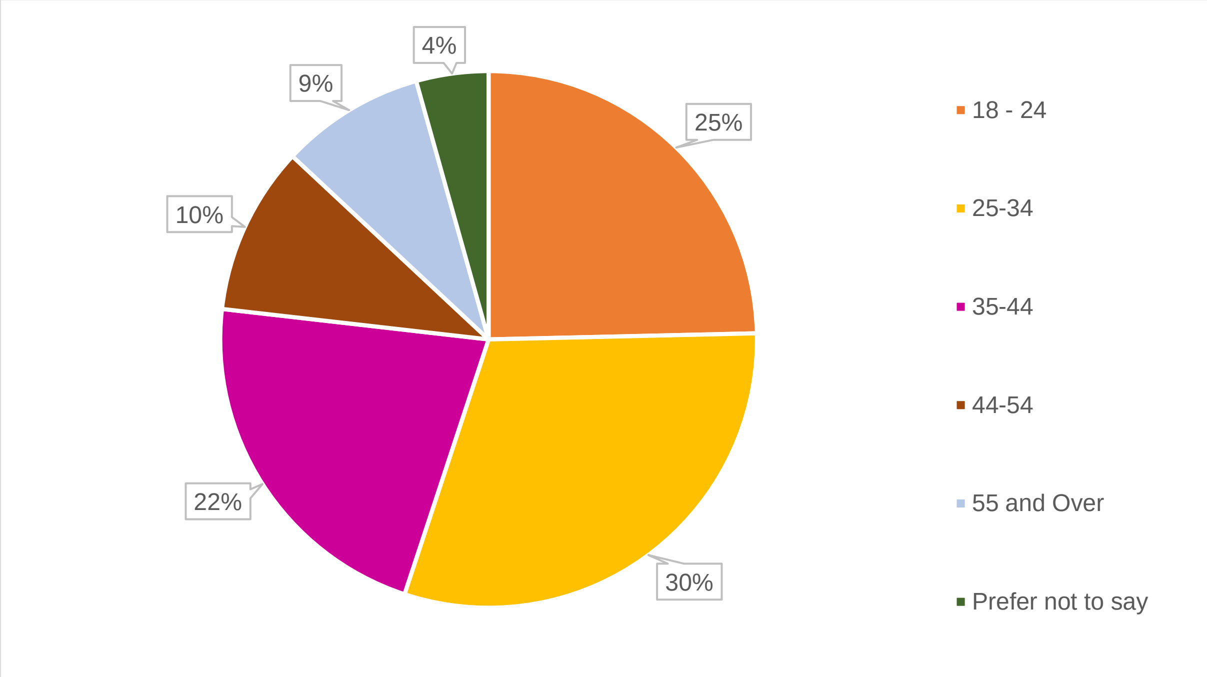

Figure 4:2: Percentages of respondents per age group.

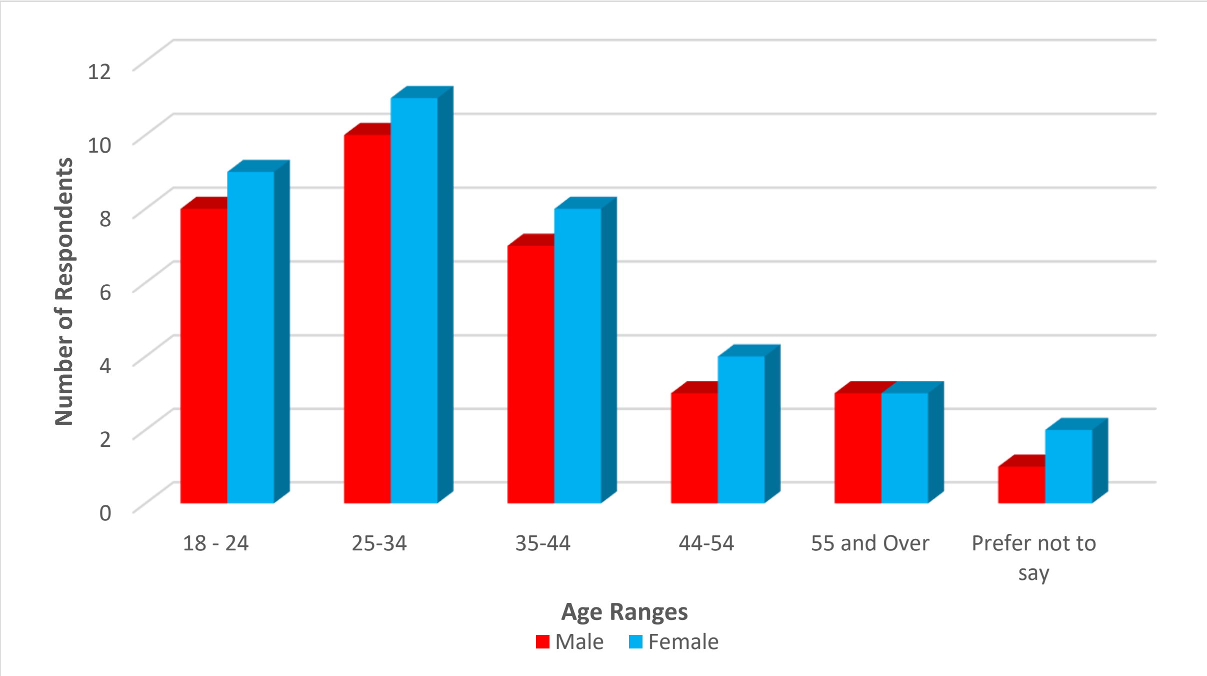

Figure 4:3: Age distribution per gender of the respondents.

4.4.3 Employment

Figure 4.4 shows employment statuses in percentages for the individuals who participated during the survey. It can be clearly noticed that most of the population found on the study area are unemployed as represented by 68.1% of the surveyed area. This is followed by 17.4 % who are employed, while 14.5% are self-employed.

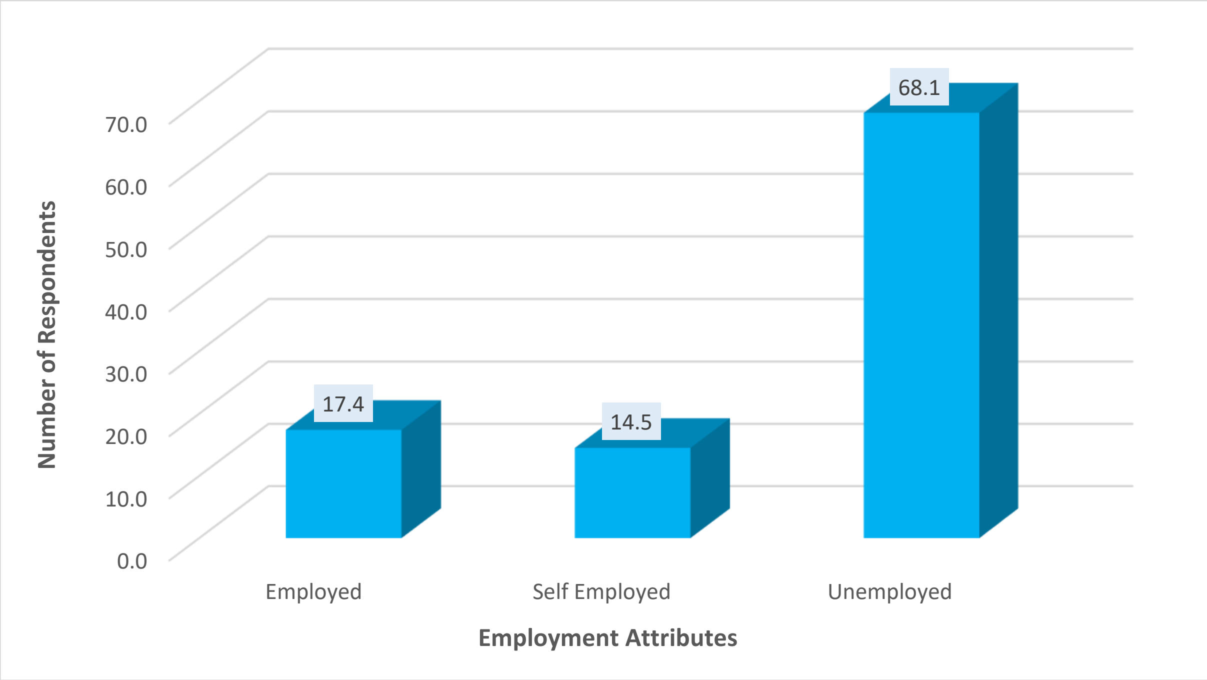

Figure 4:4: Employment statuses of the respondents.

4.4.4 Education Level

Figure 4.5 shows the educational level of the respondents interviewed. As it can be observed from this graph, the majority of the respondents (50.7%) do not have any formal education. This is followed by 42% who have matric and the remaining 7.2% percentage has college/university qualifications.

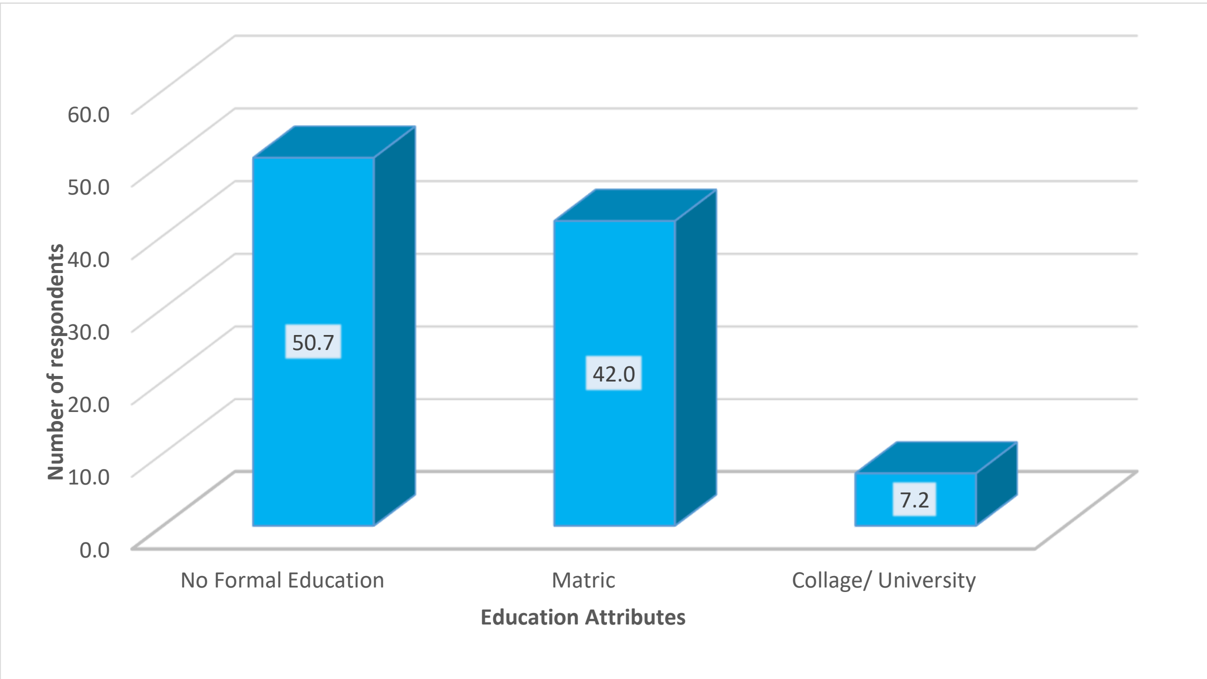

Figure 4:5: Education level of the surveyed respondents.

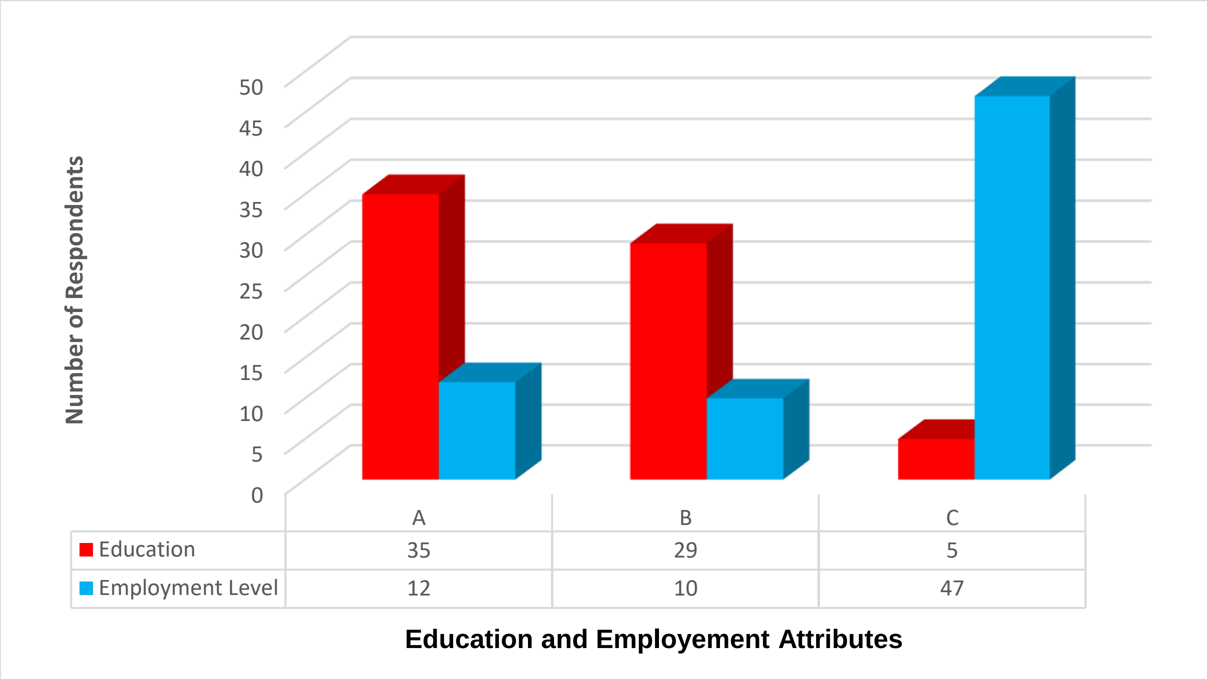

Figure 4:6: Comparison between level of education and employment status.

4.4.5 Number of Age Distribution Per household

As part of the survey it was also important to get the number of individuals per age group (Figure 4.7). The data obtained has shown that most of the participants or respondents were adults from the ages of 19 to 65, thus having a large number of an employment force with a percentage of 47.7. Though the majority of the respondents are adults, there is a huge number of unemployment amongst this category. This is then followed by 18.5 % which basically reflects teens between the ages of 14 -18 years old. This age group is usually receiving high school education. The third percentage in the age group is 17% for young children followed by 14.5 % who are infants to toddlers and the final percentage was 1.6 % of adults over the ages of 55 to 70 years who are pensioners.

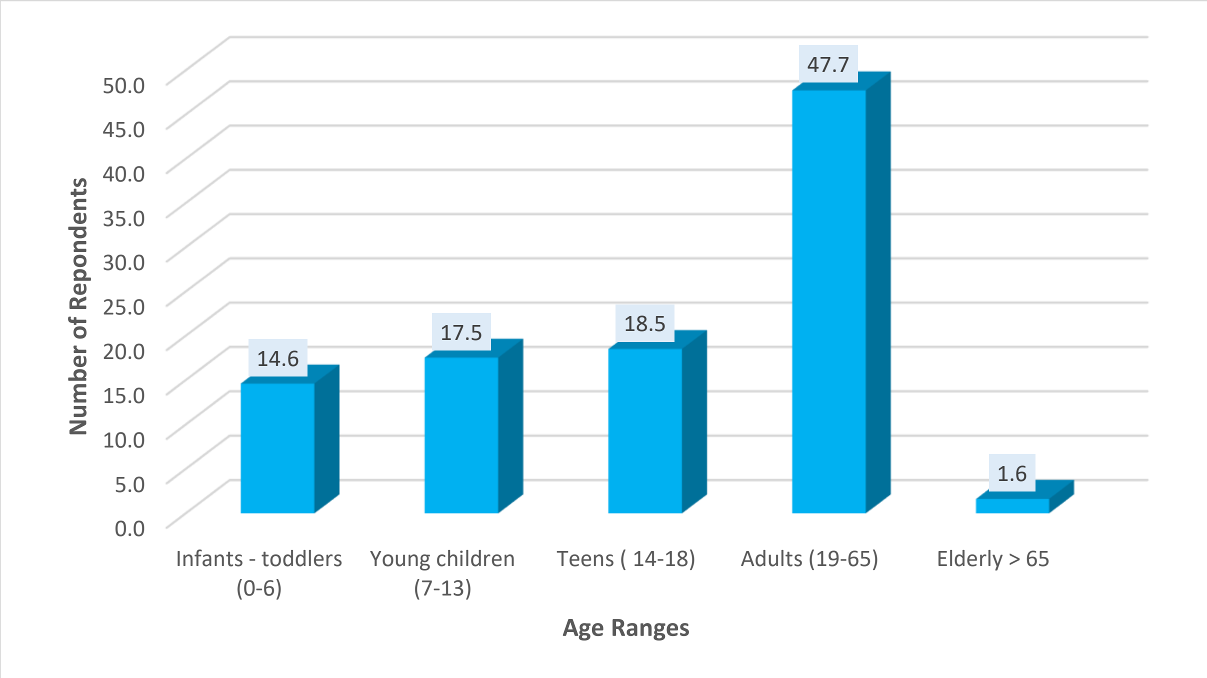

Figure 4:7: Age distribution per house household.

4.4.6 Period of stay in the settlement

This section highlights the amount of time in years that the respondents have been staying in the study area. As indicated in Figure 4.8, the majority of the respondents have been residing in the area for more than 5 years. During the data collection phase, most respondents have reflected most frequently that they have been living in the settlement for more than 10 years. The greater number of the population which is 62.3% have been staying in the area for more than 5 years but less than 20 years. This is then followed by 17.4% that has been staying in the area for more than 3 years but have not exceeded 5 years. Then, the third ratio is 15.9 % that has been in the area for more than 20 years and the last percentage is 4.3 % with less than 3 years in the area.

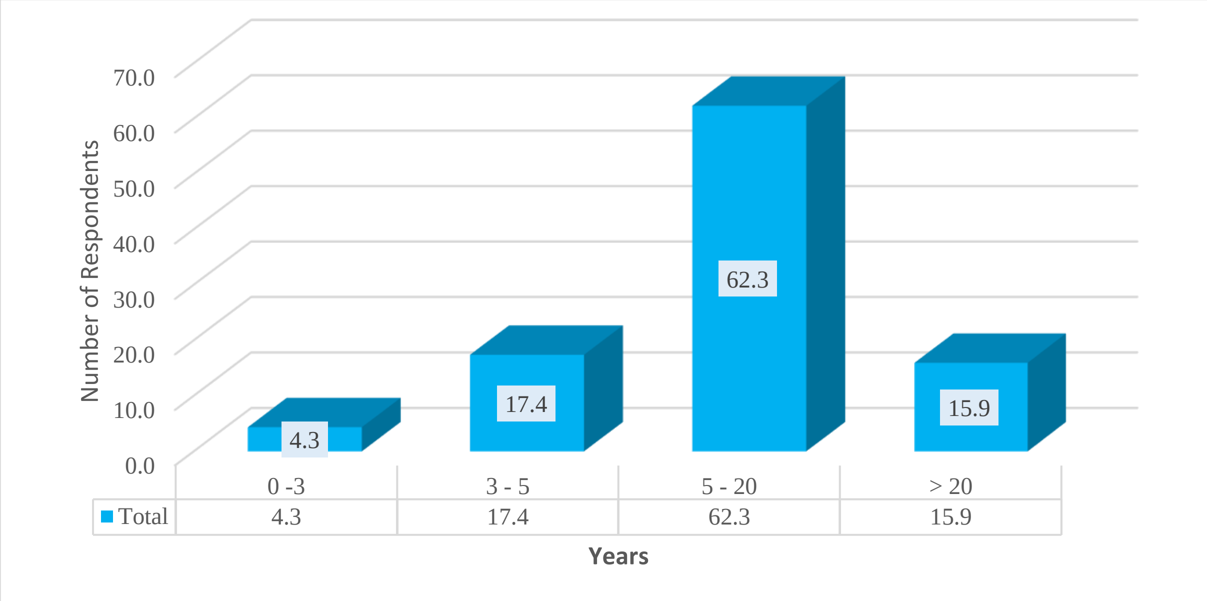

Figure 4:8: Number of years the respondents has been residing in the settlement.

4.5 Greywater Generation and Sources

4.5.1 Water Access

Most of the residents in Monwabisi Park receive their water from communal standpipes as shown in Figure 10, which is represented by 92.9 % and the other population represented by only 7.1 % have tap connected into their household (Figure 4.9). The number of household standards attached to standpipes set out by national government is 1:25 whereby 1 stand pipe is used by 25 households.

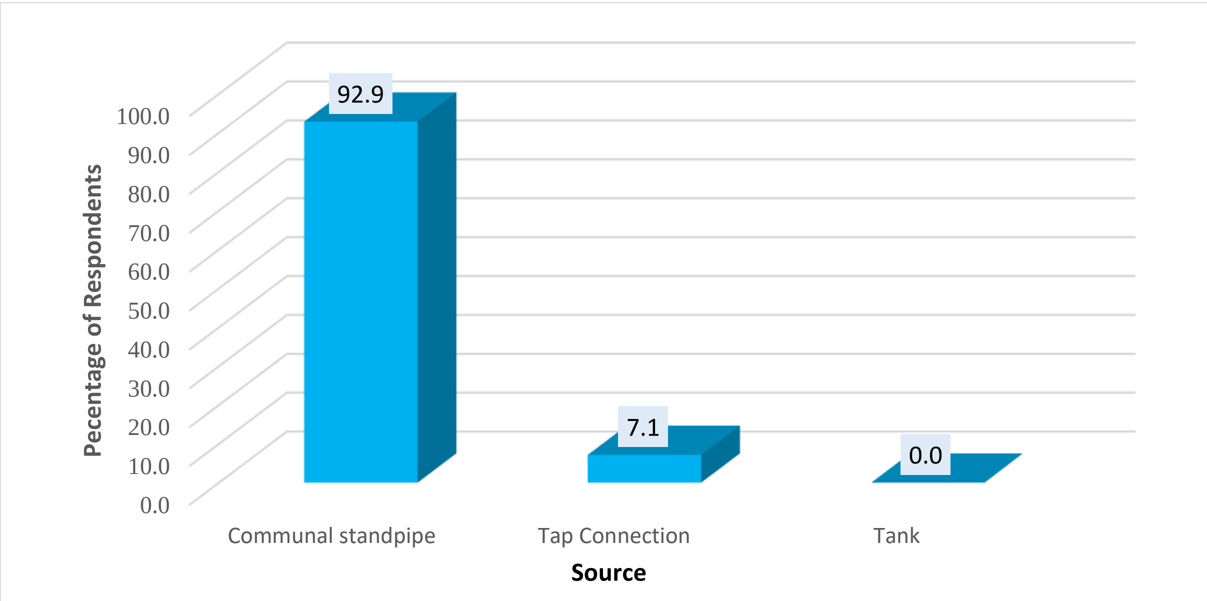

Figure 4:9: Sources of water access for the respondents.

Figure 4:10: Communal standpipes.

4.5.1.1 Distance from the house to the standpipe

Figure 4.11 and 4.12 shows the distance the respondents have to walk to get to the communal stand pipe. This is expressed in meters from the household of the respondents to the nearest standpipe. Figure 12 summarises that 48% of the respondents are within 0 – 50 meters from the standpipe, while 33% are between 20 – 200 meters and then lastly, 19 % are between 200 – 500 meters.

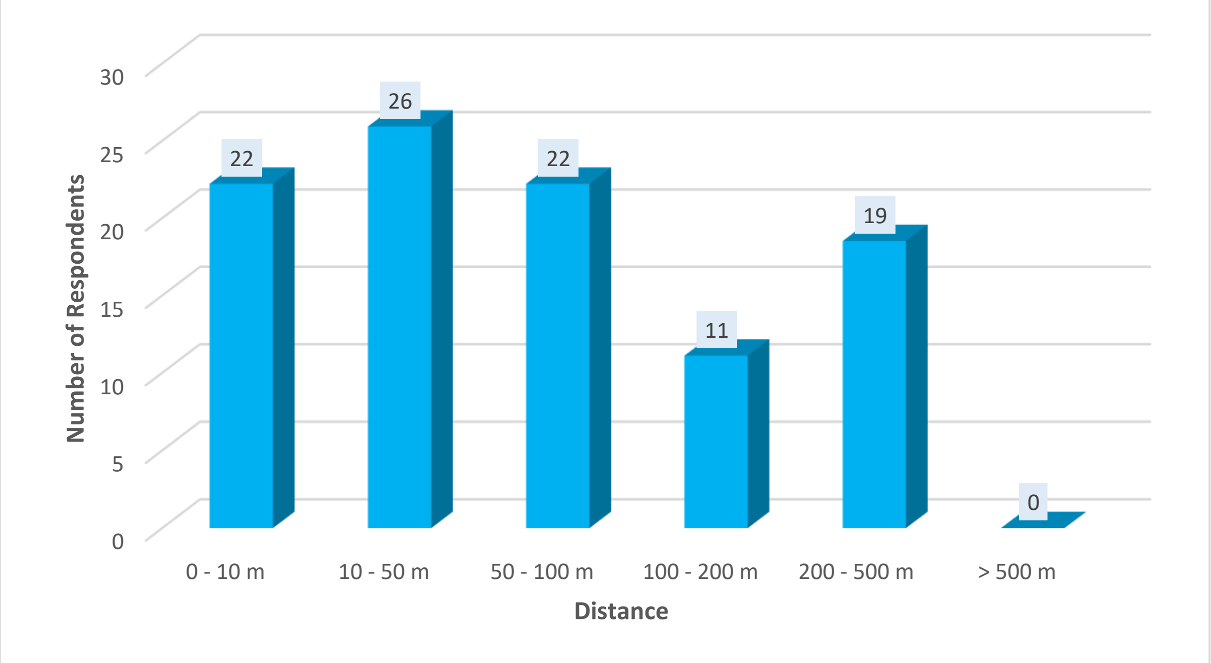

Figure 4:11: Distance from the water source (communal standpipe).

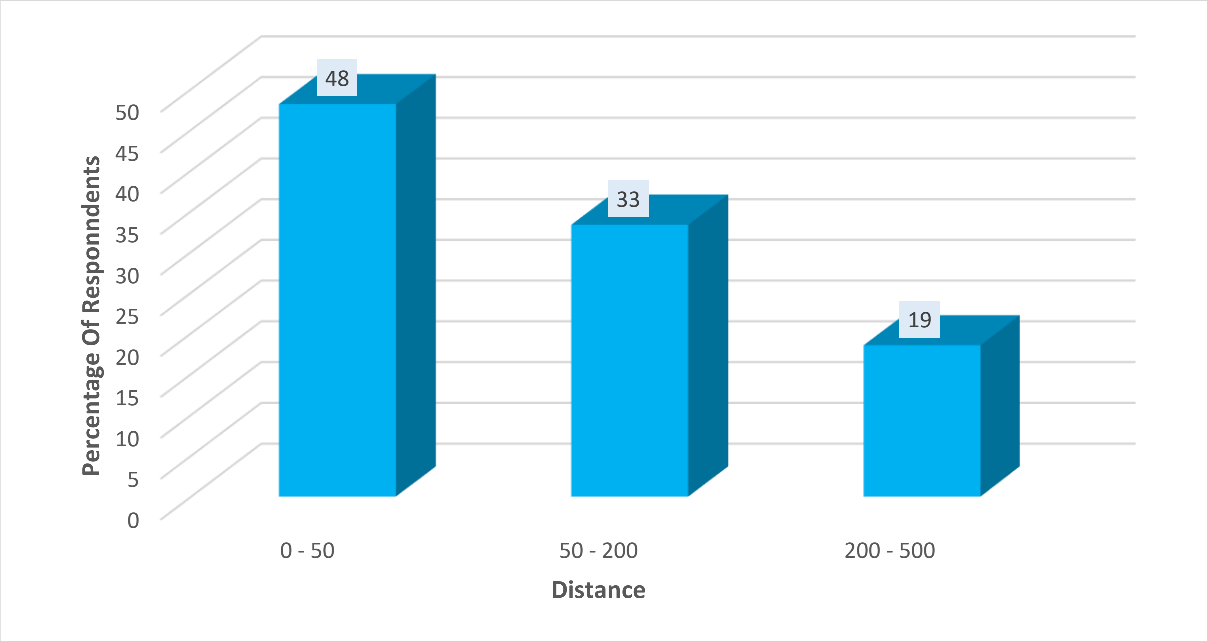

Figure 4:12: Summary by category of distance from the water source.

4.5.1.2 Daily water uses in the household

Figure 4.13 and 4.14 shows the volumes of water that are used daily by the respondents. Most of the respondents do not exceed 50 litres which is represented by an overall percentage of 81 % but this is determined by the number of people found in the individual households. The reported number that exceeds 50 litres which is represented by 19% is due to having multiple children below the ages of 6 living in the household.

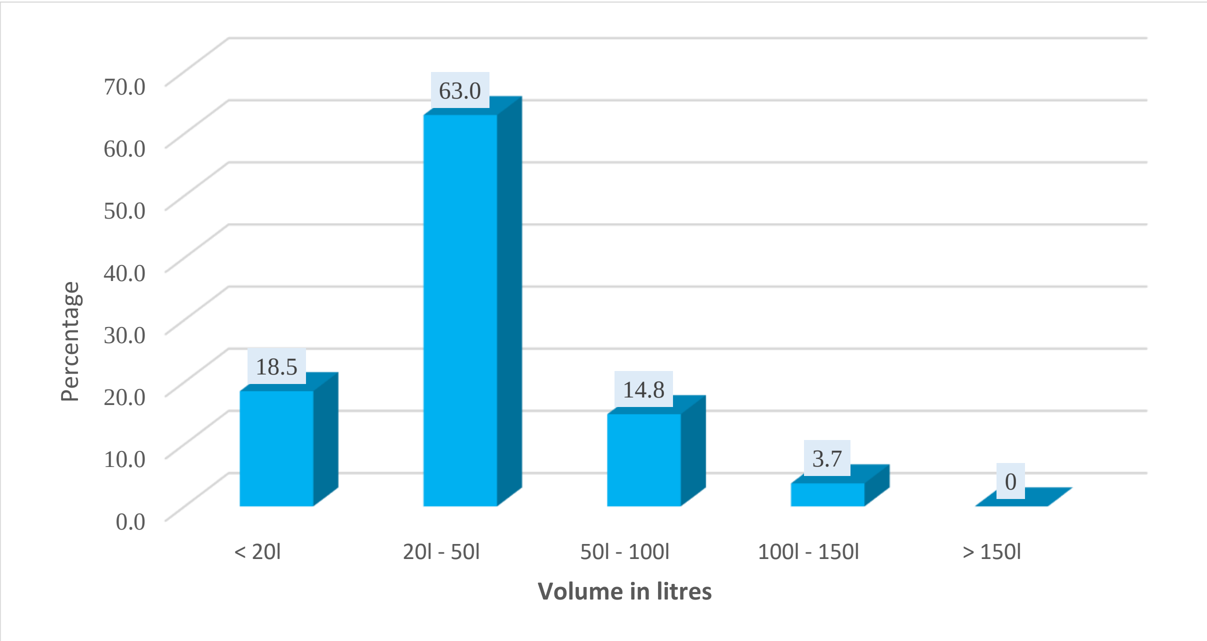

Figure 4:13: Volumes of water collected by households per day.

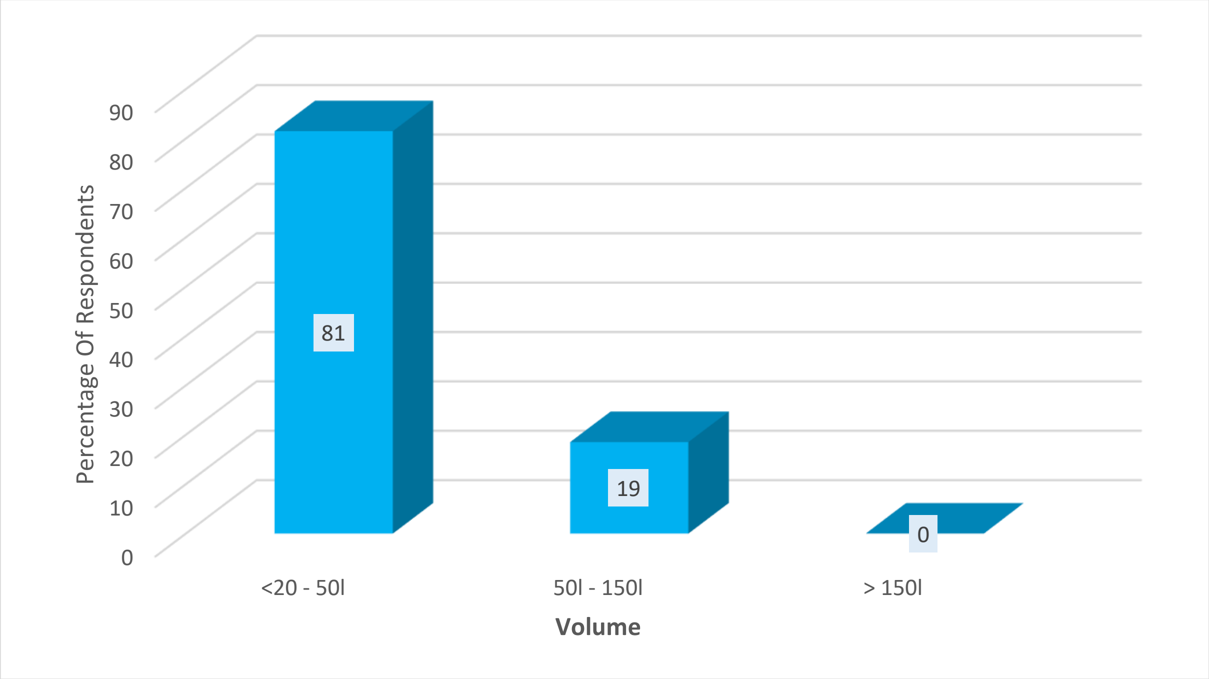

Figure 4:14: Summary of volumes per category.

4.5.1.4 Other water sources

Out of the respondents who participated in this study, 89.9% stated that they do not receive water from any other source than their communal standpipes installed in the area. This is the followed by 7.4 % which was inconclusive because the respondents did not give any response to the question and then lastly, the remaining 3.7 % have indicated that they do receive any water from other sources.

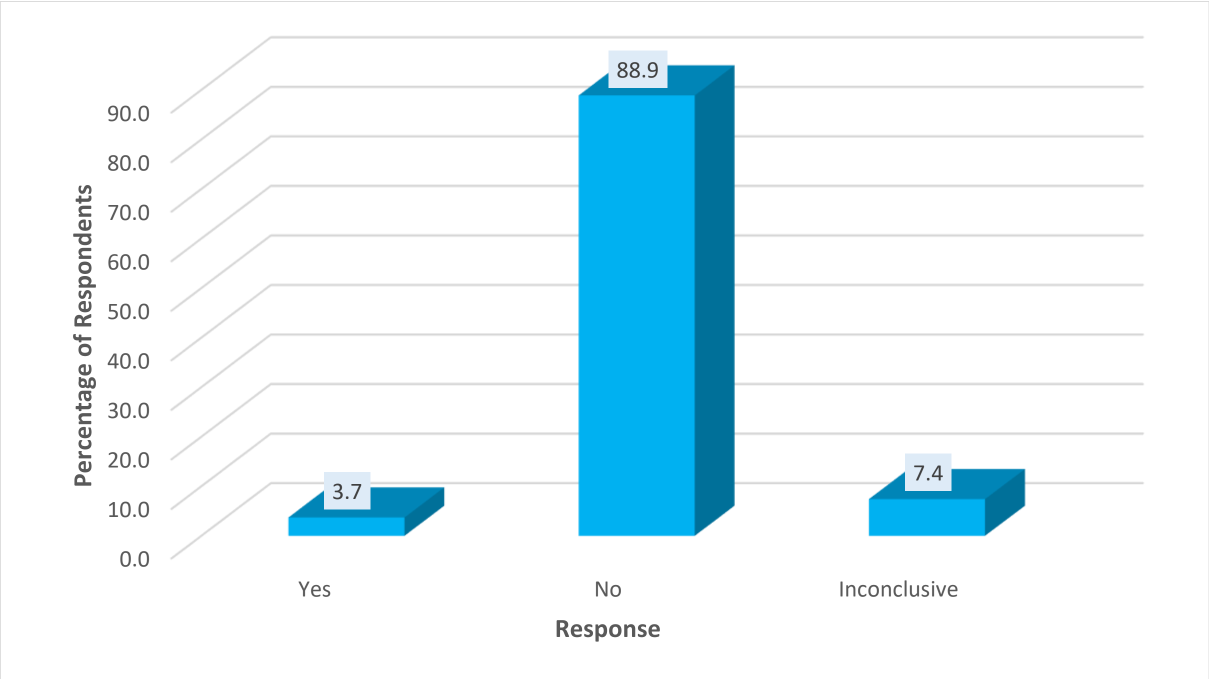

Figure 4:15: Percentage reflecting if respondents receive water from other sources.

4.5.1.5 Main usage of water in the households

It has been captured that 35% of the water that is used in the area is for bathing (Figure 4.16). Residents in informal settlements particularly in the study, make use of washing basins to bath themselves. This is then followed by laundry related activities which takes up 28% of water usage. The amount of water in both of these is determined by the age groups found in the household and by the number of people within a household which includes children/ infants that are often bathed frequently and so is washing their nappies and clothing, thus, increasing the amount of water used for those activities. Therefore, it can be expected that both of these activities generate the largest amount of greywater effluent. The third water intake is for cooking, which is represented by 17 %. This activity does not have much greywater unless in instance of rinsing veggies and foods which consists of starch (e.g.) rice and stamp which is quite a common practise. Nevertheless, usually 90 % of the water used for cooking can only be counted as water loss which generates very little to no greywater effluent. The Forth water consumed in households in the study is for washing kitchen utensils which contributes a total of 10 %. The fifth percentage is for cleaning/ mopping of floors with a percentage of 8% and the last percentage which sits on 2% is for other activities such as irrigation and car washing in households with cars.

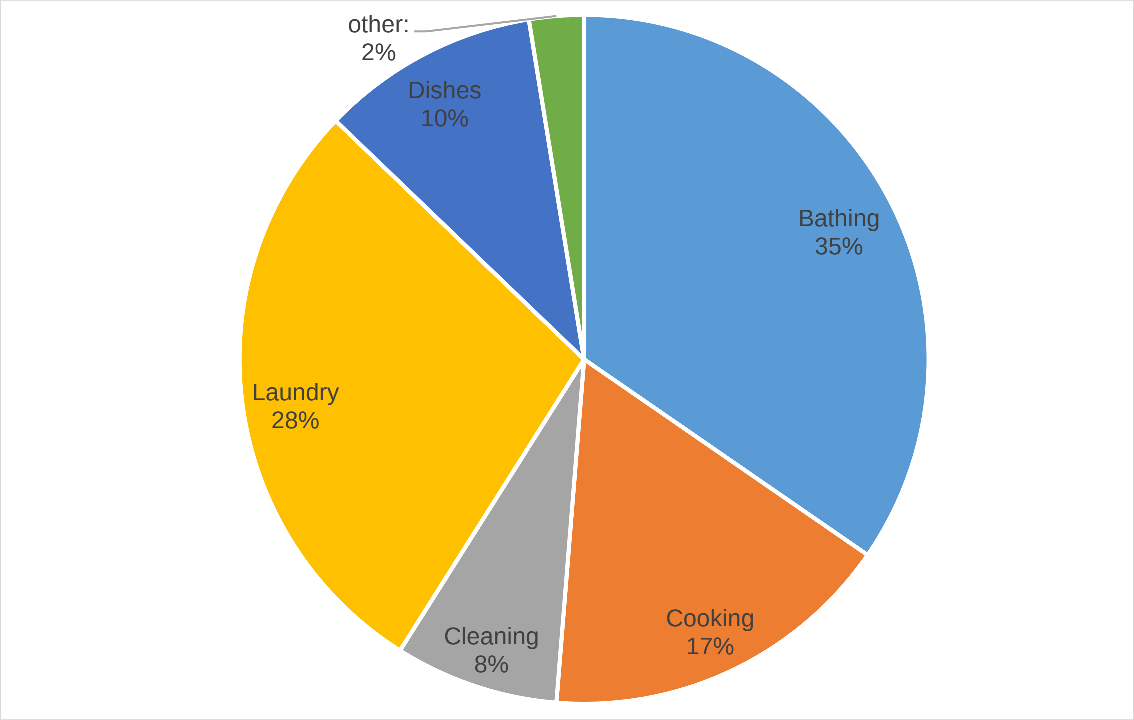

Figure 4:16: Main usage of water per household.

4.5.1.6 Volumes of water that are kept in the household during a single day

The volumes of water kept during the day is based on the assumption that respondents would like to use more water than they currently do and the distance from their household to the location of the standpipe. Respondents (63%) have reported to keep at least a 20l bucket of water as seen in figure 4.17. Following this, 37 % of the respondents have indicated that they keep between 20 – 100 litres of water in their household. This means that those respondents who have more people in their household including children usually keep more than 40 to 50 litres of water in the house.

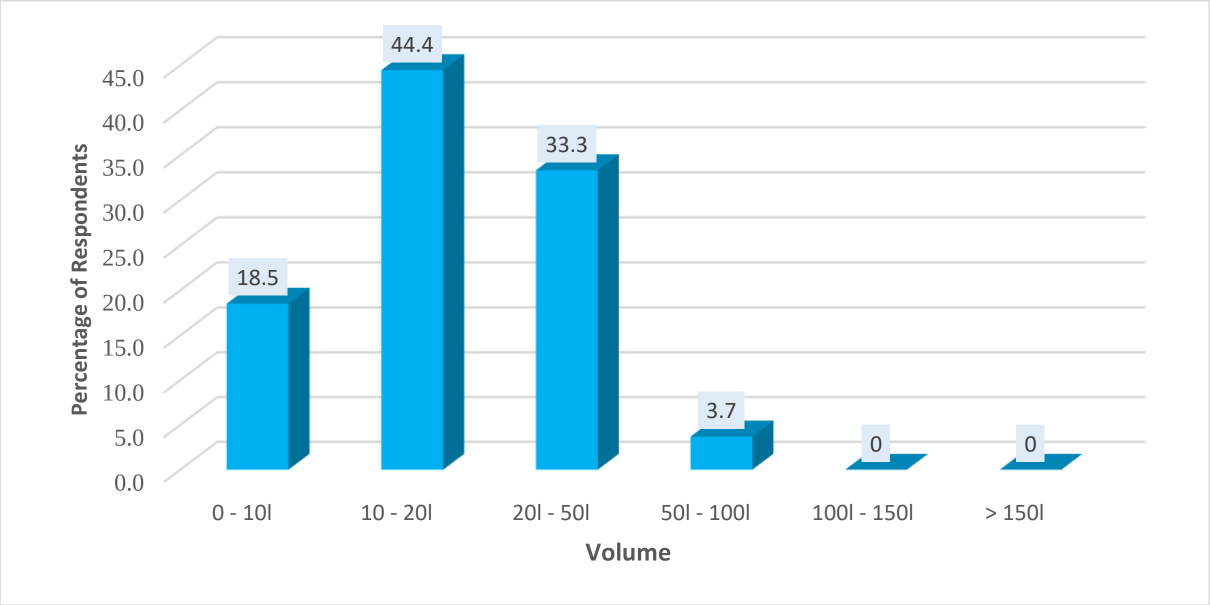

Figure 4:17: Daily volumes of water kept per household

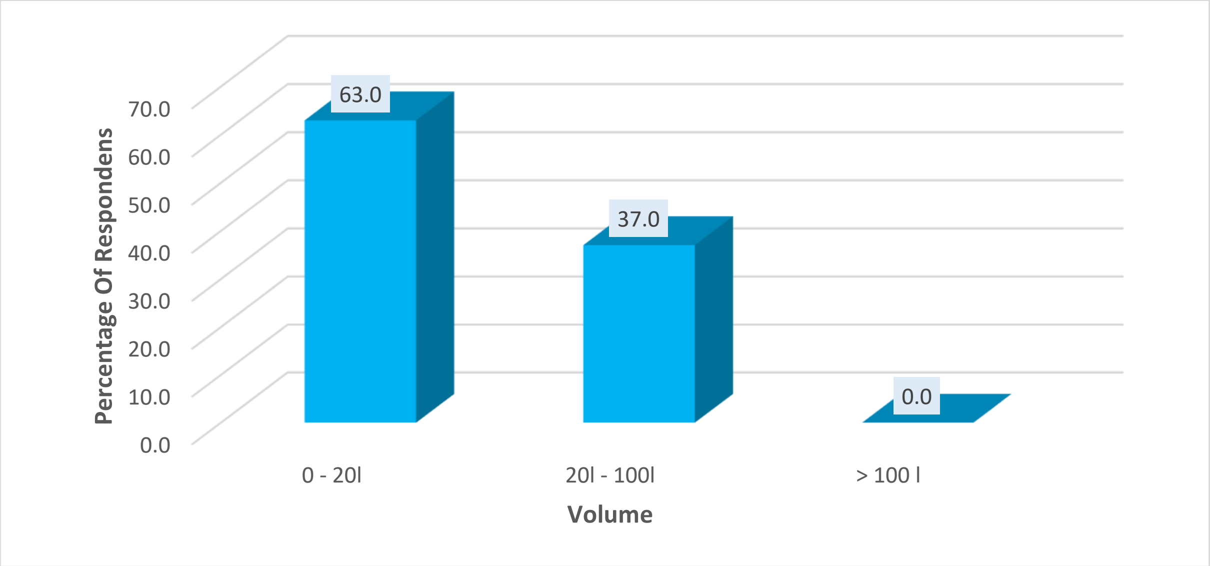

Figure 4:18: Summary of volumes of water kept per category.

4.5.1.7 More Water usage

This section shows the willingness of the respondents to use water from other sources. From this, 59.3 % of the respondents have indicated that they do not want to use more water, while 29.6% indicated that they would like to use more water than they currently do. The hampering effect to this end, is the distance from the communal standpipe to their household and lastly 11.1 % of the response was inconclusive as some of the respondents did not respond to this question.

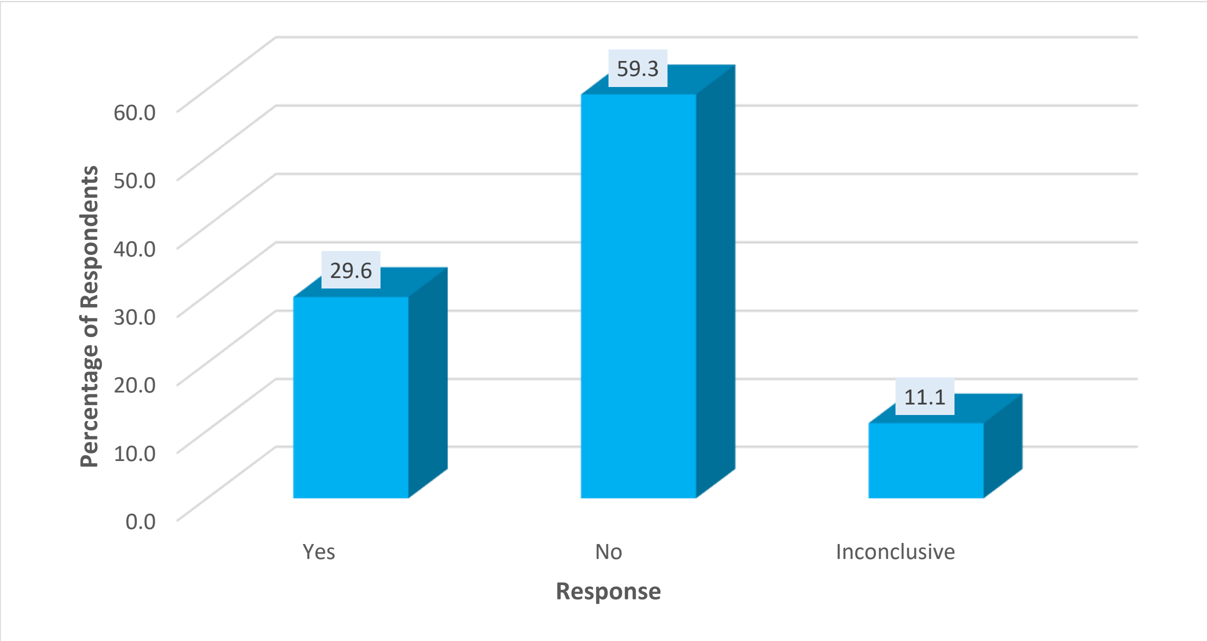

Figure 4:19: Willingness to use more water.

4.5.2 Sanitation

There are different types of sanitation services that the City of Cape Town rolls out to informal settlement communities. The 3 major ones that have been found in recent years in the area are Pour flush (Figure 4.21a), Chemical and portable flush toilets (PFT's). Pour flush toilets is the main type of sanitation facility found in the area due to its location. The area has a heterogeneous landscape with somewhat steep slopes and low-lying areas where water runs and accumulates in the winter season as it is a norm in the area to have excessive winter rainfall. There is no formal reticulation system that is can allow the area to have full flush toilets hence a decision based on site investigations at the time led to the installation of pour flush instead. Pour flush toilets are somewhat similar to full flush in the sense that water is used to get rid of the faecal matter. The only difference is that in this instance, a person must manually do the flushing by using at least a 10 to 20 litres bucket of water which then finds its way into a conservancy tank that is being serviced on a weekly basis. Due to the increase in population and the fact that they use a single toilet which is shared by 5 families as basic services legislations stipulate, some residents have erected their own toilets (pit-liner) which can be also found in the area. In the area, 55% of the respondents make use of pour flush. This is followed by a total of 10/39 (14%) respondents who have erected self-made pit-line toilets. Then 13% which is a combination of A and B section residents (9/69) respondents ask for a toilet to relieve themselves, from residents in nearby settlement called Harare, across the M44 road. Then, another 13% are residents who make use of PFT. The last 4% which is total of 3/69 respondents have indicated that they use the bush especially at night because of either no toilet or the distance is far for the pour flush toilets from the household.

4.5.2.1 Type of Sanitation facility used

Figure 4.20 reflects the types of sanitation facilities that are used in Monwabisi Park. In the study, 55% of the respondents have reflected that they make use of pour flush toilets, while 14 % have reflected that they have erected self-made Pitliners toilets, 13% who are found along the M44 road have reflected that they do not have any sanitation close to them and thus they ask from formal households situated in Harare, then the other 13% makes use of PFT's and lastly the others make use of the open environment around bushes, represented by 4%.

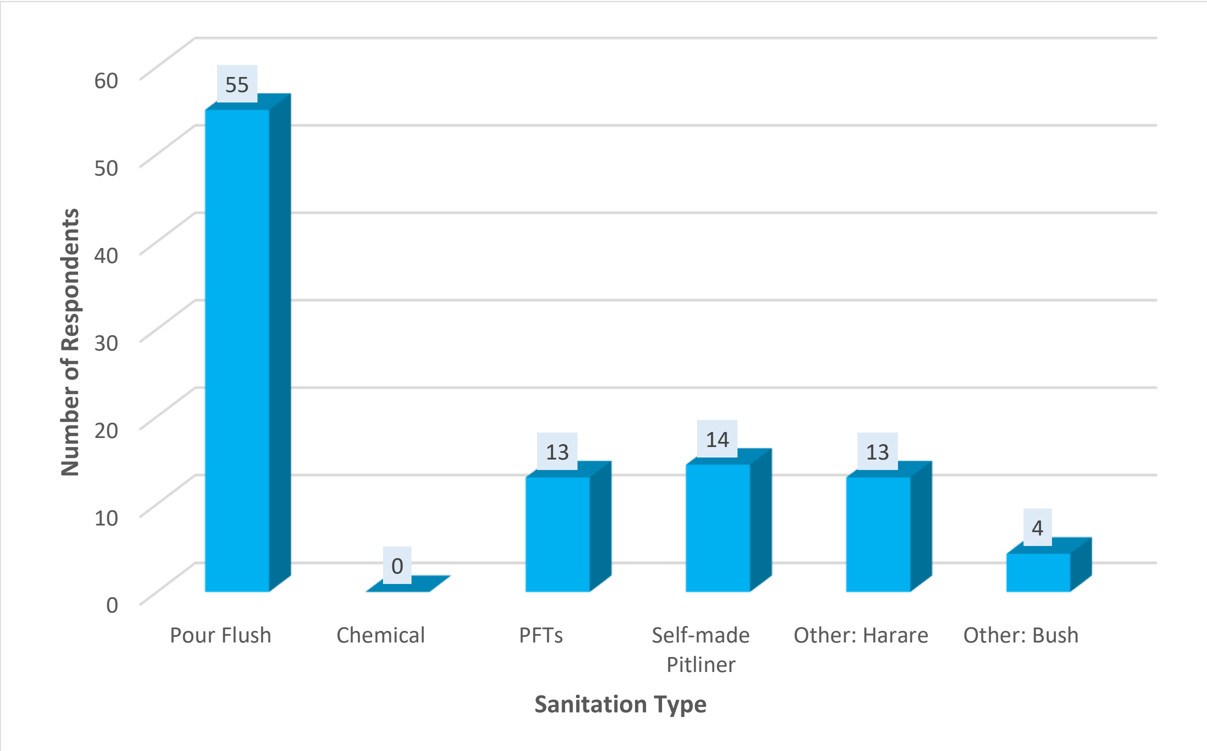

Figure 4:20: Types of sanitation used in the study area.

Figure 4:21: Communal pour flush toilets.

4.5.2.2 Nearest Sanitation facility

Most of the toilets in the area have been placed in areas where the ground is level and where the servicing company is able to enter. As a result, other residents are far from the areas where they have pour flush toilets, especially the ones that live in steep slopes. This means that they must walk down or up to get to the toilets to relieve themselves. As a result of this, other households either make use of self-made Pitliners, PFTs, using the bush to relieve themselves and asking from formal settlements to use the bathroom.

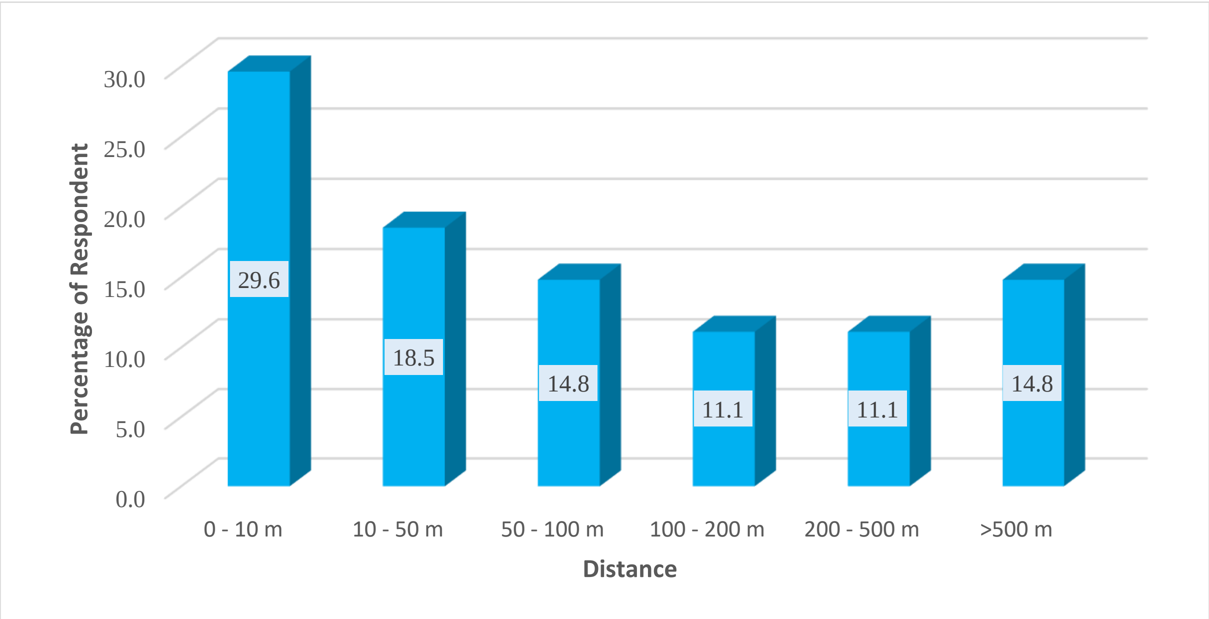

Figure 4:22: Distance to the nearest proper toilet facility.

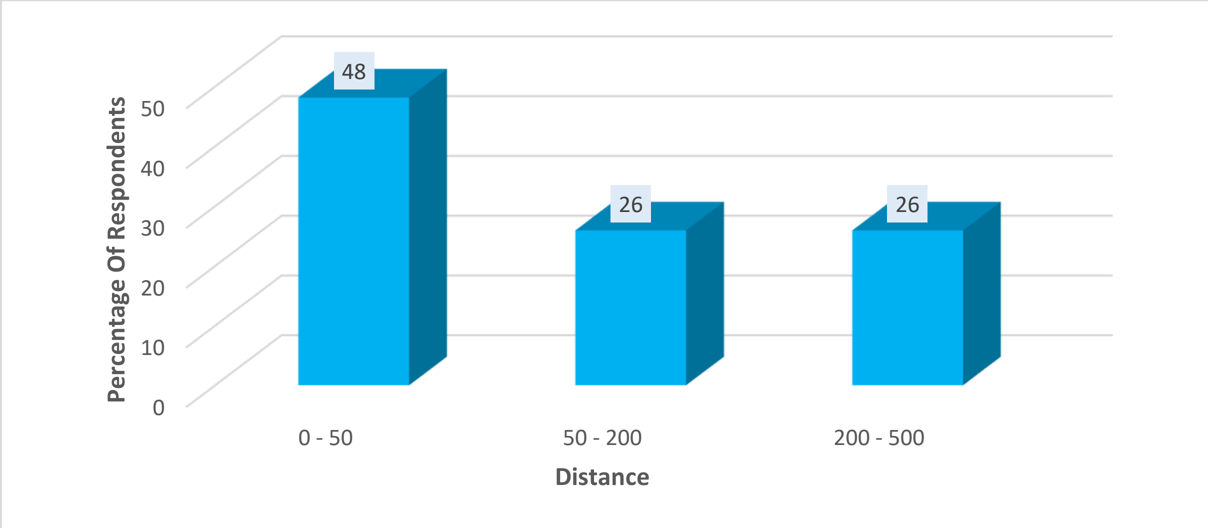

Figure 4:23: Summary of distance from communal sanitation facility to the household of respondents.

4.5.2.3 Daytime and Night time used of Sanitation facilities

Some residents have indicated that they do not use the toilets at night due to crime. There are generally high crime rates that occur mostly at night in the area and women and children are at risks of being raped and for males at night, they risk being robbed or murdered (Grasveld and Mdedetyana, 2016). Figure 4.24 below reflects that 66.7 % of the respondents say they use toilets at night, and these respondents reside close to the communal pour flush toilets that is why they are able to use it at night. Following this, 29.6% of the respondents have reflected that they do not use the toilets at night. Lastly, the other 3.7% reflects a combination of those that ask to use the toilet in the formal houses of Harare, PFTs, using the bush and self-made Pit-liner toilets and thus, therefore these are those who do not use the communal pour flush toilets at night.

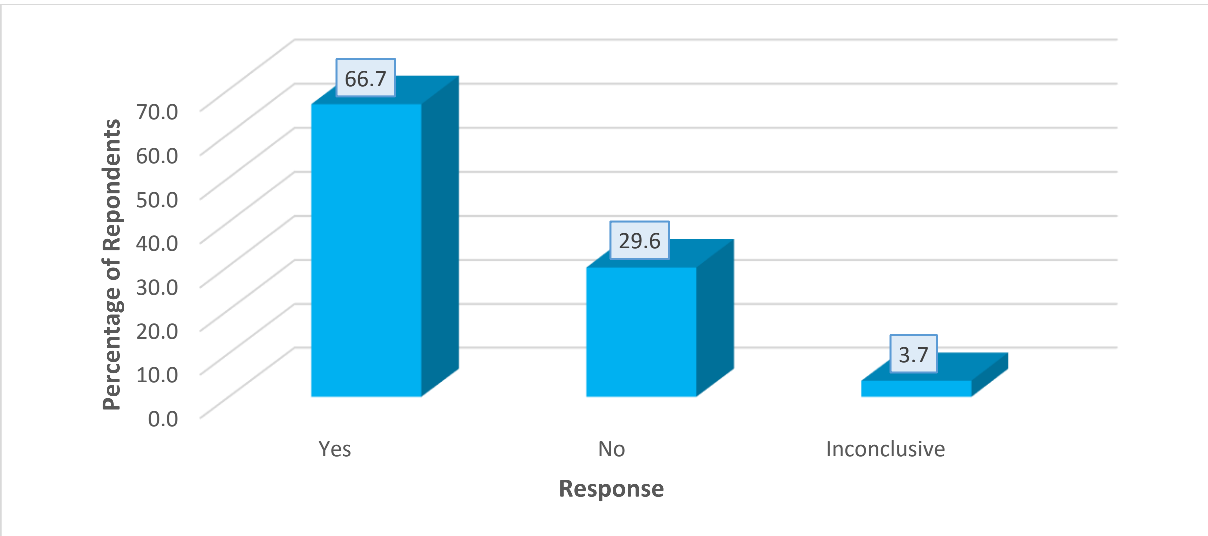

Figure 4:24: Usage of communal sanitation facility at night.

4.5.2.4 Hand washing facilities

The respondents were asked if there are any hand washing facilities around the toilets and 88.9 % of them indicated that there are no hand washing facilities, while 3.7 % indicated that they have hand washing facilities and 7.4 % was inconclusive as some of the respondents did not give any feedback to this question. The only facility that is near the sanitation service points is only water service points (communal standpipes).

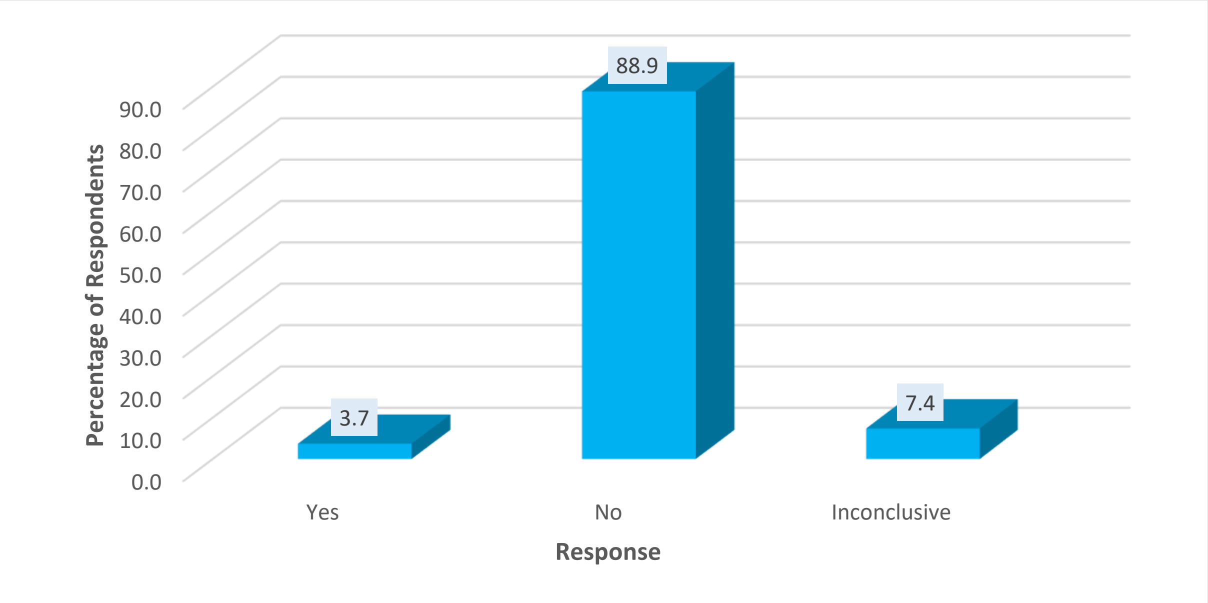

Figure 4:25: Presence of hand washing facilities from the toilets.

4.5.2.5 Amount of water used for flushing

Figure 4.26 below shows the volume of water used for flushing the communal pour flush toilets. In their response it has been revealed that 78% use from 0 – 20 l of water to flush the toilet (7.4 %, 0 -5l, 48.1% is for 5 l -10 l, while 22,2 % is 10 l – 20 l); 11,1% use 20 l to 30 l; and the remaining 11.1% was inconclusive as they are the residents that make use of toilets in formal households.

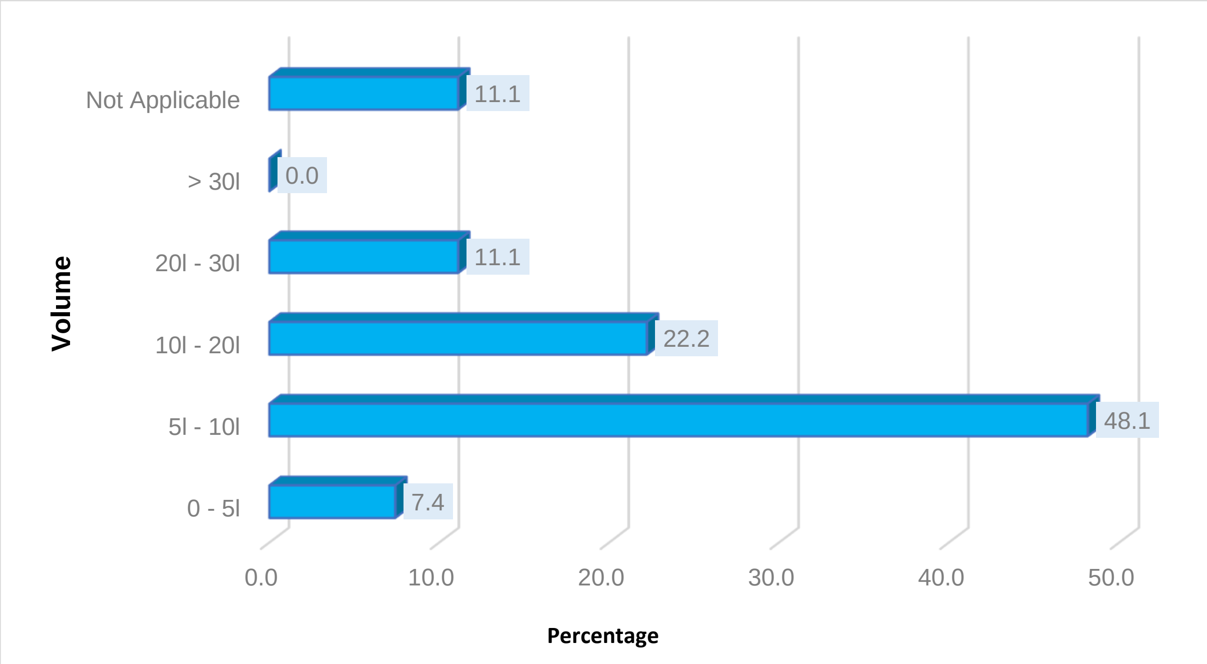

Figure 4:26: Percentages of respondents using certain amount of water for the toilet facilities.

4.5.2.6 Source of flushing water

The respondents were asked about the source of the water they use for flushing toilets. As shown in figure 4.27, 70.4% of the respondents use clean drinking water from the communal standpipes while 14.8 % make use of laundry greywater, 3.7 % make use of bathing greywater from washing basins. The remaining 11.1 % of these respondents is not applicable as they make use of toilets in the formal settlement.

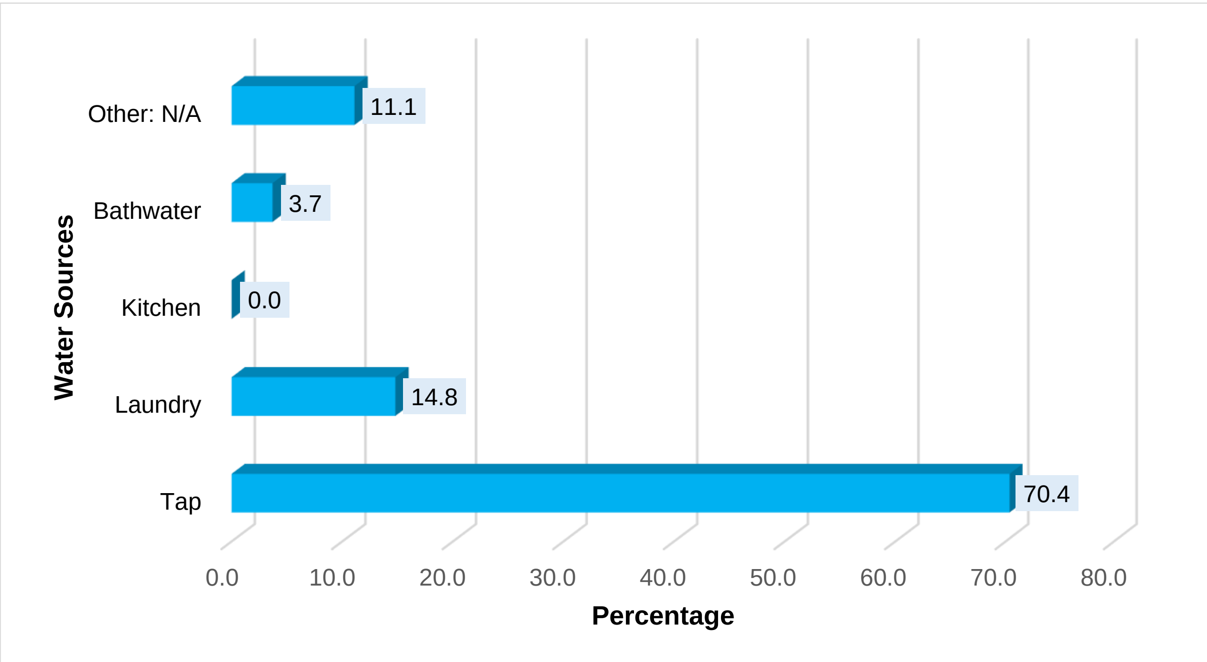

Figure 4:27: Source of greywater used for flushing communal toilets.

4.5.2.7 Distance from the household to water and sanitation facilities

The distance from the respondent's household to both sanitation service point and water service points were compared and it is shown in Figure 4.28. When it comes to the distance from the respondents' household to the sanitation services point 29.6% respondents are between 0-10 meters, while 18.5% where between 10-50 m, 14.8% is between 50-100m, 11.1% is between 100-200 and 200-500 m and the remaining 14.8% is greater than 500 meters from the sanitation points. Secondly, when it came to water service points, 22.2% respondents are between 0-10 meters, while 25.9% were between 10-50 m, 22.2% is between 50-100m, 11.1% is between 100-200, and lastly, 18.5% is between 200-500 m.

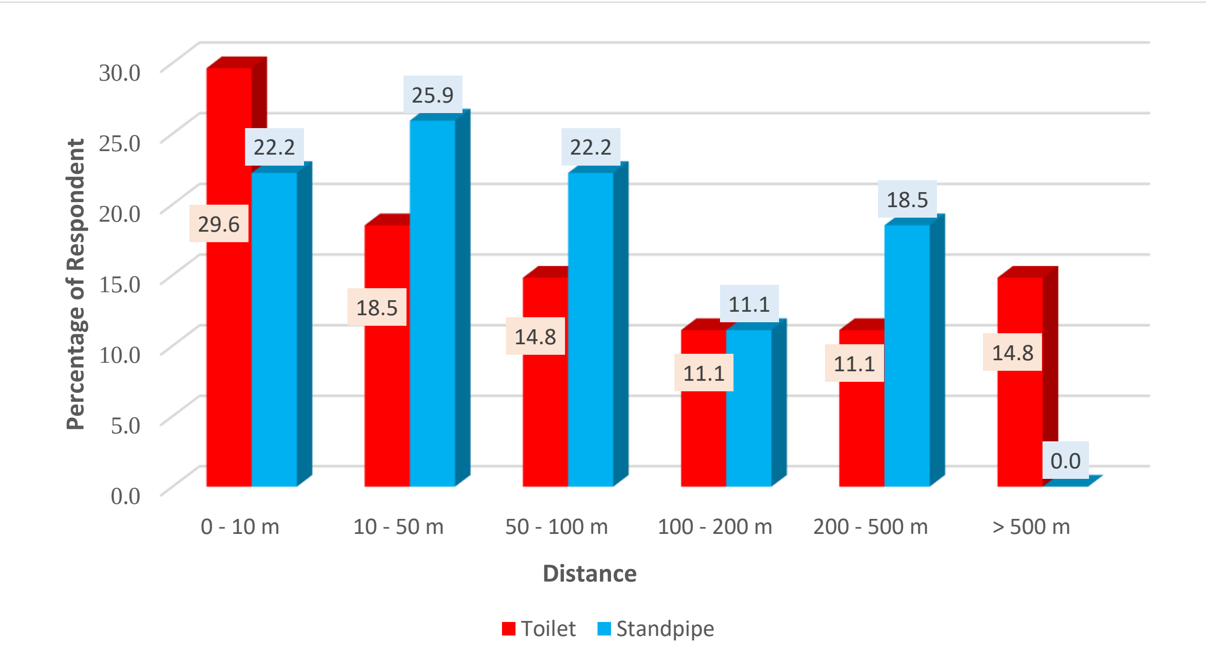

Figure 4:28: Distance from water services points versus sanitation service points.

4.5.3 Water kept and water used

Figure 4.29 shows both the water that is usually kept by the respondents in Monwabisi Park, together with the water that is consumed daily for various domestic activities in the household. As can be seen from Figure 4.29, the daily use of water is between 20 to 50 litres while the residents usually keep most at least a 20l of bucket of water throughout the day. From the questionnaire it is evident that the influence for this is due to the number or people living in the household, the demographical characteristics and their lifestyle. The residents with many children in the household use more water on a daily basis than those households dominated by adults.

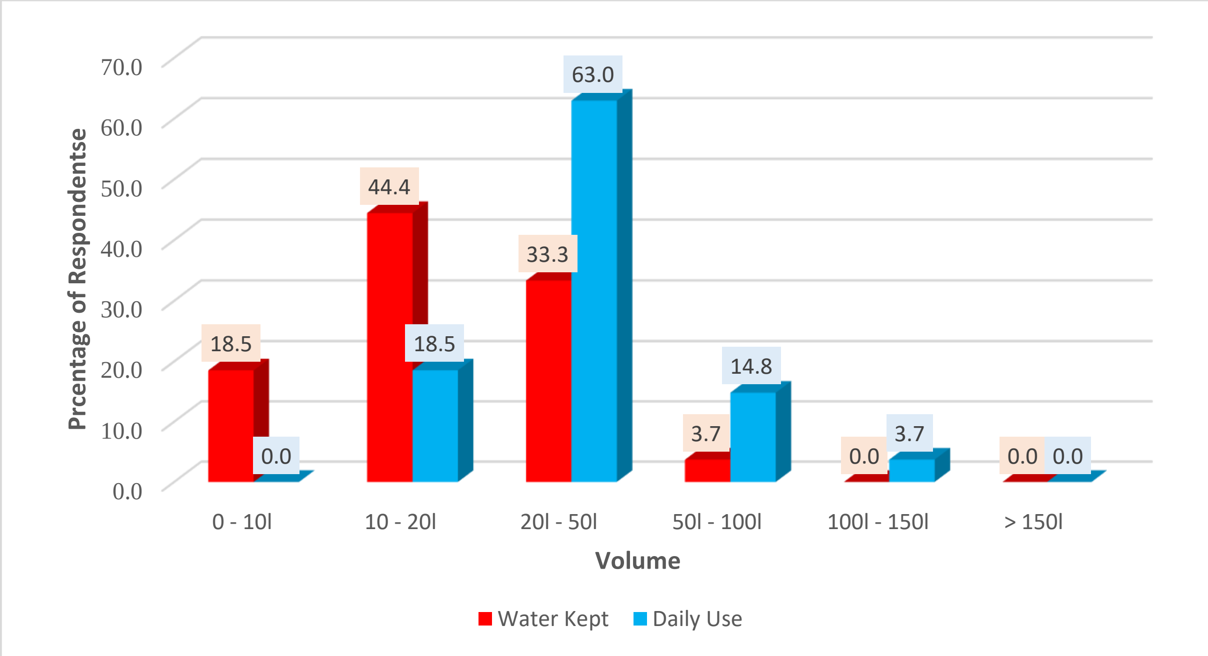

Figure 4:29: Volumes of water kept versus daily water used.

4.5.4 Comparison

Various response with regards to finding out if the respondents receive water from other sources (Q13), if respondents would like to use more water (Q16), if the respondents make use of the communal sanitation service points, for both day time and at night (Q19) and the presence of handwashing facilities near the sanitation service point (Q20), were compared amongst each other as shown by Figure 4.30.

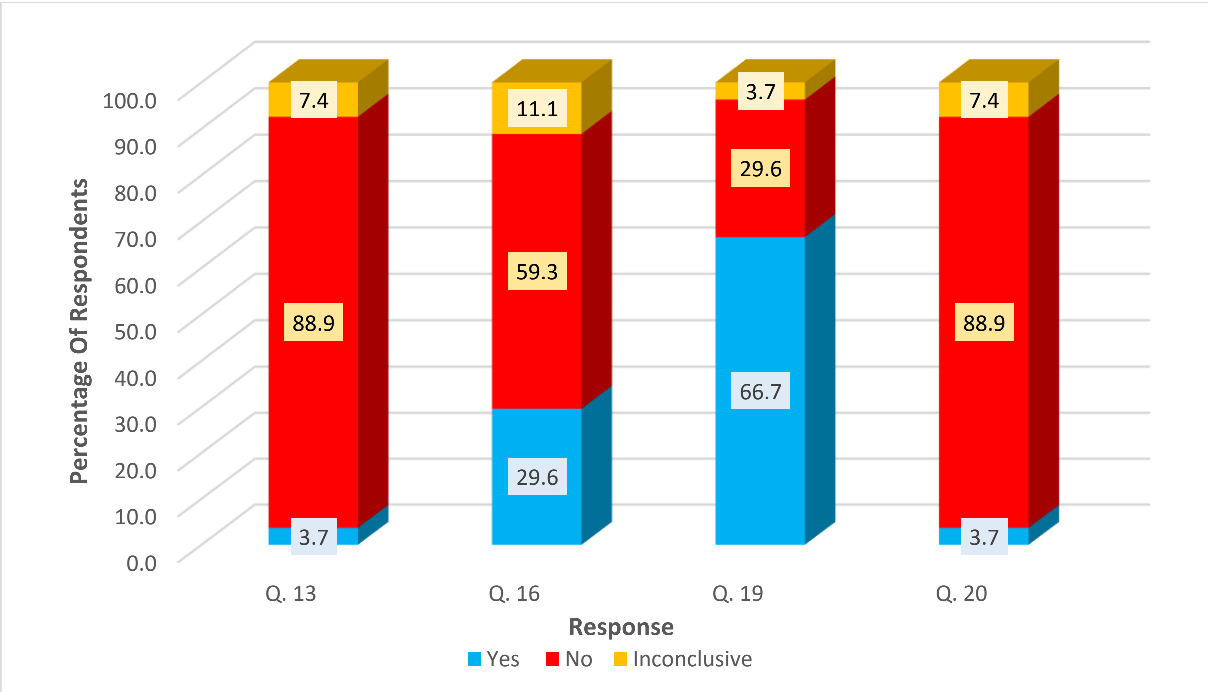

Figure 4:30: Agreement with the respective questions.

4.5.5 Particular water usage for domestic activities

This section aims to get into more detail regarding the general usage of fresh water systems from an informal settlement perspective. This is of importance in that the patterns, frequency and the manner water is used by households in informal settlements can be controlled by various factors which is different from its formal settlement counterpart. Moreover, for non-sewer or settlements that do not have a reticulation system, there is no mechanism that is able to collect and direct waste water to a treatment facility in large volumes that can be treated for reuse? For other purposes or disposed after having met greywater recharge standards set in the country. The Monwabisi Park informal settlement in this instance can be predominantly classified as a non-sewer settlement. Owing to this, there are different sources of greywater effluent produced around the household of informal settlements (Figure 4.31). For each of these sources, the extent to which resident reuse and how they dispose greywater, is based on their physical and locational settings (Figure 4.32 – 4.41).

Some types of greywater effluent can be an input resource for other activities around the household that do not necessarily need the use of clean water. The idea behind this thinking also incorporates sustainable use of fresh water as it is a scarce resource. The foundation of this thinking is to enforce sustainable development in water resource management initiatives which will be able to restore and maintain a continuous flow of fresh water. During the collection of data in this study, the general notion observed was that communities are aware of waste water resources from a basic perspective. However, they are not adequately informed of their types and the extent to which they can be utilised as a resource or an input for other uses.

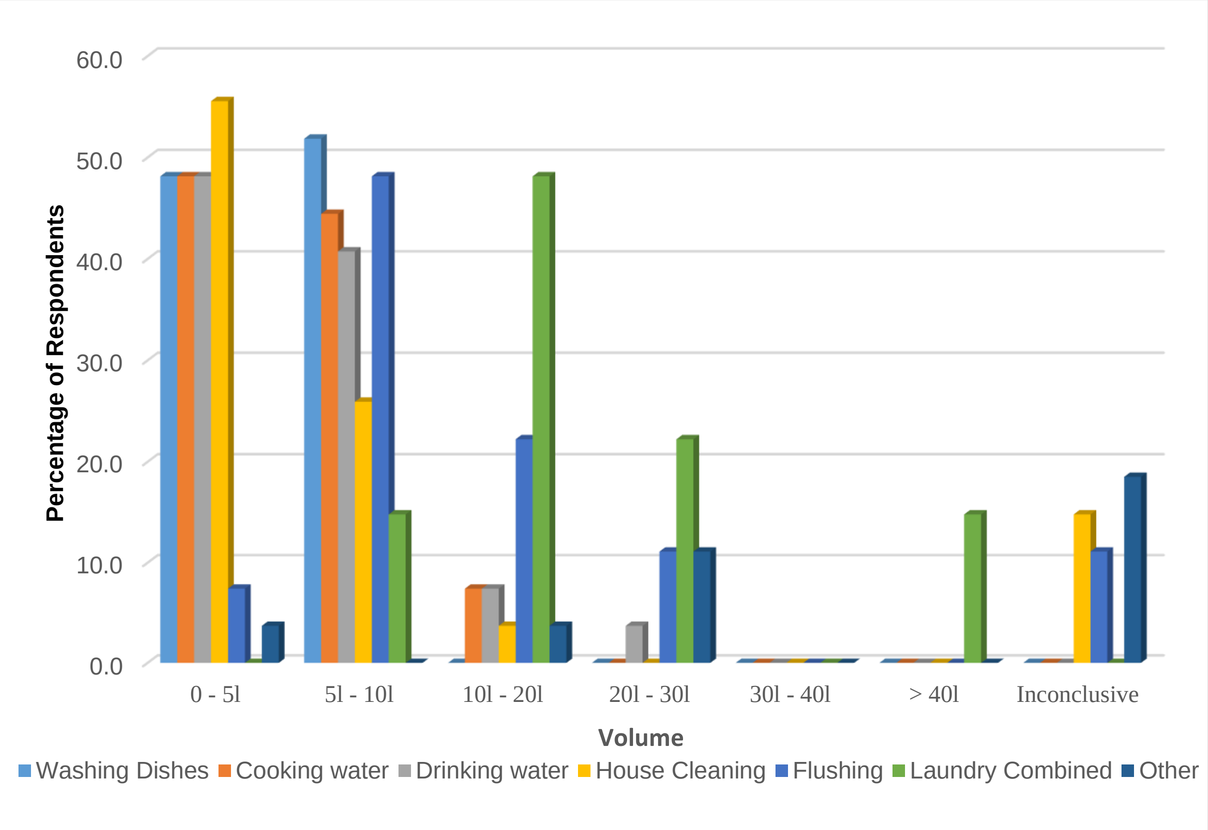

Figure 4:31: Domestic water loss and usage per households.

4.5.5.1 Cleaning and Flushing Water

Figure 4.32 shows the source of cleaning and flushing water. Basically, most of the time residents prefer to use clean water from the tap for flushing toilets and for cleaning their house as represented by 70.4 % and 56.1%, respectively. This is followed by the use of laundry rinse water for flushing (14.8% and14.6%). Some have indicated that they also use kitchen rinse water (7.3 %) and bathing water to clean their households (3.7%) and bathing water for flushing (12.2 %). The other categories that have been reflected as not applicable are those residents that use toilets in Harare (11.1%), hence there is no flushing water that they make use of and indicated other sources of water (9.8%) which was not specified for cleaning. Since the residents use the formal adjacent area to use the toilet, the response of not applicable has been denoted.

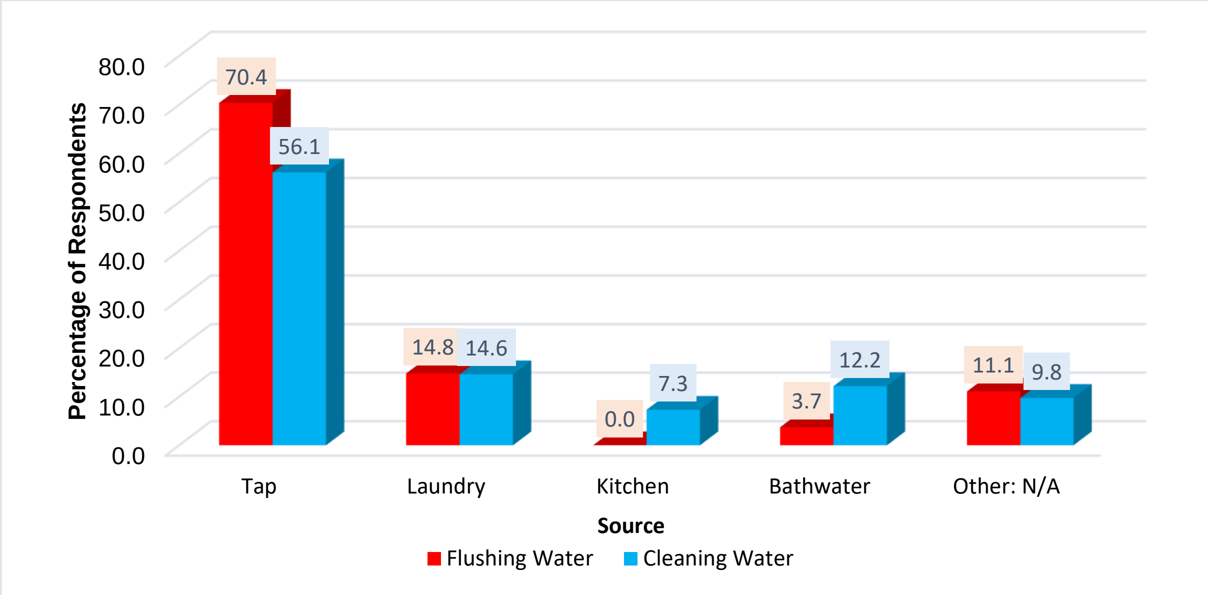

Figure 4:32: Source of water used for cleaning versus flushing.

4.5.5.2 Kitchen water

Figure 4.33 shows the greywater effluent from kitchen first wash water and rinse washing of kitchen utensils which is disposed on the street (Figure 4.34a). As can be seen below on Figure 4.33, 85.2% of first wash is disposed, while 53.6% of rinse wash is disposed by being thrown away on the street. Following this 3.7% of first wash is used to water plants while 3.6 % of rinse wash is also used to water plants. Then 7.1 % of rinse wash is used to rewash kitchen utensils, 10.7% used for cleaning floors, 3.7 % is disposed through flushing of toilets 7.1 % is used for flushing toilets and 7.4 % is used for other purposes that were not specified and so is 17.9% of rinse wash of kitchen utensils.

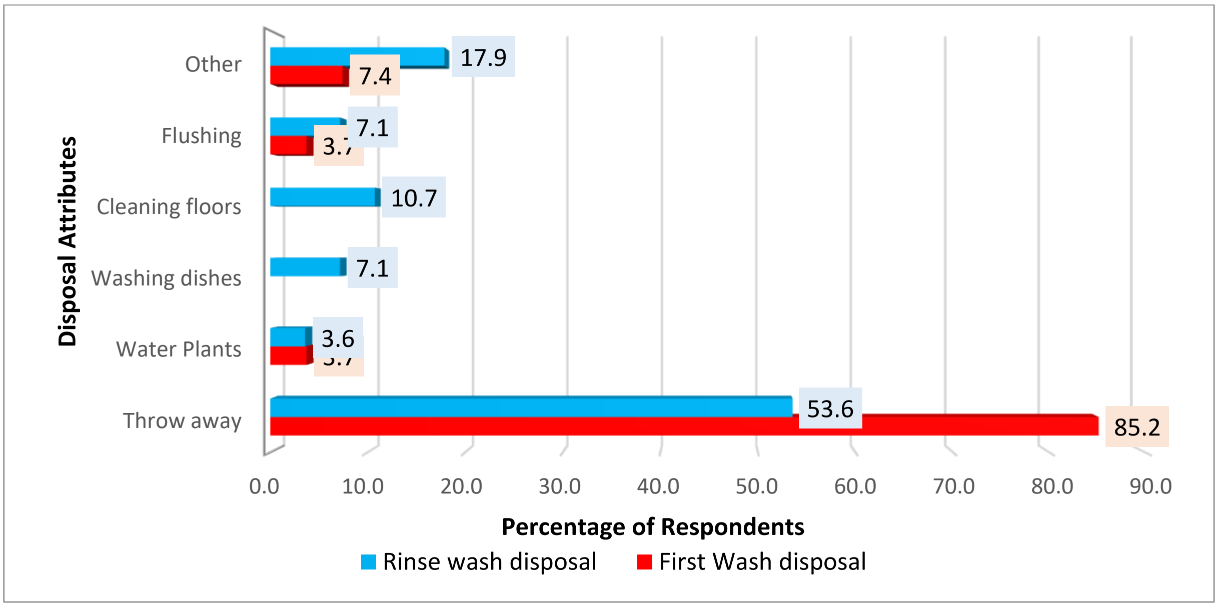

Figure 4:33: Water used to wash kitchen utensils versus rinse wash water.

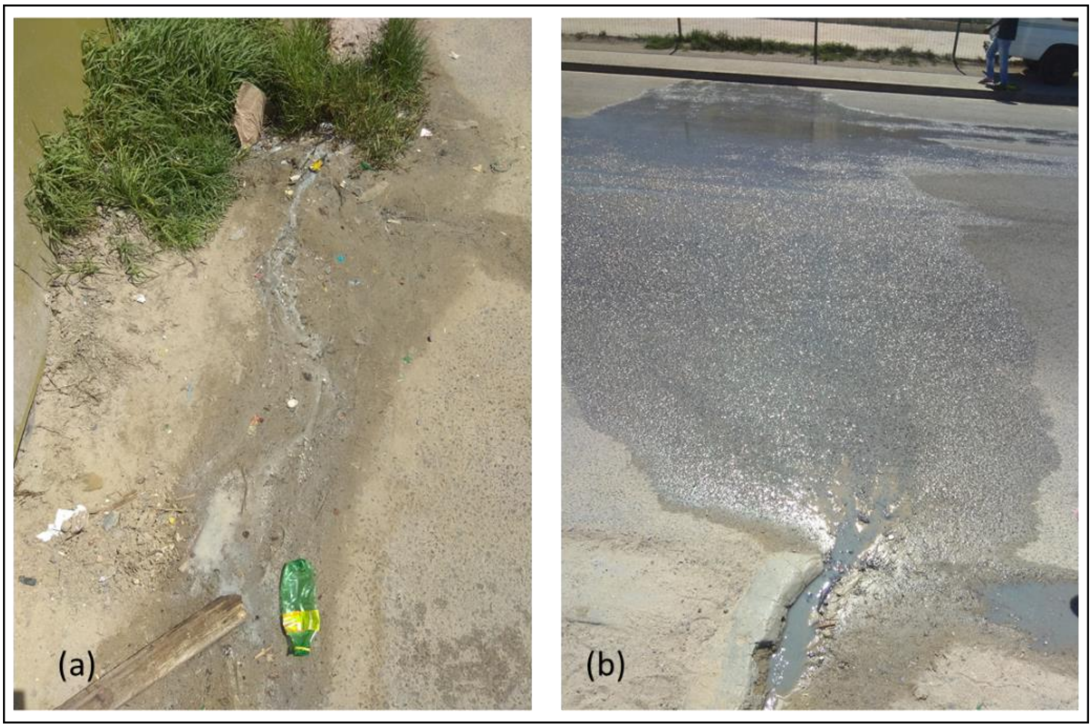

Figure 4:34: Kitchen and laundry greywater.

4.5.5.3 Laundry Water

Figure 4.35 shows the disposal of laundry first wash (85.7 %) and rinse wash (58.6 %) in which the respondents have reported that they throw it away (Figure 4.34 b). Following this 3.4% of laundry rinse water is used to water plants, 14.3 % of first wash is used to rewash and 27.6% of rinse wash is used to rewash laundry again. Only 10.3% of rinse wash is used for the flushing of toilets.

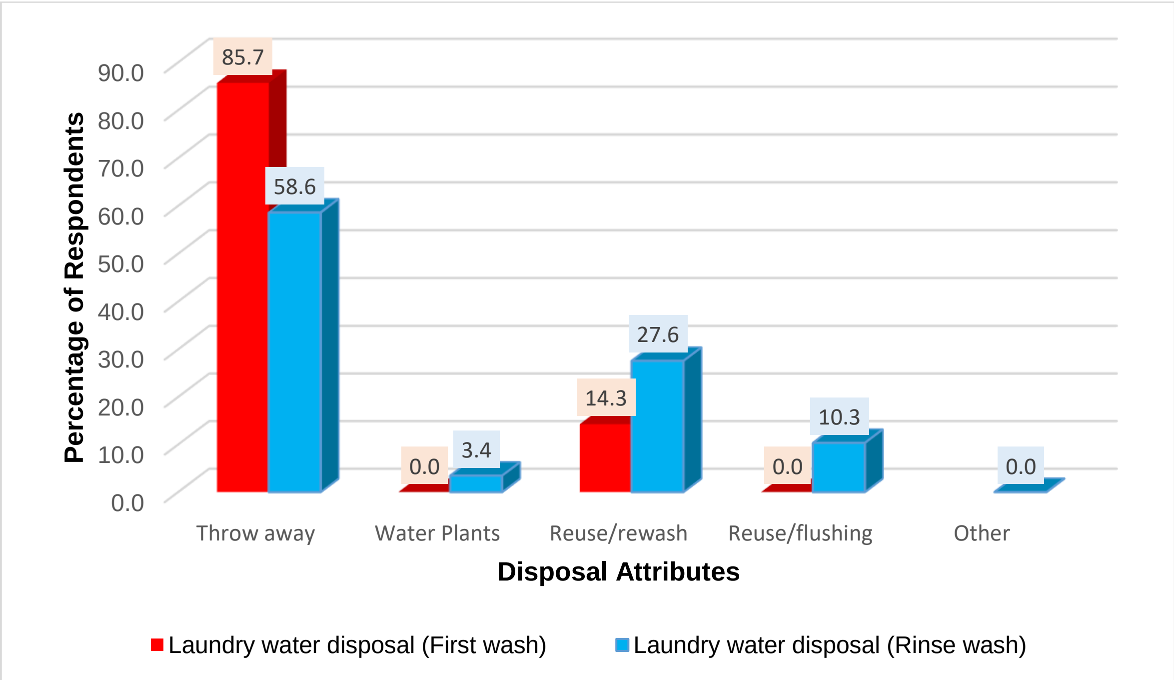

Figure 4:35: Disposal of laundry first wash versus rinse wash.

4.5.5.4 Washing kitchen utensils and bathing frequency

Figure 4.36 shows the frequency of washing kitchen utensils and bathing in which 77.8% of the respondents wash themselves once a day and 66.7% of kitchen utensils are washed once a day. Following this, kitchen utensils are washed twice per day as represented by 33.3% while 18.5% reflects bathing twice a day. Then 3.7% respondents indicated that they wash three times a day which is mainly households with infants and young children.

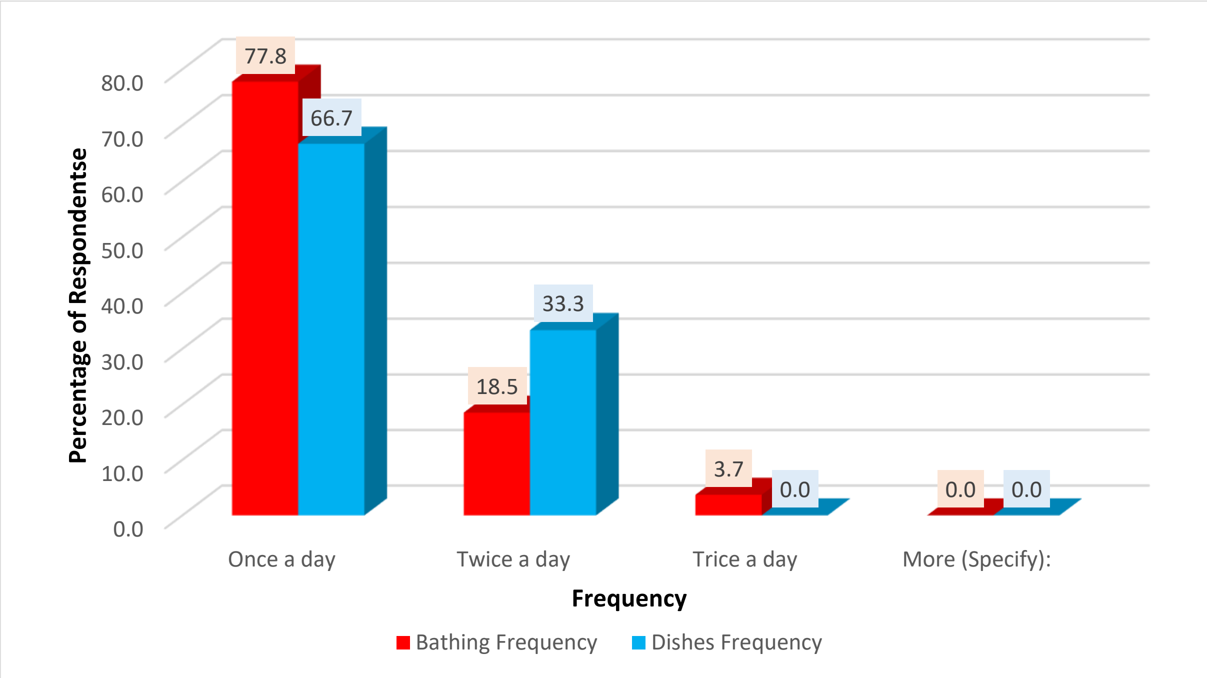

Figure 4:36: Washing of kitchen utensils frequency versus bathing frequency.

4.5.5.5 Laundry and House cleaning Frequency

Figure 4.37 shows the frequency of laundry and cleaning in which 40.7% of the respondents clean their floors once a day. This is followed by 55.6% of the respondents who have indicated that they do laundry twice a week while 33.3% have indicated that they clean their floors twice a week. A further 29.6 % do their laundry three times a week. Households which have infants and young children have specifically reflected that they do their laundry twice a day (14.8%) and clean twice a day (7.4%). Other respondents have reflected that they clean their house once a week (3.7 %) and lastly 14.8 % have reported that they do not use any water for cleaning.

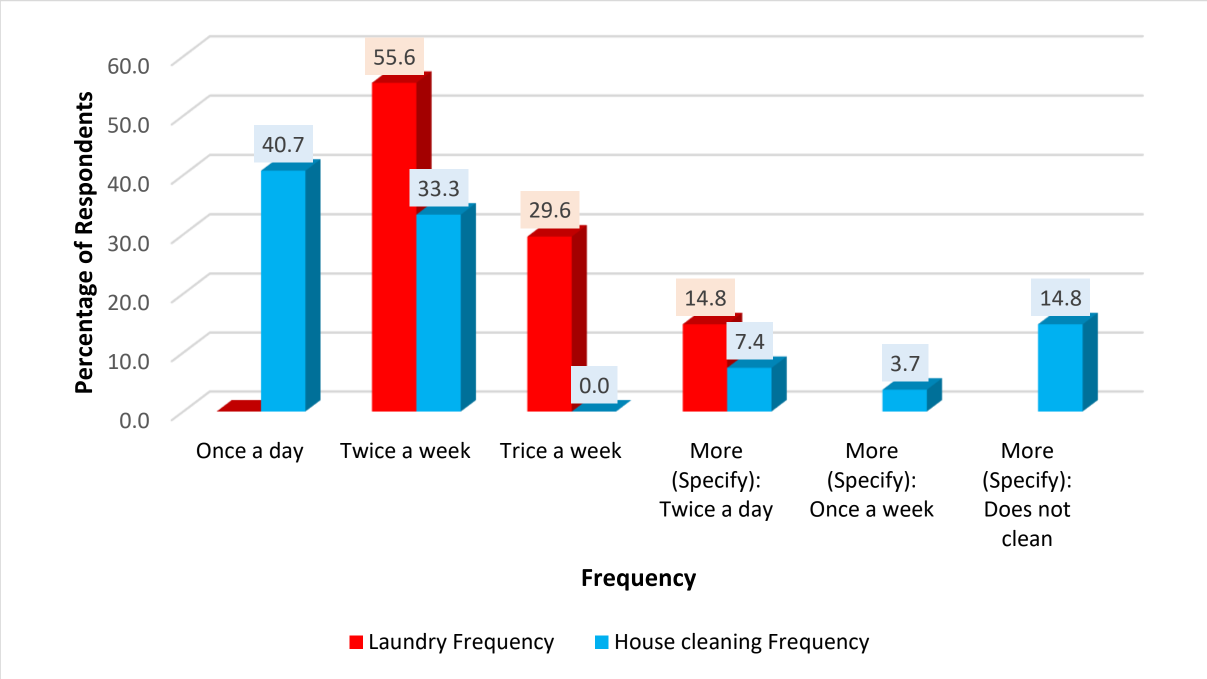

Figure 4:37: Laundry and house cleaning frequency.

4.5.5.6 Disposal of house cleaning and bathing greywater

Figure 4.38 below shows the disposal of cleaning water and bathing water in which 88.9% and 77.8 %, respectively is thrown away on the streets. Following this, 11.1% of bathing water is reused for flushing and 7.4% of cleaning water is used for flushing. The other 14.8 % of cleaning water was reflected to be used for other functions which were not specified.

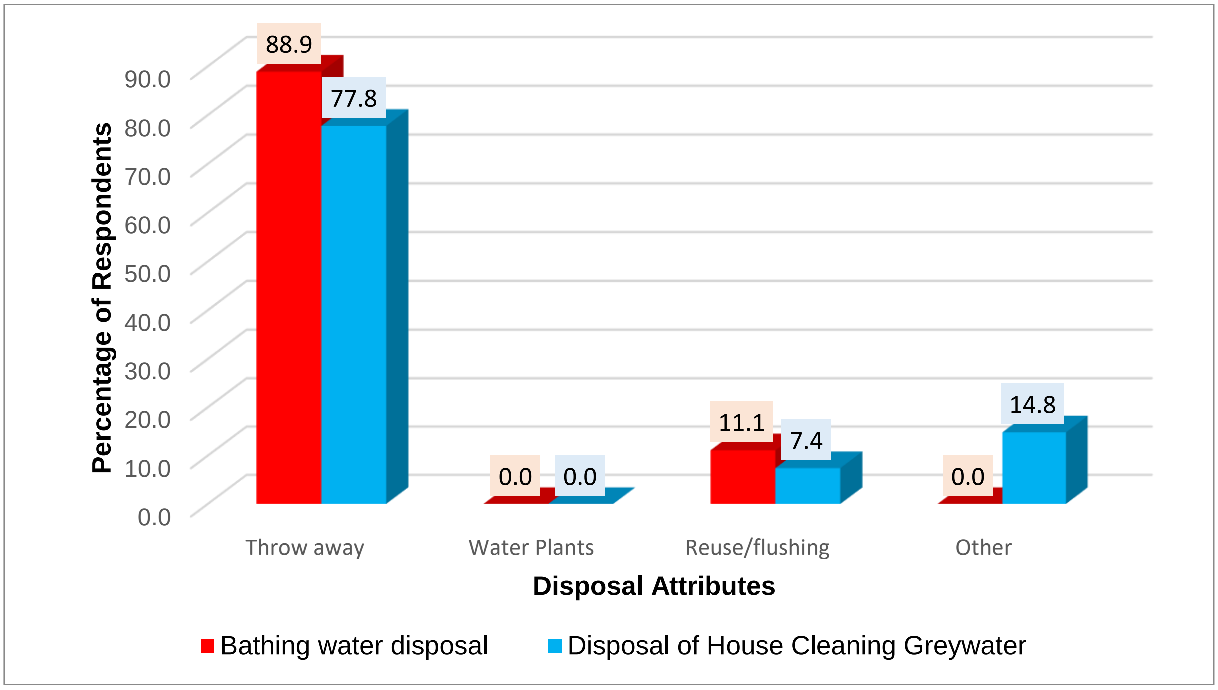

Figure 4:38: Disposal of house cleaning and bathing greywater.

4.5.5.7 Cleaning Products

Although the study does not focus on any greywater quality tests, the questionnaire also incorporated asking the respondents about their choice of cleaning products from the various household for domestic activities. When the respondents were asked about their choice of detergents for bathing, washing kitchen utensils and doing laundry the most common answer was the use of sunlight products. They have stated that it is a norm also for them to use the green sunlight soap across the activities in the household. Not many of them make use of fabric softer particularly sta-soft as a choice and some have generally indicated that sometimes they make use of bleach or jik. When it came to their washing powder choices, they have pointed out that they use mostly Sunlight, Aerial, Maq and OMO in that order. They mentioned that their choice of washing powder was also linked to the market price at the particular time of purchase. In other instances, they also use Sunlight soap when they run out of their washing powder. For the kitchen the respondents indicated that they use Sunlight, Maq and no name brands or the retail stores' brand as a choice of dishwashing liquid and/or Handy Andy as a brand or the retail store brand which is normally based on its affordability at the time it was purchased. The level or percentages of the uses of all these products are represented in Figure 4.39 – 4.42.

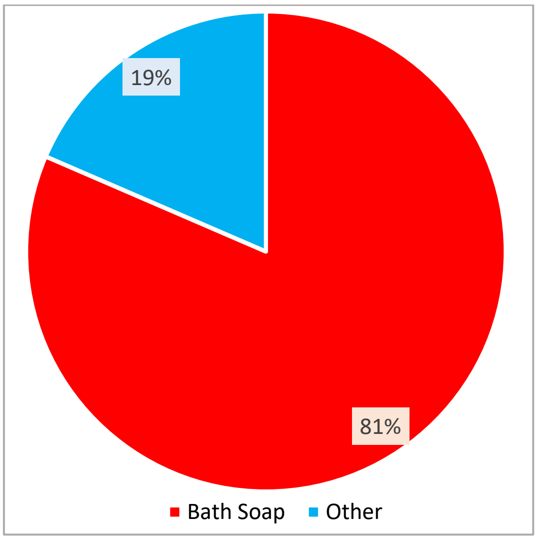

Figure 4:39: Bathing products used.

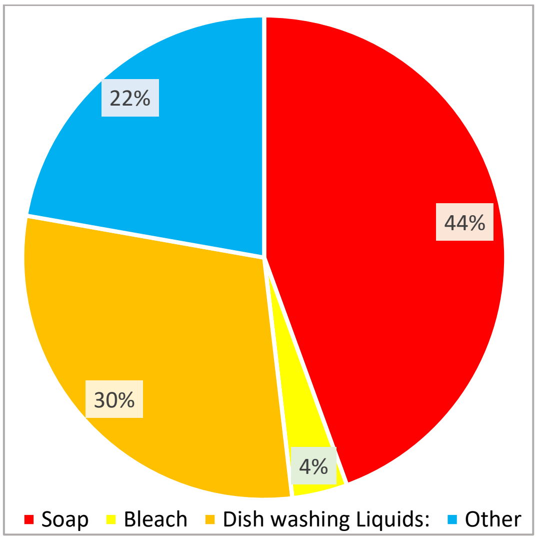

Figure 4:41: Dish products used.

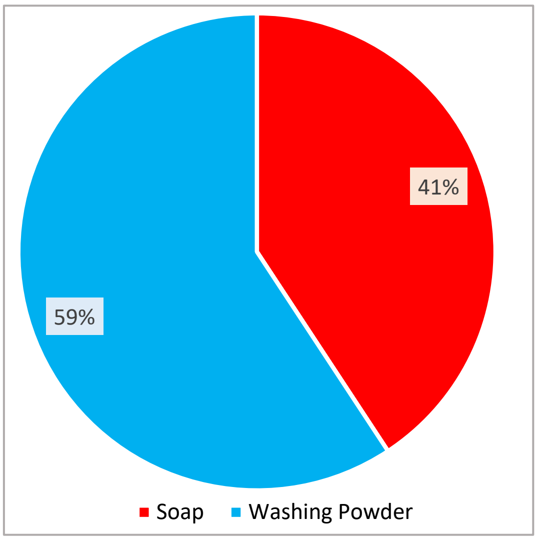

Figure 4:40: Laundry products used.

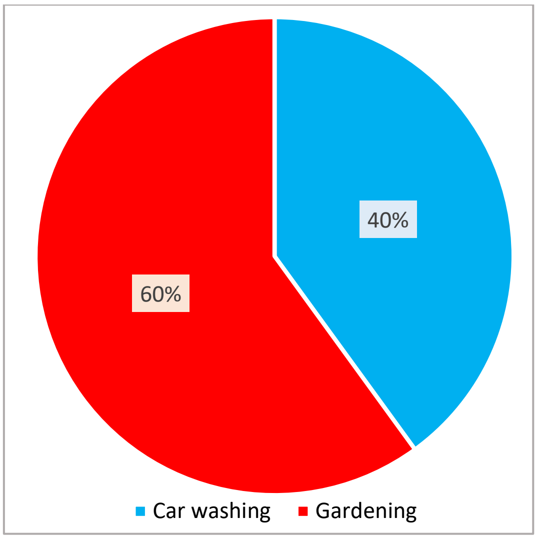

Figure 4:42: Other uses of water around the household.

4.6 Greywater Management

This section involved a few open-ended questions which were intended to elicit opinions in the use, recycling, environmental health and disposal issues that are associated with greywater effluent in the study area. Most of the respondents indicated that they prefer to throw away all their types of greywater effluent in the preceding sections, while others prefer to reuse or re-wash some of it particularly when it comes to rinse water. The researcher has observed that the perception of the respondents is shaped by their knowledge, socio-economic status and the manner of their living conditions. As the majority of the population is without any formal education, it is no surprise that the only concern that they have is that of employability. The respondents are also hoping that one day they will receive a government subsidised house. It can be deduced from this that education can play a significant role in altering the perceptions of those residents. Moreover, it also reflects that individual social statuses influences their way of thinking based on their knowledge of how greywater management issues are applied in isolation to their social standing. Also, gender plays another role as the data indicates that, more females seemed to be the ones in most frequent cases that make use of greywater around the household with applications attached to cleaning, rewashing and irrigation. A majority of the males only use greywater for irrigation and washing of cars.

4.6.1 Greywater use perception

A number of respondents which is represented by 30% of the participants during the interviews conducted have indicated that they would like and already do use greywater around their household. Such usage is in often times, rinse water is used for rewashing, irrigation/watering plants (vegetable gardens) and flushing of toilets for those respondents who particularly live very close to the communal pour flush toilets. Then 22% of the respondents preferred not to use any greywater and they immediately dispose it by throwing it away just outside their yards or against their fences (Figure 4.44a). The remaining 48% was inconclusive. This means that 70% of the population who took part in the study have no interests in any greywater management matters. This is no surprised when considering the first section where the majority of the respondents indicated that they are unemployed, and they also have no formal education. The participants that make use of greywater indicated that considering the recent drought conditions they felt the need to use greywater as a way to save water.

The respondents feared that as residents who live in poor conditions, they would be the first ones to be targeted should there be any water cut outs which does already happens at times. Other respondents do not care because they feel that ‘there is enough water in the world’ and that any water shortages would be a targeted decision. Residents mentioned that the government does not care about the needs of poor societies but the affluent and middle class. Hence, even decisions to save water would be for the benefit of the affluent and middle class not them hence they refuse to even consider it.

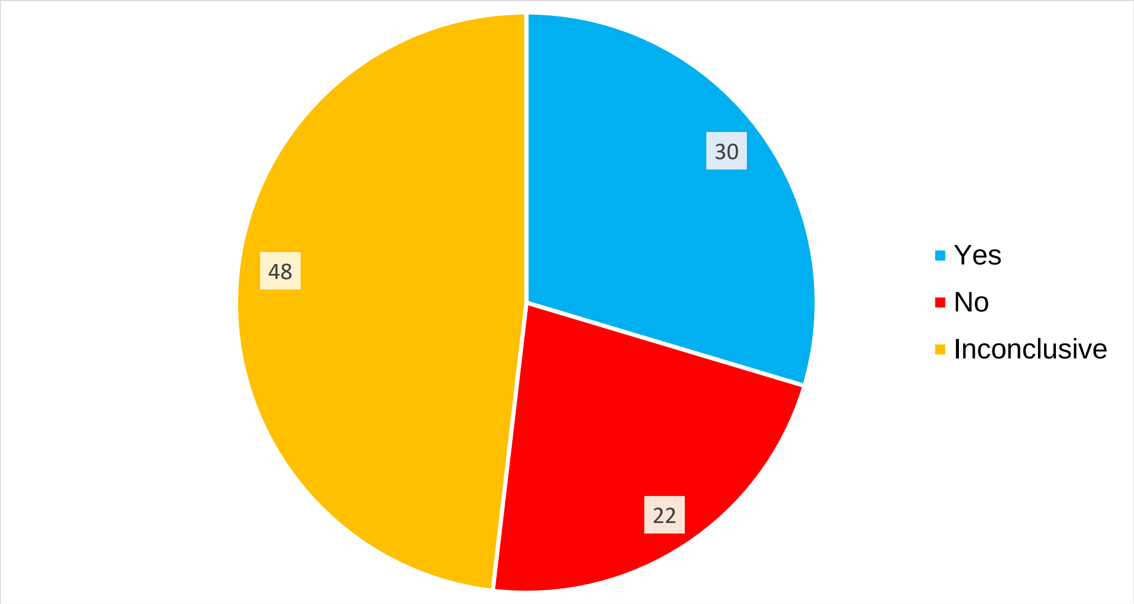

Figure 4:43: Perceptions on the use of greywater in the household.

Figure 4:44 (a): Disposal of greywater against resident’s fences.

4.6.2 Greywater recycling

During the semi-structured interviews, the survey questionnaire has captured that 22% of the participants do think that greywater recycling would benefit them or their community. This has been justified by some respondents that due to recent drought conditions, recycling of their greywater effluent can be their contribution in reducing the pressure attached to the demand and use of freshwater for items around their household that do not need the use of clean water. Another respondent mentioned that she does recycle her own greywater sometimes but feels that the general community does not. Then 33 % of the respondents felt that such an idea can never work in their community because of various reasons. Their disagreement and lack of support for the matter was based on the justification that 'water is free'. While other respondents had mentioned that their reasoning for this is because people are unemployed, and they generally do not care of such matters. One respondent has mentioned that people in his community may need to be educated about the subject so that they can feel the need to support any interventions associated with greywater recycling.

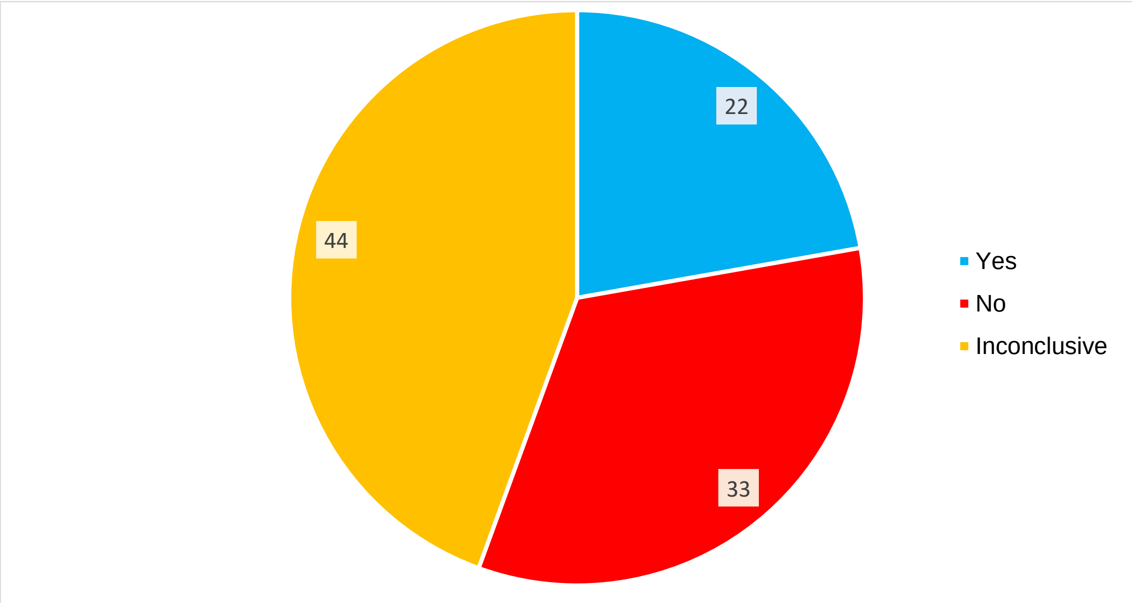

Figure 4:45: Respondents perceptions on the recycling of greywater.

4.6.3 Greywater environmental health issues

When it came to getting views from the respondents about their thoughts if they think that greywater entails any major health problems in the community. The response indicated that 26 % on the respondents agreed with the statement. Some residents have substantiated their answer with the fact that it causes 'infections'. Another resident pointed out that the soaps particularly from any first wash effluent, has dangerous chemicals that cause rush in their children who play with the disposed greywater that has ponded. These respondents seem to be quite clued on the matter from an experience point of view. Other respondents have indicated that greywater is not good for them when it comes to watering plants because it affects the growth of plants. On the contrary, 37 % of the respondents have mentioned that they personally feel that greywater does not have any environmental health issues but nonetheless, these respondents do not even use the greywater from the responses of their questionnaires. Another respondent indicated that greywater does not have health issues provided that it has been treated. Some mentioned that when it is used to flush toilets, it can assist the community not to have any environmental health problems associated with pondering (Figure 4.47 a & b) where kids like to play with accumulated water. Lastly, two of the respondents have highlighted that only rinse water is safe to use, and it can be applied in a number of other activities (e.g.) rewash, cleaning floors, flushing (etc.). The remaining 37% was inconclusive, making 74 % of the population not to have an idea about issues associated with greywater but in essence, they did however express that they do not want to use it for anything.

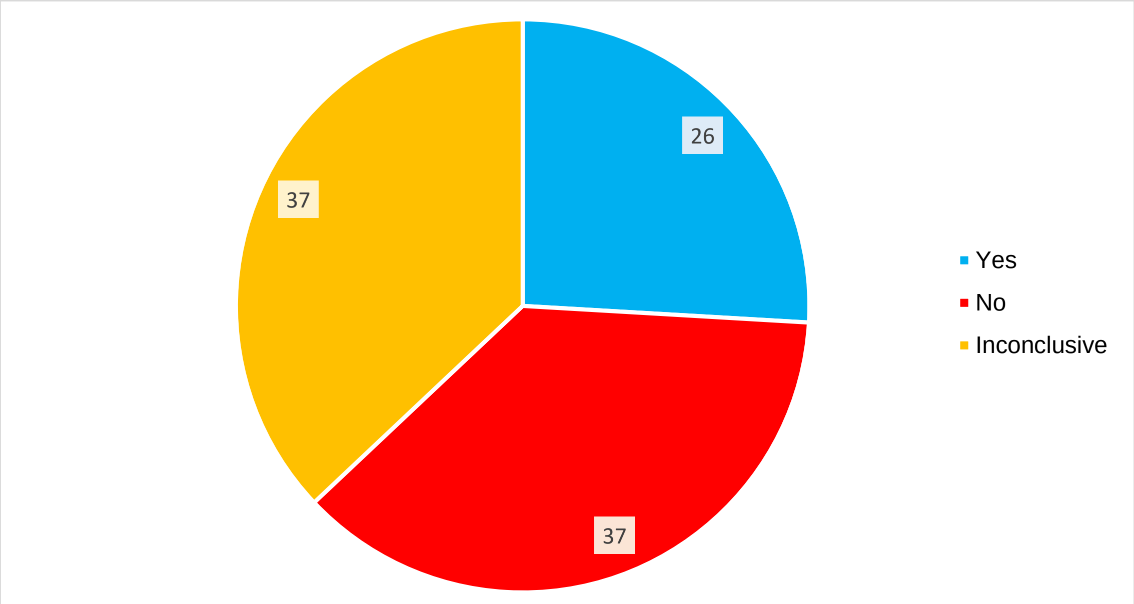

Figure 4:46: Perceptions on greywater environmental health and safety issues.

Figure 4:47: Ponding of greywater.

4.6.4 Greywater disposal

The respondents were asked if they had any suggestions for managing greywater disposal issues in their community. From their response, 15% percent of the respondents were people who already make use of greywater and their suggestions were that some greywater effluent can be reused around the household for cleaning floors, flushing toilets, rewashing (etc.). Other respondents have pointed out that they think that residents should be educated about using greywater for irrigation purposes whether it is for food gardens or watering flowers. One other respondent pointed out that greywater should be sent to a recycling facility/Treatment plant before it can be reused. And lastly one other respondent further expressed that the community must do their own reuse of greywater so that they can save water. About 33% of the respondents indicated that they did not have any suggestions for the disposal of greywater. The last percentage 52% was inconclusive. This means that 85 % of the community have no interest in the management of greywater in terms of how it is disposed currently by the community. As shown in Figure 4.49 (a & b), resident dispose water on the street as there are not much greywater management facilities that are found in the area.

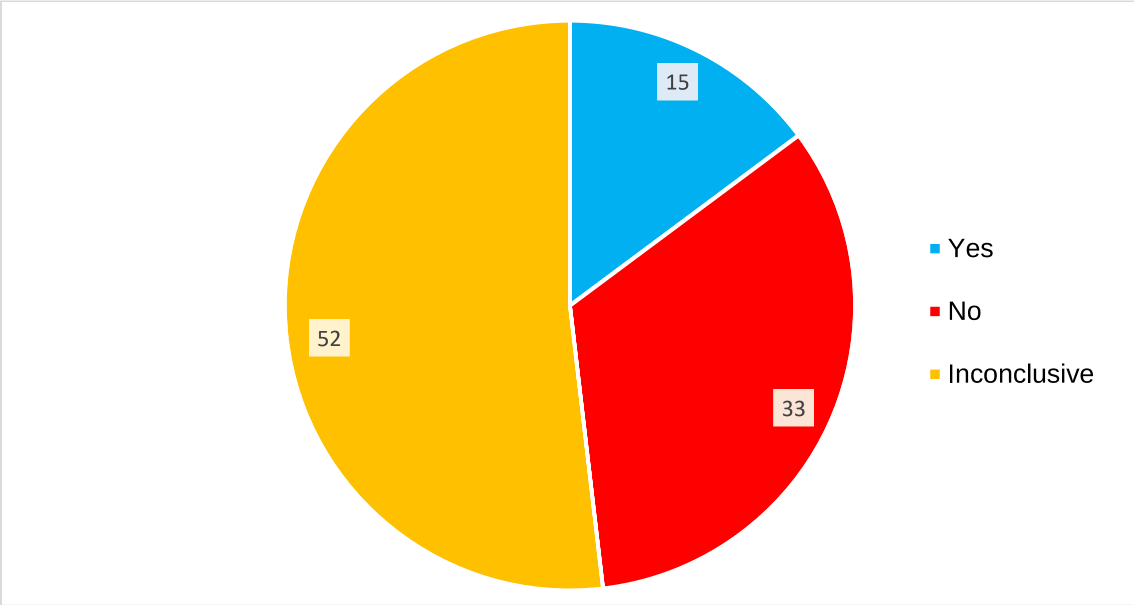

Figure 4:48: Suggestions on how to dispose greywater.

Figure 4:49: Disposal of laundry greywater on the streets.

4.7 Observations (Existing greywater reuse and disposal mechanisms)

There are very few facilities that are designed to capture or collect greywater effluent in the study. The ones that have been noted are not necessarily directly designed for greywater management purposes. Figure 4.50b shows that even with the presence of stormwater channels and kerb inlet residents still throw away their greywater on the streets as it is a norm and they are not well versed on the subject. In some areas the disposal of greywater on the streets is also affected by the lack of mechanisms that are present to manage the effluent. It must be pointed out that even in areas where there are stormwater mechanisms that may guide or transfer greywater to kerb inlets or manholes the residents generally ignore such facilities and thus educating residents about such matters is crucial to get them to start somewhere.

Figure 4:50 : Manhole and stormwater channel and kerb in-let.

4.7.1 Other infrastructure around standpipes

During the field visit, the researcher performed site observations with regards to the presence of mechanisms or facilities that can act as a greywater diversion and/ or collection points. Most standpipes had both concrete slabs and gullies, but they do not divert the water into a drain or a reticulation system. Furthermore, there were storm water channels that can assist in the diversion of both stormwater and greywater, but they were not widely spread across the four sections of Monwabisi park. Lastly, there were also a few manholes that seemed to be blocked and one did not have a lid (Figure 4:50a), which is quite a danger to residents walking at night and in generally mostly, for children across the day. Regardless of the presence of greywater and stormwater diversion facilities, the community still randomly throws water on the streets as it is evident above in Figure 4:50 b.

Table 4.3: Presence of greywater management mechanisms on-site.

Infrastructure	Sections			
	A	B	C	M
Soak-away	No	No	No	No
Concrete slab	Yes	Yes	Yes	Yes
Gulley	Yes	Yes	Yes	Yes
Storm water Channel	Yes	Yes	No	No
Kerb in-let	No	No	No	No
Wash-trough	No	No	No	No
Grease-trap	No	No	No	No
Stormwater manholes	Yes	Yes	Yes	No
Ablution facility	No	No	No	No
Greywater sand filters	No	No	No	No

4.7.1 Existing greywater management systems

There are a few greywater management systems in the study area, most noted are gullies around standpipes. This is then followed by the Emithonjeni areas as show in Figure 4.51 (a & b), that have been created for a number of reasons which involves being a social gathering area where residents can do laundry with other residents while having a social conversation and also watching their children play. The other physical constructed structures are channels that can also be helpful in directing greywater to avoid it entering the household of the residents. Typically, the resident just throws away their greywater effluent just outside their yards and/or on the street. There haven't been any particular mechanisms that have been found that are designed for such other than one that contribute in reverting it away from the household and those few Emithonjeni facilities with diversion and disposal mechanisms.

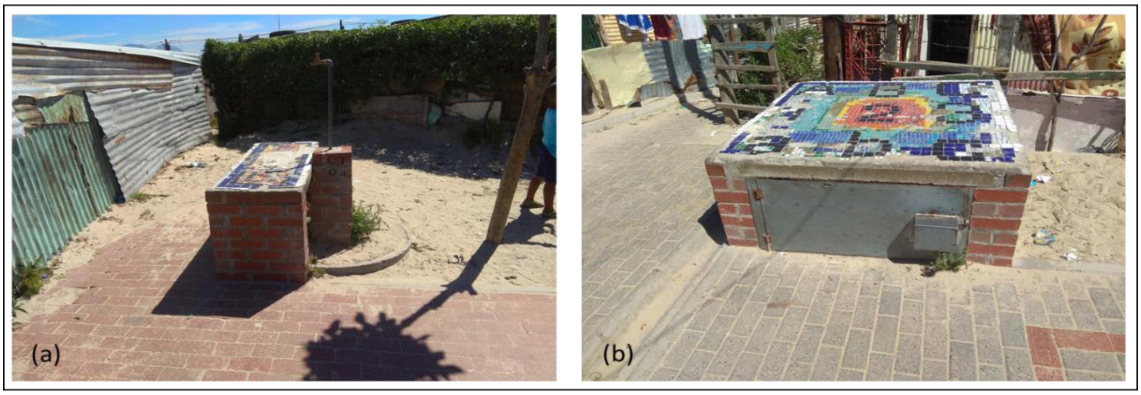

Figure 4:51 : Emthonjeni fitted standpipe and greywater disposal manhole.

4.7.2 Observations and Comments

The images/photographs represent a variety of things in the study area but more particularly the disposal of greywater by the residents of Monwabisi Park across all sections. The other photographs show standpipes and the structures that to some extent can assist in the diversion of greywater effluent. The majority of people who live in all the sides that face M 44 road and Steve Biko road most often dispose their greywater on the streets which finds its way to stormwater catchments/ drains. There are some sewer manholes that have been particularly found in section c, together with stormwater channels and inlets that are meant for stormwater primarily but also assist in redirecting greywater effluent to a common direction. A majority of the residents just simply throw their water in the sand and those that have washing machines have connected black pipes with a diameter of around 5 to 8 cm which they extend from the house and digged a trench across roads to dispose that water. Some areas have Emthonjeni facilities which are defined to be places of learning and socialisation where adults do their laundry while watching their kids play as a safety precaution. Most of these areas have been fitted with channels that are able to direct greywater effluent. These areas can be found across all sections in Monwabisi though some do not work as the taps have been vandalised.

Figure 4:52 : Emthonjeni facilities in section B and C.

4.8 Summary

This chapter dealt with the presentation and analysis of the information that has been collected using semi-structured survey questionnaires in which it was used during a one-on-one interview process with respondents in Monwabisi Park informal settlement. This was the main instrument used in relation to the research objectives and answering of the research questions set. This was shown as basically biographical information/ particulars of the respondents, water access, sanitations, particular usage of water for domestic and other purposes in the household, greywater management activities used at household level and ended up with field observations for the presence of greywater reuse and disposal mechanisms in the study. This chapter has discussed that socio-economic statuses including the demographic make of a household which consist of employment, education statuses The number of infants or your children found in a specific household has played a significant role in the understanding of the main research aim. Moreover, location and presence of facilities also tend to influence people's decisions from the amount of water they collect to use and the use of sanitation facilities. The type of greywater also determines its fate in terms of reuse. The next chapter will deal with the discussions, findings, conclusions and provide recommendations.

CHAPTER FIVE: DISCUSSIONS

5.1 Introduction

The purpose of this chapter is to discuss the results of the study as presented in the previous chapter, the analysed data will be cross-reference with available literature. This will be done, particularly with reference to the information collected during interviews and the field survey that distributed the semi–structured questionnaires and in answering the research questions that have been formulated in the beginning of the study, in chapter 1. The study seeks to answer the research questions that entails (1) the categorisation of the sources of greywater that are produced from the households of Monwabisi Park informal settlement which have been highlighted, (2) ascribing the volumes of greywater produced, (3) deducing the disposal of the different greywater sources generated within the household, (4) determining the sustainable reuse of greywater effluent and (5) highlighting the potential impacts of unmanaged greywater disposal on the surrounding environment and for the residents health and welfare. The overall findings and results will be discussed in more detail and a conceptual framework will be provided to support any arguments made. Thus, the findings presented will be referenced to the literature reviewed. This will provide support to the contradictions and similarities of these results and findings. This chapter consists of the discussion for the analysed information that was collected.

5.2 Discussions

5.2.1 Domestic sources of greywater in informal settlements

In chapter one, there were five research questions in which the current study seeks to answer. The first research question focuses on classifying the greywater produced in the household of the study area for domestic purposes. Water utilised in each household depends on various factors. It has been observed that education and employment are factors influencing water use in each household. This has also been supported by Ilemobade *et al.,* (2010), they stated that water consumption tends to be higher with the increase in income structures, and it also lowers with decreasing household occupancy and increased level of development (Table 5.1).

Jefferson *et al.,* (2004) maintained that greywater is defined as urban wastewater without any input from the toilet which generally includes sources from baths, showers, hand basins, washing machines, dishwashers and kitchens sinks. In the studied informal settlement, it has been determined that bathing (washing basin), laundry (washing/bathing basin and buckets), washing kitchen utensils (dish washing basin), cleaning the house (mopping floors) are the main sources of greywater. The other water collected and used for drinking and cooking which has no waste can only be counted as water lost (Carden *et al.,* 2007c). Based on the frequency and the number of respondents found per household, bathing generates most of the greywater effluent produced, followed by the water used for laundry. This is then followed by kitchen utensils and lastly, cleaning water. The choice of 'which sources to include is a balance between the water available and the level of pollution contained within it' (Jefferson *et al.,* 2004).

In the study, the main water usage that has generated high levels of greywater was bathing, with 35% effluent produced. Bathing greywater effluent is then followed by laundry with 28%. The third greywater sources is 10% which originates from washing kitchen utensils and then lastly, 8% is used for cleaning. In a study conducted by Edwin *et al,* (2014) which was applied on a formal urban residential area, it was found that on average, 62% of greywater is generated with 49% of this coming from bathroom greywater which is followed by laundry, kitchen and washing basins. In comparison to this, informal settlements do not necessarily make use of washing basin sources in separation with bathing/showering water, it is counted as one category. Jorden (2006), also reported that 61% of the total wastewater stream has been found to be greywater. And in line with this, there is consistency in terms of where the greywater comes from.

Table 5.1: Domestic water consumption in l/p/d for different end uses in various countries.

References	**Butler (1991,1993)**	**Surendran and Wheatley (1998)**	**Mikkelsen *et al*., (1999)**	**Van der Hoek *et al*., (1999)**	**Laak (1974)**	**Ligman *et al.,* (1974)**	**Siegrist *et al.,* (1976)**
Country	**UK**	**UK**	**Denmark**	**The Netherlands**	**USA**	**USA**	**USA**
Toilet	31	61.3	40	30.5	75	76	36
Kitchen	13	29.7	20	10.5	14	13	18
Wash basin	13	25.5	-	5.4	8	-	-
Bath and shower	28	34.4	45	59.7	32	47	38
Washing machine	17	25.6	10	23.1	28	38	41
other	-	35.9	45	15.4	-	6	-
Total (l/p/d)	102	212.3	160	144.6	157	180	133

Adopted from Ilemobade et al., *(2010).*

5.2.2 Volume of greywater produced per household

The aim of the second research question was to reveal the volume of greywater produced by the respondents. In the current study, it has been observed that from the water collected from the standpipes, 81% (Bathing 35%, laundry 28%, washing of kitchen utensils 10%, and cleaning 8%) of it can be classified as greywater effluent. Jordan (2006) has pointed out that the amount of greywater produced by most households will not be the same and will vary depending on the underlying forces found in that specific household. Thus, the greywater generated is directly related to the consumption of water in a household (Carden *et al.,* 2007c). Also the type and level of service provision, particularly in informal settlements, the positioning of standpipes in accordance with the occupants households influences the amount of water collected daily and thus, the amount of water consumed. The consumption of water is predominantly influenced by factors such as their life style characteristics, the age range within a household, the distribution of the occupants across the household, the number of occupants in a household, the climatic conditions in a region, water-usage patterns in the area and household and the cost of water (Jordan, 2006).

In this study, it has been observed that households that have more people/occupants living in it, including the presence of infants to toddlers and young children, use more water than households dominated by adults. This is because children less that 10 years old are frequently bathed twice a day and their laundry is done more frequently which has been noted by twice a week or atleast weekly compared to households with adults who have pointed out that they do their laundry in a two weeks cycle or once a month. Jorden (2006) has pointed out the various percentages of wastewater produced in a household as shown in Table 5.2.

This is within the reported range figures of greywater return factor that is between 65% and 87% (Carden *et al.,* 2007a). In their study, they have discovered that greywater generated in non-sewered areas in South Africa had a returning factor of 75% taking into consideration that there was no distinctive measuring scale. Thus, it can be assumed that all water used in non-sewered areas end up as greywater effluent with only the exception of cooking, drinking water and water left on surfaces of washed items. Due to the absence of proper measuring mechanisms that can only be counted as water lost. The water can only be properly accounted as water usage if there were water meters in place. During the collection of data using surveys questionnaires, it has been captured that a majority of people use between 20 *litres* to 50 *litres* of water per day. Although in the general absence of a metering system, this cannot be accurately a true reflection of the total water used from the reticulation system and taking into consideration that leaks or spillage is not accounted for.

T*able 5.2: Approximation of the percentages of wastewater generated per household.*

Wastewater Type	Total wastewater		Total greywater	
	Total (%)	(L/day)	Total (%)	(L/day)
Toilet	32.0	186.0	-	-
Hand basin	5.0	28.0	8.0	28.0
Bath/shower	33.0	193.0	54.0	193.0
Kitchen	7.0	44.0	-	-
Laundry	23.0	135.0	38.0	135.0
Total	100.0	586.0	100.0	356.0

Adopted from (Jordan, 2006).

5.2.3 Disposal of greywater in the household

The focus of the third research question was getting a background on the disposal of each of the greywater sources that are generated within the household of the study area. From the observations made and the data collected, the current disposal of greywater is through throwing it out on the streets. In some areas there are stormwater channels with a kerb in-let that can convey and transfer the greywater into an underground channel that should feed into the municipal system. The drawback is that such mechanisms are not widely available in the study, hence people prefer to just dispose-off the water on the streets. Moreover, due to lack of knowledge, the people near toilets prefer to throw the greywater on the ground or in front of the toilets instead of flushing with it, even if they did not make use of the toilet at the time. Only a few people practice sustainable ways of disposing greywater. It has been established that some respondents do use greywater to flush the toilet and such people are found within close proximity to the toilets.

It has been found that people most often prefer to throw away their bathing and laundry water. It is evident that to offset freshwater use and to promote reuse of greywater, people need to be educated more about the different types of greywater effluent and the extent to which they can be reused it instead of simply disposing it of on the streets. The random disposal of greywater raises a concern such that greywater disposal in densely-settled non-sewered areas is likely to result in significant health and environmental impacts, particularly in urban environments where large volumes of greywater are generated (Carden *et al.,* 2007a). The greywater which excludes toilet wastewater (black water), would then refer to greywater from showers, baths, washing basins, hand basins, laundry, kitchen, house cleaning. As such, on the greywater sources mentioned above, they can be categorised into light and dark greywater whereby light greywater is of better quality and excludes kitchen effluent. In an attempt to further provide proper disposal of each of the greywater sources, these first need to be broken down into classes. In the current study, the greywater found in Monwabisi Park informal settlement can be grouped into the following categories which entails class 1 and class 2 as light; and class 3 and class 4 can be classified as dark greywater:

- Class 1: Bathing greywater – Greywater sourced from washing basins and baths.
- Class 2: Laundry greywater – Greywater sourced from laundry basins and washing machines.

- Class 3: Kitchen greywater – Greywater sourced from kitchen sinks and dishwashing machine.
- Class 4: Cleaning greywater – Greywater sourced from cleaning houses.

The first two classes are the only ones that have a potential for reuse around the household. The third class can be excluded in reuse because it can be highly alkaline and contains high concentrations of organic material, fats and oils (Kotze, 2018). It will require extensive biological and physical treatments in order to have the potential to be reused otherwise in most cases it is not recommended at all. The last source is associated with the moping of floors. Most frequently, households would use greywater sources for this function but there are others that make use of clean water. The quality of this source does not have any literature; thus, there is less attention about it on the research readings acquired. The reason would be mostly that the volumes of it are not significant, but the research has included it and considered it necessary to be mentioned as it does exist, although it may contain a mixture of other materials that can be found across all greywater source types and more (Ludwing, 1997; Al-Joyyousi, 2003; Carden *et al.,* 2007b; Edwin *et al.,* 2014).

5.2.4 Sustainably reuse of greywater

The fourth research question of the study seeks to find out how to sustainably reuse greywater effluent in informal settlements household for domestic purposes. The notion of this research question is basically to try and offset the usage of clean drinking water consumption. This is because the reuse of greywater effluent offers one means of relieving pressure on freshwater supplies as some household activities need not to use freshwater like the mopping of floors. Global greywater reuse is mostly promoted as an alternative water resource and it can be useful and important especially for areas like Cape Town which was recently struck by drought conditions. This is because greywater reuse provides the ability not only to offset freshwater but also provides a reliable water service for those remote or environmentally sensitive areas such as gardens for household activities that do not need fresh water. Also, it reduces the amount of water thrown away that could cause health hazards. Furthermore, reuse of greywater can assist in the mitigation of rising costs of meeting drinking water treatments and waste discharge standards, lowers sewage discharge to water bodies (Ilemobade *et al.,* 2012). It also assist with the recovery of nutrients for agriculture, ground water recharge, sustainable water resource management (Bakare *et al.,* 2016) and it lowers water tariffs.

The residents of Monwabisi Park informal settlement seem not to be well informed about the reuse of greywater and its benefits. There is only a handful number of people that make use of greywater within the settlement. It has been established that education and socio-economic statuses are one of the biggest drivers that play a significant role in this regard. From a broad perspective there are a number of other factors that guide and determine the reuse of greywater effluents. In a nutshell, such factors include the volume of greywater produced, organic strength, energy requirements, reuse applications, socio-economic factors, geographic location and acceptable by the general public (Edwin *et al.,* 2014). Thus, the quality of greywater is highly variable and depends to a large extent on the household in which it is generated and the number of people living in that household, their lifestyle and ages.

This basically means that if the volume of greywater generated exceeds the reuse and as such, the amount of reuse greywater can be able to lower consumption of freshwater is significantly lower as people prefer to use clean water for functions that do not necessarily need it. Such functions vary according to the type of greywater, for instance, rinse water can be kept for flushing of toilets, cleaning the house, watering gardens (irrigation) and car washing facilities (Edwin *et al.,* 2014). Jefferson *et al.,* (1999) has pointed out that bathroom/shower (bathing greywater) alone is sufficient to be used for instances such as flushing toilets as it consists of very low pollution load and is high in its availability. It has been argued that greywater reuse for flushing toilets and irrigation in South African can reduce the consumption of clean water for those activities to up to 50 % (Kotze, 2018). In the international context, it has been mentioned that the most commonly described application for greywater reuse is toilet and urinal flushing which can reduce water demand within dwelling by up to 30% (Karpiscak *et al.,* 1990). The success in the notion of reusing greywater in the household for the area generally will depended upon the resident's acceptance. The role of the public is an important aspect when it comes to the development and implementation on any reuse mechanism and technologies innovated for the area.

In the presence of sophisticated means, greywater can be treated as there has been scientific developments that allow treatment of greywater to be reused for non-portable water reuse applications. Such uses include gardening, irrigation and toilet flushing on a broader perspective taking into consideration that there should be a reticulation system that collects all wastewaters to a wastewater treatment plant (Edwin *et al.,* 2014) or devising some form of on-site treatment where it is possible and allowed. Another important point to make in the greywater reuse sphere is to stress that greywater cannot be stored for a longer period. This is because it can lead to changes in its chemical and microbiological composition which generally entails the increase of its pollution load (Carden *et al.,* 2007c). This fact is well documented as it was also highlighted by Winward *et al*., (2008), who stressed that 'one thing that is well established is the fact that greywater intended for treatment and reuse should not be stored for longer periods of time as this encourage the growth of microbial population present in it'. It has been found that most often greywater when stored must be at least used within two to three days to avoid the development of pathogens before it reaches anaerobic stage (Ghunni *et al.,* 2008). Bathing greywater from households with children is not safe as there is the potential of it consisting of higher counts of coliforms from faecal matter and this also applies to laundry greywater associated with washing of children clothes (Rose *et al.,* 1991). Therefore, residents must stay away from reusing such greywater effluent. Thus, in households that have infants and small children, the greywater generated from there is said to contain high faecal content and urine. Such greywater content is not safe for reuse as it poses a potential of contaminant that can compromise the health of the occupants of that households (Kotze, 2018).

The greywater effluent that has been produced from kitchens related activities especially for washing kitchen utensils and food also contains very high and complex organic material, oils and fats. Such material need complex and expensive biological treatment in order to meet reuse standards (Palmquis and Hanaeus, 2005; Morel and Diener, 2006; Paulo, 2013; Shafiquzzaman *et al.*, (2018). Thus, kitchen greywater is also not suitable for reuse as it is considered to have high biological organic strength of pollution load. Greywater can be used for irrigation for certain plants, but it must be noted that not all plants can be irrigated with greywater as it can have an effect in reducing its yields. Moreover, the long-term use of greywater irrigation for soil conditions is unknown and further research is needed in that area. The application of greywater in excess of plants requirements and/or changing greywater irrigation events with freshwater watering events has a possibility of increasing leaching of salts found in the greywater (Lubbe *et al.,* 2016). Nevertheless, Rodda *et al.,* (2010), maintains that 'the active promotion of greywater use for irrigation in gardens and small-scale agriculture would have the potential not only to maximise use of limited water supplies, but also to improve food security in low income settlements'.

5.2.5 Potential impacts of unmanaged greywater

> *"Improper greywater management can lead to a variety of health concerns, including mosquito breeding (from ponding of greywater); contamination of drinking water supplies; and odours from stagnant water," "There is also a risk of transmitting water based diseases if the greywater has been cross-contaminated with faecal waste" Carden tells The Water Wheel.*

As greywater effluent is presented to be the majority of wastewater stream in informal settlements, it needs to be managed in an environmentally friendly and responsible way, in order to minimise any negative health impacts on the surroundings. The idea in this instance, is to adopt ecologically sustainable development principles that will make sure that greywater effluent will not pose any threats to human health and also simultaneously contribute in offsetting the use of clean or portable drinking water that will promote sustainable water supply (Jordan, 2006). It is well known that unmanaged greywater effluent which creates pondering attracts flies and mosquitoes, has a bad odour and is generally a nuisance (Carden *et al.,* 2007b). In the study area there is no real provision for the disposal of greywater; thus, the occupants opt to throw their greywater on the streets.

The study area is characterised by the disposal of greywater effluent on the streets. The sight of such activities as can be observed from Figure 4.34 in the previous chapter and generally these does not have a good look or aesthetic value in the area. Moreover, the continuous disposal and lack of greywater management facilities creates pondering. This has been shown on the previous chapter in Figure 4.47 which is currently taking place in the area. Kotze (2018) states that pathogens found on greywater effluent has the possibility to transmit and cause disease when the people and especially children come in direct contact with it. Also when the water is utilised for irrigation of home food garden with the consumption of those products that were irrigated by it. This has been also supported by Carden *et al.,* (2007b), that 'it must be noted that greywater does have the potential to transmit bacteria and diseases specifically for children and residents with a compromised defence system such as HIV/AIDS patients'. The pondering of greywater specifically is a health risk because of its ability to attract flies and mosquitoes. Furthermore, during the wet season such pondering will be mixed with stormwater creating bad odour. The pondering of greywater also can contaminate groundwater resources, especially in areas with poorly grained soils and where the water table is close to the surface (Carden *et al.,* 2007a).

There is not much known about the reuse of greywater for irrigation due to the fact that the pollution effects of various detergents are still yet to be established properly, especially in areas where the people do not have water based services (non-sewered) settlements (Carden *et al*., 2007c). Greywater is generally considered to be harmful to certain species of plants in that one of the other negative impacts of greywater effluent used for irrigation is that it inhibits plant growth and has been indicated that it has the ability to change soil characteristics. As such, greywater effluent that is reused without applying caution may poses significant potential and negative risks to both the human health and the surrounding natural environment (Kotze, 2018).

5.3 Summary

This chapter has provided the discussions associated with the results that have been presented in Chapter four, for the sustainable disposal and potential reuse of greywater effluent for the Monwabisi Park informal settlements. The results reported were a analysed from the data gathered from the respondents involved in the project. These results have indicated that many of the respondents in the study are not only unemployed, but also do not have any formal education. This should be no surprise to have noted that the majority of them basically do not view greywater management as important to them other than securing a job or receiving a government subsidised house. The only way that could assist in engaging the community in greywater management initiative will be a huge deal of educational initiatives that will aim to reflect on the benefits of greywater reuse, the disadvantages of unsustainable disposal and unmanaged greywater effluent to their health and the surrounding environment. The next chapter will provide recommendations and thus concluding remarks for the study.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This last chapter provides recommendations for the research study. Recall that this research study set out to investigate the sustainable disposal and reuse of greywater effluent in Monwabisi Park informal settlement, Cape Town, South Africa. The following three main objectives guided the study:

- To classify (categories) greywater produced in the different domestic purposes around the household.
- To assess sustainable disposal of each source of greywater by deducing the least contaminated greywater source around the household.
- To determine potential reuse of greywater in and around the household to prevent environmental health hazards while promoting water conservation.

Furthermore, general findings associated with the content of the research have been summarised. This chapter will end with concluding remarks with specific applications to the notion of reuse, recycling and safe disposal of greywater effluent in informal settlements. The limitations of the study will be highlighted to give a platform for making a few recommendations for future studies.

6.2 General findings

Based on the data that has been collected from the semi-structured survey questionnaire and field studies conducted in the community of Monwabisi Park informal settlement. The general findings include:

- Almost 70% of the residents in Monwabisi park are unemployed and most of these are youth.
- The residents of Monwabisi Park informal settlement have shown little interest in greywater management matters. Their particular concern as they have reflected in the research was the hope of getting employment which can provide for their daily needs and also the hope that one day they can receive a government subsidised house.
- There is a huge deal of environmental education that is needed to be done in order to teach the residents of any wastewater management and related interventions. The community seems very unlikely to partake in any greywater

management activities because it is not a priority and they do not see any importance in it.

- This would then mean that also greywater disposal would need to be dealt with the same ways as sanitation, refuse collected and stormwater management matters from a government enforced standing.
- Currently, it seems that the local municipality currently has no solution in dealing with greywater disposal and management issues thereof, as there were a lot of disposal issues found in the informal settlement and no programme or mechanisms are put in place that are able to deal with short term greywater management issues at this present moment.
- Informal Settlements attention is only focused on the provision or water and sanitation in the realm of the topic.
- A short-term solution is immediately needed to deal with greywater disposal. This will assist in also dealing with any environmental health risks that may emerge as a result of the current ponding of greywater.
- There is no real provision for the disposal of domestic greywater and, bearing in mind that South Africa is a water scarce country, the municipality should be investigating ways of using the greywater effluent as a resource rather than viewing it as waste.
- At least there are a few respondents represented by 30% who have indicated that they do make use of greywater, compared to the 70% of the respondents who do not make use of greywater effluent.
- New research also adds more value to the broader research realm particularly where there is lack of information with regards to some topics.

6.3 Recommendations

Based on the findings for this research, the researchers would like to recommend that the following be done.

- From a legislative point of view, there is a need for policies that will tackle greywater management from the national level and then goes down to delegate powers to local spheres of the government. This will ensure effective application of greywater management guidelines that have been developed thus far by everyone including informal settlements residents. To allow for the reuse of greywater for various circumstances and conditions and the safe disposal of this wastewater stream thereof. Having a specific law or act that speaks to wastewater management viz. greywater will create structures in place whose role is to provide administration, monitoring, evaluation and management of wastewater management matters (greywater) the same way as water access and sanitation.

- More research needs to be done on low cost treatment mechanism for greywater effluent which can be applied in the Monwabisi Park informal settlement and possibly, similar informal settlements. Such research should incorporate the collective line of thinking into the operation and the management of such a system.
- There is a huge need to provide educational initiatives to informal settlements residents and educate them more on wastewater and the use of greywater. Communities should be aware of the benefits and also the disadvantages of unmanaged greywater and its implication to their health and surrounding environment.
- There must be some provisions made during the rolling out of water service points (communal standpipes), mechanisms that will allow for the collection of greywater and leakage from water in and around the standpipes; preferably infiltration beds and soakaways should be provided at the standpipes (or drainage to gravitate the greywater to an appropriate site for handling and disposal) so that ponding of contaminated water is minimised.
- The residents who use greywater currently need to be informed more about the types of greywater to use and to what extent they can use it. Moreover, the disposal part also requires a mixture of short term and long-term solutions to minimise risks involved for both the health of residents, especially children and for the benefit of the receiving environment.

6.4 Limitations of the study

This study wishes to point out the following limitations that the study consists of the current limitations:

- The quality of the different types of greywater wastewater effluents generated in the households of the study was not part of this research.
- Treatment of greywater effluent found on the individual households in the study was also not part of this research

- Stormwater effluent was not part of this research
- The effect of pondering of greywater effluent of the ground/soil was not part of the current study
- Soil chemistry and the effects of greywater on the soil characteristics was also not part of the subject of this research project.

6.5 Recommendations for future research

The following are suggested for future studies:

- The study should try to find out the combination of stormwater effluent with greywater and the impacts it has on the environment and the reticulation system.
- Chemical composition and quality of greywater effluent in informal settlements as a case study in comparison to formal settlements.
- Low cost and effective treatment technologies that can be useful in these informal settlements.
- Establishing the pollution effect of different detergents on various plants and the soil when greywater effluent is being used for irrigation in small-scale agriculture or home gardens.
- The continuous disposal of greywater in an environmentally sensitive area like the study needs to be investigated in more details by making a case study on the impacts of greywater on the groundwater resources, soil texture, biodiversity and humans, particularly children.

6.6 Concluding remarks

The current study has provided an insight into the sustainable disposal and potential reuse of greywater produced at household level in the Monwabisi Park Informal Settlements. This was achieved by assessing the different sources of greywater effluent that are produced at household level in the study area. Sustainable reuse of greywater effluent has been well documented and referenced above. It has a variety of advantages including just to recall, the reduction in the consumption of freshwater resources, the ability to recover nutrient for plants, can contribute to food security for small gardens, can be used for flushing which doesn't necessarily need clean water, reduced money spent for the treatment of wastewater, just to name a few. Not also forgetting the disadvantages pointed out above (e.g.) nuisance, inhibiting plant growth but to name a few. In order to promote sustainable disposal of greywater effluent, the residents of the area need to be educated more about greywater management and reuse capabilities associated with this resource and also the negative parts of greywater in order to exercise caution. Thus, the key to successful greywater management appears to be very much linked to the attitudes of the community towards the greywater management issues as well as the willingness and commitment of both the community and local authorities (Municipality) in driving initiatives that will realise its success.

The study has revealed that the residents of Monwabisi Park do not necessarily care about greywater management. Their priority is the efficiency of receiving basic services and the hope of receiving a suitable formal house one day. They consider this as the main concern and ultimate solution as opposed to greywater management. To promote reuse and sustainable disposal of greywater, the event must be two-fold. Firstly, local authorities need to invest in mechanisms that will be able to manage greywater effluent. Secondly, the people of the area need to be educated more about greywater, which greywater is safe to use and to what extent it can be used around the household. Thus, there is no greywater management initiative that can be simply taken elsewhere and applied universally. Only guideline may steer up the initiative towards the right direction. The planning and implementation of greywater management initiative needs to be for a local scale and the attitudes of the people who are meant to make use of such mechanisms need to be well versed. Therefore, active education towards altering mind-sets, changing perceptions and instilling caution is the starting point. This means that both the residents and local authorities can co-operate the management of a successful greywater management mechanism in alleviating the greywater disposal problems in that specific community.

It can be concluded that the study has contributed to the understanding of sustainable use and safe disposal of greywater effluent in informal settlements to avoid nuisance and potential spread of viral infections. The study has demonstrated that socio-economic status and education level has reciprocal outcomes on the communities' understanding of environmental issues (e.g.) greywater management. Moreover, the study has shown that education can transfer a good image to the community and may assist in altering the communities' way of thinking. It is very important to kick-start any initiatives to avoid any further risks associated with health of the residents and the environment they are currently live in. Eliminating inappropriate disposal and providing means to sustainable reuse of greywater effluent is the key. The municipality must endorse such an initiative and involve the community in the formulation of the mechanisms to utilise greywater appropriately.

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ANNEXURES

Appendix 1: Questionnaire

Survey Questionnaire : Monwabisi Park Informal Settlement

Questionnaire for residents

Section 1: Particulars of the Respondent

1 Respondent No: ____________________

2 Date: ____________________

3 Settlement Section: [ ] A [ ] B [ ] C [ ] M

4 Gender: Male [ ] Female [ ]

5 Age: [ ] 18 - 24 [ ] 25 - 34 [ ] 35 - 44 [ ] 45 - 54 [ ] 55 and over [ ] Prefer not to say

6 Employment status: [ ] Employed [ ] Self-employed [ ] Not employed

7 Educational Level: [ ] No formal education [ ] Matric [ ] Collage/University

8 What is the number of people living in the household?

[ ] Infants - toddlers (0-6) [ ] Young children (7-13) [ ] Teens (14-18) [ ] Adults (19-65) [ ] Elderly > 65

9 How long have you been staying in this household?

0 - 3 Years [ ] 3 - 5 Years [ ] 5 - 20 Years [ ] > 20 Years [ ]

Section 2: (A) Water Access

10 Where do you get water from? [ ] Standpipe [ ] Tap connection [ ] Tank

11 Distance from the house to the standpipe:

[ ] 0 - 10 m [ ] 10 - 50 m [ ] 50 - 100 m [ ] 100 - 200 m [ ] 200 - 500 m [ ] > 500 m

12 Daily water use in the household:

[ ] < 20*l* [ ] 20*l* - 50*l* [ ] 50*l* - 100*l* [ ] 100*l* - 150*l* [ ] > 150*l*

13 Do you get water from other sources? Yes [ ] No [ ]

If yes where? ____________________

14 What is the main usage of water in the household?

[ ] Bathing [ ] Cooking [ ] Cleaning [ ] Laundry [ ] Dishes [ ] other: ____________

15 Volumes of water that are normal kept in the household during a single day:

[ ] 0 - 10*l* [ ] 10 - 20*l* [ ] 20*l* - 50*l* [ ] 50*l* - 100*l* [ ] 100*l* - 150*l* [ ] > 150*l*

16 Would you like to use more water and why? Yes [ ] No [ ]

Why? ____________________

(B) Sanitation

17 Which sanitation facility do you use?

[ ] Pour Flush [ ] Chemical [ ] PFTs [ ] Self-made Pitliner [ ] Other: ____________

18 Where is the nearest toilet?

[ ] 0 - 10 m [ ] 10 - 50 m [ ] 50 - 100 m [ ] 100 - 200 m [ ] 200 - 500 m [ ] >500 m

19 Do you also use it during the day and at night? Yes [ ] No [ ]

If No, why? ____________________

Sustainable disposal and potential reuse of greywater produced at households in informal settlements: A Case study of Monwabisi Park Informal Settlement 1

20 Are there any handwashing facilities near by? Yes ☐ No ☐

Elaborate ______

21 How much water do you use for flushing per day in the household?

☐ 0 - 5l ☐ 5l - 10l ☐ 10l - 20l ☐ 20l - 30l ☐ > 30l

22 Where is the water coming from?

☐ Tap ☐ Laundry ☐ Kitchen ☐ Bathwater ☐ Other ______

(C) Particular water usage for domestic activities

(i) **Kitchen** (Cooking, Drinking, Washing dishes)

23 How much water do you use for **drinking per day?**

☐ 0 - 5l ☐ 5l - 10l ☐ 10l - 20l ☐ 20l - 30l ☐ > 30l

24 How much water do you use for **cooking on average?**

☐ 0 - 5l ☐ 5l - 10l ☐ 10l - 20l ☐ 20l - 30l ☐ 30l - 40l ☐ > 40l

25 How often do you **wash dishes?**

☐ Once a day ☐ Twice a day ☐ Trice a day ☐ More (Specify): ______

26 How much water do you use for washing dishes?

☐ 0 - 5l ☐ 5l - 10l ☐ 10l - 20l ☐ 20l - 30l ☐ 30l - 40l ☐ > 40l

27 How do you dispose the **first wash kitchen** wastewater?

☐ Throw away ☐ Water Plants ☐ Flushing ☐ Other ______

28 How do you dispose the **rinse wash kitchen** wastewater?

☐ Throw away ☐ Water Plants ☐ Washing dishes ☐ Cleaning floors ☐ Flushing Other ☐ ______

29 What products/brands do you use for washing the dishes?

Soap ______ Washing Powder ______

Bleach ______ Dish washing Liquids: ______ Other ______

(ii) House Cleaning

30 How often do you mop/ clean your floors?

☐ Once a day ☐ Twice a week ☐ Trice a week ☐ More (Specify): ______

31 How much water do you use?

☐ 0 - 5l ☐ 5l - 10l ☐ 10l - 20l ☐ 20l - 30l ☐ 30 - 40 l ☐ > 40 l

32 Where does the water come from?

☐ Tap ☐ Laundry ☐ Kitchen ☐ Bathwater ☐ Other ______

33 How do you dispose the wastewater?

☐ Throw away ☐ Water Plants ☐ Reuse/ Flushing ☐ Other ______

(iii) Bathroom/ Bathing

34 How often does everyone in the household take a bath or shower?

☐ Once a day ☐ Twice a day ☐ Trice a day ☐ More (Specify): ______

35 How much water do you use in one bath

☐ < 20l ☐ 20l - 50l ☐ 50l - 100l ☐ 100l - 150l ☐ > 150l

36 How do you dispose the wastewater from bathing?

☐ Throw away ☐ Water Plants ☐ Reuse/ Flushing ☐ Other ______

37 What product do you use for bathing, showering and handwash?

Bath Soap ______ Shower Gel ______ Bathfoam ______

Hand wash soap ______ Hair Shampoo ______ Other ______

(iv) Laundry

38 How often do you do your laundry (washing)?

☐ Daily ☐ Once a week ☐ Twice a week ☐ More (Specify): ____________

39 What do you use to wash laundry and its size? Size

Washing Basin ☐ — ☐ 0 - 10 *l* ☐ 10 *l* - 20 *l* ☐ 20 *l* - 50 *l* ☐ > 50 *l*

Washing Machine ☐ — ☐ 5 - 8 *kg* ☐ 10 - 13 kg ☐ 13 - 15 kg ☐ > 18 kg

40 How do you dispose **first wash?**

☐ Throw away ☐ Water Plants ☐ Reuse/ Flushing ☐ Other ____________

41 How do you dispose **rinse wash?**

☐ Throw away ☐ Water Plants ☐ Reuse/ Rewash ☐ Reuse/ Flushing ☐ Other ____________

42 What product do you use for your laundry purposes?

Soap ____________ Washing Liquid ____________ Washing Powder ____________
Bleack/jik ____________ Fabric Softener ____________ Other ____________

(v) Other

43 Other purposes for using water?

☐ Beer Brewing ☐ Car washing ☐ Gardening ☐ Tools ☐ Other (Speficy): ____________

44 How much water do you use for them?

☐ 0 - 5*l* ☐ 5*l* - 10*l* ☐ 10*l* - 20*l* ☐ 20*l* - 30*l* ☐ *30 - 40 l* ☐ > 40 *l*

Section 3: Greywater Management

45 Would you like to use greywater for other purposes around the household and why?

____

____

46 Do you think that greywater recycling would be useful in your household and Community Please elaborate?

____

____

47 Do you think greywater entails major health problems in the community and Why?

____

____

48 Do you have any suggestion of managing greywater disposal issues in the community?

____

____

49 Do you have any questions to ask me?

Interviewer: ____________ Signature: ____________

Section 4: Existing greywater reuse and disposal mechanisms (Observations of by the interviewer on site)

50 Are there any of the following in standpipes?

☐ Soak-away ☐ Concrete slab ☐ Gulley ☐ Kerb in-let ☐ Wash-trough ☐ Grease-trap

☐ Stormwater Channel ☐ Stormwater manholes ☐ Ablution facility ☐ Greywater sand filters

51 Are there any existing greywater management systems working? If not, why not?... Please give comments?

____

____

52 Please indicate a reference number and take photographs where the interview site occurred:

____

Thank you for participating in this survey questionnaire.

Appendix 2: City of Cape Town Approval letter to conduct the research

CITY OF CAPE TOWN
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STAD KAAPSTAD

INFORMAL SETTLEMENTS,& BACKYARDERS

Llast Mudondo
Head: Informal Settlements
T: +27 21 444 5380
E: Llast.Mudondo@capetown.gov.za

DATE : **25 September 2018**

SUBJECT : **Request to Conduct research in Monwabisi park**

This is to confirm that Simamnkele Magaba reports to me and that I am aware of the Research he plans to conduct in Monwabisi Park related to Grey Water management. The research is aligned to our core function of delivering basic water and sanitation to informal settlements.

Yours faithfully

Llast Mudondo
Head Informal Settlements

CIVIC CENTRE **IZIKO LOLUNTU** **BURGERSENTRUM**
12 HERTZOG BOULEVARD CAPE TOWN 8001 P O BOX 298 CAPE TOWN 8000
www.capetown.gov.za

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Appendix 3: Indemnity form by the researcher/Student

Cape Peninsula University of Technology

Indemnity Form

RESEARCHER

Indemnity in respect of conducting a research at the City of Cape Town Metropolitan Municipality

Name: Simamnkele Luvo Mogobo

Address: 104 Viking Villas, Viking Drive
Kraaifontein, 7570

Telephone 021 400 2647 Fax: ____________

Age: 28 Tel/Mobile: 061117 3562

Occupation: SENIOR GIS TECHNICIAN & RESEARCHER

I, the undersigned, Simamnkele Luvo Mogobo hereby acknowledge that I requested the CoCT for an opportunity to explore the sustainable disposal and potential reuse of greywater produced at households in Monwabisi Park Informal Settlements as a case study September 2018 (date).

I will not hold the Municipality liable for any risks or damages that may occur during the period of this research.

Signature [signature]

Date 07/09/2018

Appendix 4: Approval to Collect data

OPP 181

CITY OF CAPE TOWN
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Date: 19 December 2018
TO: DIRECTOR: Organisational Policy & Planning
REF: OPPRR-0048

Research Approval Request

In terms of the City of Cape Town System of Delegations (July 2018) - Part 29, No 1 Subsection 4, 5 and 6
"*Research:*

(4) To consider any request for the commissioning of an organizational wide research report in the City and to approve or refuse such a request.

(5) To grant authority to external parties that wish to conduct research within the City of Cape Town and/or publish the results thereof.

(6) To after consultation with the relevant Executive Director: grant permission to employees of the City of Cape Town to conduct research, surveys etc. related to their studies, within the relevant directorate

The Director: Organisational Policy & Planning is hereby requested to consider, in terms of sub-section 6, the request received from

Name	: Mr Simamnkele Magaba
Designation	: Master's student
Affiliation	: CPUT- Faculty of Applied Science at the Cape Peninsula University & a staff member in the Informal Settlements & Backyarders Department
Research Title	: "Sustainable disposal and potential reuse of greywater produced at households in informal settlements: a case study of Monwabisi Park, Cape Town, South Africa".

Taking into account the recommendations below (see Annexure for detailed review):

Recommendations

That the Director: Organisational Policy & Planning grants permission to Mr Simamnkele Magaba in his capacity as a Masters student at the Department of Environmental Management and Occupational Studies in the Faculty of Applied Science at the Cape Peninsula University of Technology [CPUT], as well as a staff member in the Informal Settlements & Backyarders Department in the capacity as a Senior GIS Technician and researcher to conduct research in the City of Cape Town subject to following conditions:

- The Director: Informal Settlements and Backyarders is engaged on the research aims and approach to input into and guide into the research questions to obtain maximum benefit for the City;
- That the researcher makes reference to the City Guidelines on Alternative Use of Water Sources [after it has been published] to all interviewees;
- A minimum of 2 and a maximum of 4 CCT officials are interviewed – selected on the basis of their involvement as project managers in Monwabisi Park - with each interview not exceeding 30 minutes;
- The willingness and/or availability of CCT officials to participate in the research, in a voluntary capacity;
- Adherence to the scope and scale of the study as outlined;
- Conditions of anonymity and confidentiality being adhered to;
- A clear acknowledgement in the report that the views of the CCT officials and the researcher are not regarded as official CCT policy;
- Use of the City's logo or brand is not permitted;
- Submission of the completed research report to the Director: Organisational Policy & Planning, Manager: Research Branch -Organisational Policy & Planning and Director: Informal Settlements and Backyarders, within 3 months of completion of the report and research.

Approved [X] Comment: In order   V.C. Knight 19/12/18

Not Approved [ ] Comment: ______________

PP [signature]   27/12/2018
Hugh Cole: Director of the Organisational Policy and Planning Department   Date

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Appendix 5: Ethical clearance

Cape Peninsula University of Technology

P.O. Box 1906 · Bellville 7535 South Africa ·Tel: +27 21 953 8677 (Bellville), +27 21 460 4213 (Cape Town)

Ethics Certificate **Reference no: 217034721/08/2019**

Office of the Chairperson **Research Ethics Committee**	**Faculty of Applied Sciences**

The Faculty Research Committee, in consultation with the Chair of the Faculty Ethics Committee, has determined that the research proposal of **Simamnkele Luvo Magaba** for research activities related to a project to be undertaken for a Master of Environmental Management at the Cape Peninsula University of Technology requires ethical clearance.

Title of project:	Determination of a suitable greywater management strategy for the Monwabisi Park informal settlement, Cape Town, South Africa

Comments (Add any further comments deemed necessary, e.g. permission required)

1. Animal/human subjects are included in the proposed study.
2. This permission is granted for the duration of the study.
3. Research activities are restricted to those detailed in the research proposal.
4. The research team must comply with conditions outlined in AppSci/ASFREC/2015/1.1 v1, CODE OF ETHICS, ETHICAL VALUES AND GUIDELINES FOR RESEARCHERS.

Signed: Chairperson: Research Ethics Committee	**28/08/2019** **Date**

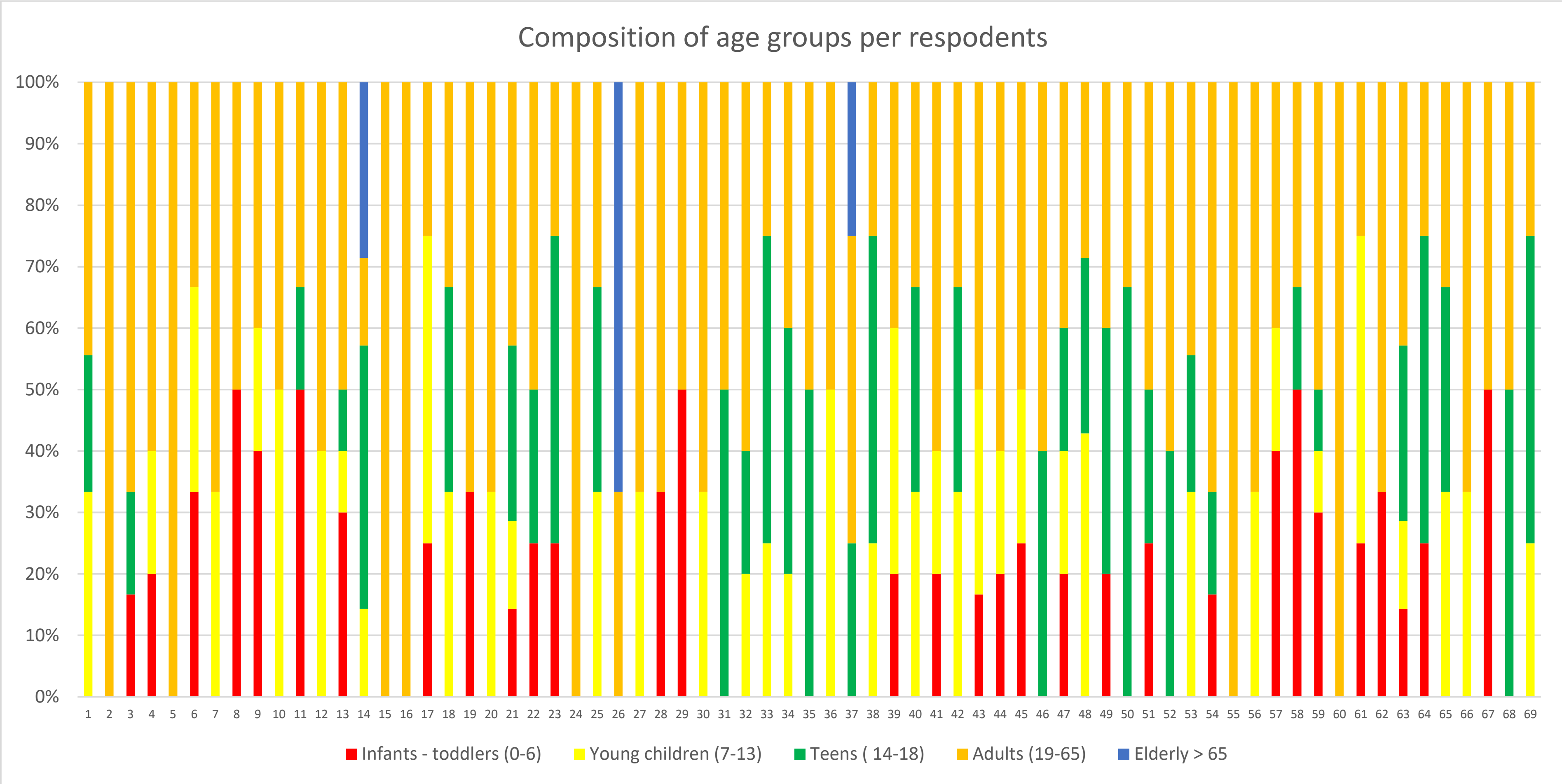
Appendix 6: Statement of Permission

Cape Peninsula
University of Technology

Statement of Permission

Data/Sample collection permission is required for this study.

Reference no.	217034721/08/2019
Surname & name	Simamnkele Luvo Magaba
Student Number	217034721
Degree	Master of Environmental Management
Title	Determination of a suitable greywater management strategy for the Monwabisi Park informal settlement, Cape Town, South Africa
Supervisor(s)	**Dr Ntokozo Malaza**
FRC Signature	
Date	30/8/2019



Appendix 7: Composition of number of occupant per age group found in the households of the respondents.

Site Observation

(a) 

(b) 

(c) 

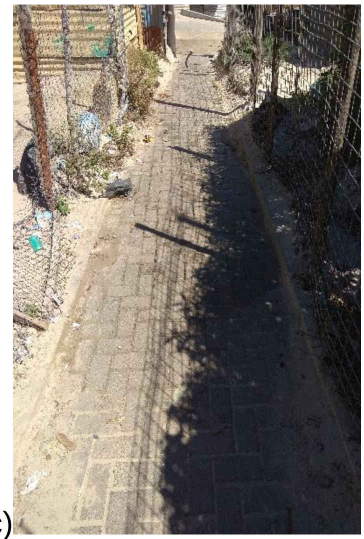
(d) 

(e) 

(f) 

(g) 

Appendix 8: (a - g): Street greywater disposal in A section along M44.

(a)  (b)  (c) 

Appendix 9: (a,b,c) : Emthonjeni Facility found in C section.

(a)  (b) 

(a)  (b) 

Appendix 10: (a & b): First wash disposal of greywater in C section in internal roads and along Steve Biko road, respectively.

(a)  (b) 

Appendix 11: (a&b) : Photo a shows greywater coming down the slope from a house in a much higher gradient and Photo b shows pondering of that greywater coming from up stream.

(a)  (b) 

Appendix 12: (a&b): Photo a shows greywater disposal of laundry water just inside the residents property and b shows the same thing but from a house that is up slope.

(a)  (b) 

Appendix 13:(a&b): Photo a & b shows stormwater channels in which photo a has greywater runoff.

Appendix 14: City of Cape Town: Safe Use of Greywater Guidelines

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THINK WATER
CARE A LITTLE. SAVE A LOT.

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Appendix 15: Chi square test of Expected Values.

Gender	A	B	C	M	Sum
Male	**8.38**	**8.38**	**8.87**	**8.38**	34.00
(O-E)	-0.38	0.62	0.13	-0.38	0.00
(O-E)2	0.14	0.39	0.02	0.14	0.69
(O-E)2/E	0.02	0.05	0.00	0.02	0.08
Female	**8.62**	**8.62**	**9.13**	**8.62**	35.00
(O-E)	0.38	-0.62	-0.13	0.38	0.00
(O-E)2	0.14	0.39	0.02	0.14	0.69
(O-E)2/E	0.02	0.05	0.00	0.02	0.08