THE GREYWATER SITUATION IN INFORMAL SETTLEMENTS OF THE EKURHULENI METROPOLITAN MUNICIPALITY – EASTERN REGION

(Gauteng, South Africa)

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Summary

In recent years growing attention of international and local water research was directed to greywater as a potential water source, as well as its significance as a possible health risk to humans and as a source of pollution. Owing to a general lack of waterborne sewage infrastructure, health risks and pollution associated with greywater generation in informal settlements are of particular concern to municipal managers. However, so far only limited information on the greywater generation, use and disposal in informal settlements is available.

Using four different informal settlements in the highly urbanised eastern region of the Ekurhuleni Metropolitan Municipality in Gauteng (also known as East Rand) this study aims to characterise selected aspects of the greywater situation as a first step towards future improvements through appropriate interventions and greywater management. Following consultations with representatives of the local municipality (colleagues of the author) the following four informal settlements with distinctly different greywater appearance were selected as study sites:

- Benoni – Harry Gwala
- Springs – Gugulethu
- Brakpan – Mkhanca
- Nigel – Soul City

As part of the reconnaissance phase of the study, each site was visited and field observations on infrastructure, habits and other greywater related aspects were made and suitable households for subsequent interviews were identified. In each settlement a total of 25 households were chosen and a representative interviewed using a pre-designed questionnaire comprising eight sections, four sections covering the following aspects: access to and sources of water, general sanitary situation, water use and associated generation as well as disposal of greywater.

Interviews were conducted between November 2006 and August 2007 and varied in duration between 20 and 30 minutes per interviewee totaling close to 48 hours. They were either conducted in Zulu or South Sotho, the most widely spoken languages of the interviewed residents. Answers were recorded in English on site. Results were subsequently captured in EXCEL and statistically evaluated.

The average volume of greywater generated by the four different water usages, i.e. bathing, cleaning, laundry washing and dish washing varies from 35 to 60 l/household/day. With each household comprising an average of four people (two children and two adults) this equals a greywater generation rate of approx. 9 to 15 l/person/day and is somewhat lower than reported in comparable studies in South Africa. Owing to the fact that all volume data are estimates, a comparatively large margin of error is to be expected, explaining why in some cases more water was estimated to be used than was actually fetched. Water use volume was found to be influenced by the availability of stand pipes and in one case was supplemented by collected rain water. Generally, however, water was not perceived to be a problematic issue compared to more pressing needs such as housing, unemployment etc.

Washing of cloths in all settlements was found to be the single most important source of greywater generation accounting for a third to almost half of all greywater generated. The smallest contribution comes from water used for cleaning (approx. 10%) while bathing and washing dishes accounts for equal proportions of the reminder.

Chemical and microbiological analyses of greywater, sampled at selected sites across the four study areas, revealed significant variations in quality between the different sites, without allowing for clear distinctions between the impacts of different brands of detergents such as soaps, washing powder and dish washing liquids.

Contrary to literature E-coli contamination was found not be confined to bath and kitchen waste water only, but also appeared in laundry water, frequently exceeding values stipulated in the general standards of waste water or effluent in South Africa. This is of particular concerns since some of the greywater is disposed of into stormwater canals and in other non-formal ways, that allow for subsequent exposure of humans to the contaminated waste water. In order to facilitate rapid drainage in some instances respondents created their own greywater disposal infrastructure e.g. by digging open waste water trenches across backyard borders. Regarding potential health risks it is to be noted that at least one respondent reported the use of the water resource (Blesbokspruit) as toilet facility.

Apart from the actual findings the study also revealed the importance of an appropriate research design and conduct that addresses the peculiarities of an informal setting. This includes overcoming logistic challenges such as limited accessibility of the study sites during wet seasons owing to flooded and muddy roads, safety and security issues as well as difficulties to conduct indoor interviews owing to a lack of light (no windows, no electricity) leading to low temperatures in winter limiting interview duration. In addition to this socio-cultural aspects and attitudes of respondents have to be taken into account in order to obtain true reflections of facts through interviewing.

In this regard it was helpful that the author, as a black female, was familiar with certain customs and perceptions regarding sensitive issues such as use of toilets, connotations of muti (= a traditional medicine that may be included in bathwater as a constituent) etc. Being aware of these peculiarities allowed the author to detect and explain differences between statements obtained from the respondents and her own observations.

Opsomming

In die laaste paar jaar is baie aandag, in beide internasionale en plaaslike waternavorsing, gemik op gryswater as 'n potensieele bron van water, sowel as die moontlike gesondheidsrisikos daarvan op die mens en as 'n bron van besoedeling. Die algemene tekort aan watergedraagde riool infrastruktuur en die gepaardgaande gesondheidsrisikos en besoedeling geassosieer met gryswater wat gegenereer word in informele nedersettings is 'n bron van groot bekommernis by munisipale bestuurders. Ongelukkig is daar huidiglik minimale inligting ten opsigte van gryswater produksie, gebruik en wegdoening in informele nedersettings, beskikbaar.

Deur vier verskillende informele nedersettings in die hoogs bevolkte oostelike streek van die Ekurhuleni Metropolitaanse Munisipaliteit in Gauteng (op die Oos – Rand) in hierdie studie te gebruik, is daar beoog om geselekteerde aspekte van die gryswater situasie as 'n eerste stap in toekomsige verbeteringe, deur toepaslike ingryping en gryswater bestuur, te karakteriseer. Na konsultasie met verteenwoordigers van die plaaslike munisipaliteit (kollegas van die skrywer) is die volgende vier informele nedersettings, met karakteristieke verskille ten opsigte van gryswater voorkoms, geselekteer as studie gebiede.

- Benoni – Harry Gwala
- Springs – Gugulethu
- Brakpan – Mkhanca
- Nigel – Soul City

As deel van die verspiedende fase van die studie is elke gebied eers besoek en veld observasies ten opsigte van infrastruktuur, gewoontes en ander gryswater geassosieerde aspekte gemaak en gepaste huishoudings is geidentifiseer vir toepaslike onderhoude. In elke nedersetting is 'n totaal van 25 huishoudings gekies en 'n onderhoud met 'n verteenwoordiger van elk gevoer, deur gebruik te maak van 'n vooropgestelde vraelys, bestaande uit agt afdelings waarvan vier handel oor ; toegang tot en bronne van water, die algemene sanitêre situasie, water gebruik en gepaardgaande produksie en wegdoening van gryswater.

Onderhoude is gevoer tussen November 2006 en Augustus 2007 en het gevarieer in tydsverloop tussen 20 tot 30 minute per onderhoud, met 'n totaal van naby 48 uur. Die onderhoude is gevoer in of Zulu of Suid-Sotho, aangesien dit die vernaamste spreektale van die inwoners is. Antwoorde is tydens die onderhoud in Engels afgeneem. Die resultate is gevolglik in EXCEL formaat ingevoer en statisties ge-evalueer.

Die gemiddelde volume gryswater wat gegenereer word deur die vier verskillende watergebruike,d.i. om te bad, vir skoonmaak, wasgoed was en skottelgoed was, varieer tussen 35 en 60 liter per huishouding per dag. Met elke huishouding wat 'n gemiddeld van vier persone (twee kinders en twee volwassenes) bevat is dit gelykstaande aan 'n gryswater produksie van ongeveer 9 tot 15 liter per persoon per dag en is dit ietwat laer as gerapporteer in ooreenstemmende studies in Suid- Afrika. Die feit dat alle volumes slegs op beraamde skattings gebasseer is, kon lei tot 'n relatiewe groot fout faktor, wat ook kan verklaar waarom, in sekere gevalle, daar meer water geskat was vir verbruik, as wat gaan haal is. Daar is bevind dat die volume water wat verbruik is, beinvloed was deur die beskikbaarheid van krane en in een geval was dit aangevul deur die versameling van reenwater. In die algemeen was water nie gesien as problematies, in vergelyking met meer drukkende behoeftes soos behuising, werkloosheid ens. nie.

Dit is bevind dat die enkele mees bydraende bron van gryswater produksie, in alle nedersettings, die was van klere is en dit verteenwoordig 'n derde tot amper die helfde van alle gegenereerde gryswater. Die kleinste bydra kom van water gebruik vir skoonmaak (ongeveer 10%) terwyl badwater en skottelgoedwater in gelyke hoeveelhede vir die oorblywende deel verantwoordelik is.

Chemiese en mikrobiologiese analises van gryswater monsters wat geneem is by geselekteerde punte regoor die vier studie areas toon aansienlike variasies in kwaliteit tussen die verskillende punte sonder om 'n duidelike verskil tussen die impak van verskillende make van seep, waspoeier en skottelgoedseep aan te toon. Teenstrydig met die literatuur is daar ook bevind dat E coli besmetting nie net beperk is tot bad en kombuis afvalwater nie, maar ook teenwoordig is in wasgoed water waar dit gereeld die waardes, soos gestipuleer in die algemene standaarde van afvalwater in Suid Afrika, oorskry het. Dit is besonder kommerwekkend aangesien daar van die gryswater in stormwater kanale en op ander 'nie –formele' maniere weggedoen word, wat tot die gevolglike blootstelling van mense aan die gekontamineerde afval water lei. Om spoedige dreinering te fasiliteer, het sommige respondente hul eie gryswater wegdoenings infrastruktuur gebou bv. deur oop afval water kanale oor erf grense te grawe. Ten opsigte van potensieële gesondheids risikos moet dit genoem word dat ten minste een respondent aangetoon het dat die waterbron (Blesbokspruit) ook as toiletfasiliteit gebruik word.

Behalwe vir die gewone bevindings het die studie ook onthul hoe belangrik'n toepaslike studieontwerp en -toepassing is, wat die informele gebiede se uniekheid aanspreek. Dit sluit in die oorkoming van die logistieke uitdagings, soos beperkte toegang van die studie area gedurende die nat seisoen a.g.v. gevloede en modderige paaie, veiligheid en sekuriteit, asook die beperkinge om onderhoude binneshuis te voer as gevolg van swak lig (geen vensters, geen elektrisiteit) wat, as gevolg van lae temperature in die winter, tot kort onderhoudstydperke gelei het. In toevoeging moes sosio- kulturele aspekte en houdings van respondente in ag geneem word om by ware feite en weerspielinge in die onderhoudsproses uit te kom.

In die geval was dit 'n aanwins dat die outeur 'n swart dame was , bekend met sekere gebruike en persepsies veral t.o.v sensitiewe aspekte soos die gebruik van toilette, konnotasies met muti (= tradisionele medisyne wat toegevoeg kan word tot badwater) ens. Bewustheid van die uniekheid het die outeur toegelaat om verskille, tussen wat gesê is en wat waargeneem is, uit te ken en te verduidelik.

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Glossary of terms and abbreviations

AIDS	Acquired Immunodeficiency Syndrome
Al	Aluminum
As	Arsenic
B	Boron
Ba	Barium
BOD	Biochemical Oxygen Demand
Ca	Calcium
Cd	Cadmium
Cfu	Colony Forming Counts
Cl	Chloride
Co	Cobalt
COD	Chemical Oxygen Demand
Cond	Conductivity
Cr	Chromium
CSBE	Centre for the Study of the Built Environment
CSIR	Council for Scientific and Industrial Research
Cu	Copper
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EC	Eastern Cape
EMM	Ekurhuleni Metropolitan Municipality
F	Fluoride
Fe	Iron
Hg	Mercury
HIV	Human Immunodeficiency Virus
GP	Gauteng
INWRDM	Islamic Network for Water Resource Demand Management
IWRM	Integrated Water Resources Management
K	Potassium
KZN	Kwa-Zulu Natal
LIM	Limpopo
l/ha.day	liters per hectare per day
l/p*d	liters per person per day
LOS	Level of Service
LOFLOS	Low Flow On Site Sanitation System
Mg	Magnesium
mg/l	milligram per liter
Mn	Manganese
Mo	Molybdenum
MP	Mpumalanga
mS/m	millisiemens per meter
N	Nitrogen
Na	Sodium
NH_3	Ammonia
Ni	Nickel
NO_3	Nitrate
OG	Oil & grease
P	Phosphorus
Pb	Lead
PO_4	Phosphate
SAR	Sodium Adsorption Ratio
Se	Selenium
Si	Silicon
SO_4	Sulphate
Sr	Strontium

TC	Total Coli
TKN	Total Kjeldahl Nitrogen
TSS	Total suspended solids
UKZN	University of KwaZulu-Natal
UK	United Kingdom
UNEP	United Nations Environment Programme
US	United States
V	Vanadium
WC	Western Cape
WHO	World Health Organisation
WRC	Water Research Commission
Zn	Zinc

1. INTRODUCTION

South Africa has made great strides in reducing the services backlog in terms of water supply services and sanitation. Before 1994, there were an estimated 12 million people or more without adequate water supply services and nearly 21 million people without adequate sanitation services (DWAF, 2003:1). Presently it is estimated that more than 9 million people have been provided with basic water supplies during the last nine years, which is an impressive achievement. Strategic Framework for water services, stipulates that, basic services is still a stark reality and progress with sanitation has been much slower (DWAF, 2003:1). It further stipulates that, lack of access to water supply and sanitation constrains opportunities to escape poverty and exacerbates the problems of vulnerable groups, especially those affected by Human Immunodeficiency Virus /Acquired Immunodeficiency Syndrome (HIV/Aids) and other diseases. However, greywater seems to have been completely ignored by current policies both with regard to being a potential source of water, as well as sanitation related issues. Regarding the latter Armitage & Hendricks (2005:15) state that it is vitally important to consider the control of greywater as it is a potential health hazard.

Al-Jayousi (2003), points out that greywater use should be seen in terms of its contribution to sustainable water development and resource conservation, without compromising public health or environmental quality. Thus it is important that alternative ways of providing water productive uses (e.g. through the use of greywater) are explored (Carden *et al.* 2007:2-19). Oasis Design (1997:2) stipulates the benefits of greywater use as replacing fresh water in many instances, saving money and increasing the effective water supply in regions where irrigation is needed.

Greywater is being defined as the wastewater that is produced from household processes (e.g washing dishes, laundry, bathing), without input from toilets. Improper greywater management can lead to a variety of health concerns, including mosquito breeding (from pounding of greywater), contamination of drinking water supplies and odours from stagnant water. Children are at risk as they play in this dirty water (Carden *et al.* 2007:1).

2. OBJECTIVES OF THE STUDY

While Carden et al (2007) investigated the potential role of greywater as an alternative source of water in informal settlements, detailed studies on the disposal of greywater in these areas are largely still lacking in South Africa. It is an aim of this study to characterise the extent and nature of greywater disposal in informal settlements of the Ekurhuleni Metropolitan Municipality (EMM) – Eastern Region in order to improve its management and minimize adverse impacts on human health and environment.

The Ekurhuleni Metropolitan Municipality (EMM) amalgamated the previous nine town councils of the East Rand into the South, East and Northern Metro region. The Eastern Metro Region entails Nigel, Springs, Brakpan and Benoni which all have informal settlements with an estimated total population of 166 000 (EMM, 2008).

Sub-questions include:

- What are the main sources of greywater in informal settlements and what is their contribution to the total greywater volume?
- What is the quality of the greywater (chemical and microbiological) from different sources?
- How much greywater is generated?
- How do people dispose of greywater?
- Does greywater pose a health risk to people living in these areas?
- What are potential impacts of greywater disposal on the receiving environment, especially water resources and wetlands?

3. LITERATURE REVIEW

3.1 Legal aspects of greywater issues in SA

When the first democratically elected government came to power in our country in 1994 it put forward as its manifesto the Reconstruction and Development Programme [Department of Water Affairs and Forestry (DWAF, 2000: 1)]. This initiative was based on the fundamental concept that people who are affected by decisions should take part in making them, and it set out five key programmes: meeting basic needs; developing our human resources; democratizing the State and society; building the economy; and implementing the Reconstruction and Development Programme. Water is an essential ingredient in each of these programmes. The Constitution of the Republic of South Africa (1996) contains both our Bill of Rights and the framework for government in South Africa. Two provisions of the Bill of Rights are particularly relevant to the management of water resources. These are sections 27 and 24, respectively which state that:

- Everyone has the right to have access to, among other rights, sufficient food and water, and the State must take reasonable legislative and other measures, within its available resources, to achieve the progressive realization of these rights.
- Everyone has the right to an environment that is not harmful to their health or wellbeing, and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation, promote conservation, and secure sustainable development and use of natural resources while promoting justifiable economic and social development.

These two documents — the Reconstruction and Development Programme and the Constitution provided the impetus for a complete review and revision of the policy and law relating to water, and resulted in the development of the National Water Policy for South Africa (1997) and the National Water Act (1998). The White Paper on a National Water Policy tabled a set of 28 "fundamental Principles and Objectives for a new Water Law of South Africa" (Gabru, 2005:22). These principles provided the basis for the National Water Act. As a result the National Water Act 36 of 1998 was promulgated to give effect to s24 of the Constitution as well as s27 to give effect to this right (DWAF, 2000:1). The Constitution allocates the management of water resources to National Government (DWAF) and the management of water and sanitation services for all citizens to municipalities (local government). This explains why there is an Act that deals with the sources of water (national responsibility) and an Act that deals with water services (local responsibility) (DWAF, 1998:8).

The Strategic Framework for Water Services of 2003 sets out a comprehensive approach with respect to the provision of water services in South Africa [Water Research Commission (WRC, 2005:1)]. It outlines the change of approach needed to achieve policy goals as a result of the progress made in establishing a democratic local government since 1994.

The status quo of Greywater in South Africa is probably dealt with as part of general sewage, and covered as such by policy, legislation and strategy. However a case may be made out that this approach is inadequate, as it is currently not legislated and neither are guidelines available in South Africa, except draft guidelines published by the City of Cape Town. Ethekwini have included greywater disposal in their business plan for the delivery of basic sanitation services as mentioned by (Carden *et al.* 2007: 5-6). In the light of this, legislation outlined below would be applicable:

- **National Water Act No 36 of 1998:**

The National Water Act (Act 36 of 1998) and Water Services Act (Act 108 of 1997) provide the legislative framework regarding water supply, sanitation services and water use (DWAF, 2005). The Water Supply and Sanitation White Paper of 1994 and the Water Services Act of 1997 provided the policy and legislative context within which service delivery took place during the first ten years of democracy. The Local Government Act of 1998 and the Municipal System Act of 2000 provide the legislative framework for local government to take full responsibility for water services delivery as mandated by the Constitution of the Republic of South Africa (1996).

Chapter 3 gives provision for the protection of water resources. This is fundamentally related to their use, development, conservation, management and control. Parts 1, 2 and 3 of this chapter lay down a series of measures which are together intended to ensure the comprehensive protection of all water resources.

These measures are to be developed progressively within the contexts of the national water resource strategy and the catchment management strategies provided for in Chapter 2. Parts 4 and 5 deal with measures to prevent the pollution of water resources, and measures to remedy the effects of pollution of water resources. Greywater is applicable if it finds its way to water resources.

Section 37 allows the minister to regulate activities having a detrimental impact on water resources by declaring them to be controlled activity, which may be relevant to section 37 (1) stipulates controlled activities as:

a) irrigation of land with waste or water containing waste generated through any industrial activity or by a waterwork. This is applicable to greywater use for irrigation. A license is not required for this activity if certain conditions are adhered to. WRC, (2006: 21), points out that greywater is unlikely to comply with these conditions unless it is treated prior to irrigation.

d) intentional recharging of an aquifer with any waste or water containing waste.

At the Johannesburg World Summit on Sustainable Development in 2003, integrated water resources management (IWRM) was included in the international policy framework, and a first goal was set for countries to establish IWRM policy goals by 2005 [World Health Organisation (WHO, 2006b:3)]. For regions in the world where water scarcity levels are highest, (like South Africa) the use of wastewater, excreta and greywater is an important component of IWRM. This would be applicable to greywater if is regarded as "waste water"

- **National Water Resource Strategy**

The strategy focuses on addressing pollution from one source type. Densely populated settlements are one of a number of cross cutting strategies of Water Resources Management Strategies that address different aspects of water resources management (DWAF, 1999:4). The strategy also gives provision on source-directed measures, which allow for the setting of standards (or management practices) that are appropriate for different pollution sources. It must be noted that the general standard, which is the quality standards for waste or effluent arising in any area other than an area in which the "Special Standard" is applicable, is used in this research as a guideline for samples taken and part of the standard mentioned in this regard. These standards aim to minimise the impact on the water resources and addresses both point and non-point sources. This conforms to the fact that government must create service supply policies, enabling all South Africans access to basic services through an enabling environment, since this is a human right. While government should supply support in obtaining those services, there is a responsibility on individuals for payment to maintain such services. However for the informal settlements, services are not affordable, therefore the community cannot provide the systems required to ensure that human health is not put at risk through inadequate or inappropriate service provision (Wood *et al.* 2001:4).

- **Water Services Act, No. 108 of 1997**

Regulations relating to compulsory national standards and measures to conserve water, made by the minister under sections 9(1) and 73(1)(j) gives provision on the following:

- Section 2 gives provision on the Basic sanitation whereby the minimum standard for basic sanitation is:

a) The provision of appropriate health and hygiene education, and

b) A toilet which is safe, reliable, environmentally sound, easy to keep clean, provides privacy and protection against the weather, well ventilated, keeps smells to a minimum and prevents the entry and exit of flies and other disease carrying pests.

- Section 3 gives provision on the Basic water supply, the minimum standard for basic water supply services is:

a) The provision of appropriate education in respect of effective water use, and

b) A minimum quantity of potable water of 25liters per person per day or 6 kilolitres per household per month:

i. At a minimum flow rate of not less than 10liters per minute.
ii. Within 200 meters of a household, and
iii. Disposal of greywater – section 7 stipulates that a water institution may impose limitations on the use of greywater if the use thereof may negatively affect health, the environment or available water resources.

- **Other relevant legislation**

Engelbrecht & Murphy, (2006:2), reported that preliminary investigation shows there is no fundamental objection to the use of household greywater for yard irrigation. Normal precautions with regard to nuisance are required in terms of common law, the Health Act No. 63 of 1977, and the National Water Act No.36 of 1998. Nuisances are here defined, inter alia as fly/mosquito breeding, objectionable odours, the surface pounding of water, and the entry of polluted water onto a neighboring property.

Water in South Africa is a scarce and precious resource that belongs to all the people of South Africa. The water is not only scarce, but also unevenly distributed throughout the country (DWAF, 1998:9) and therefore greywater use may be one option to conserve water, as there is a perception that greywater may be reused for irrigation and some other means. However, the safety of using it is not guaranteed and it is a controversial issue, as explored below, in South Africa and other countries.

3.2 Greywater use

3.2.1 South African perspective

From the literature reviewed by the author, the notion of greywater use in South Africa, is not guaranteed due to the fact that it is not controlled as in other countries, and the long term effect of reuse is not known at this stage. Hence, in all the studies done, researchers are mostly of the opinion that precaution and good management should be taken in greywater use. According to Carden *et al.* (2007:2-23), the use of greywater as a substitute for fresh water may provide some economic benefits in areas where potable water supplies are restricted, but the potential negative impacts (health) and environmental impacts from such use must be taken into account. They point out that the total volume of greywater available for use in South Africa is insufficient to make a meaningful contribution to the country's water shortage as a whole. It could however, make a local difference in the more arid areas of the country, particularly where housing is not excessively dense. The outcome would depend on both the geographic and socio-economic characteristics of the areas involved. They further state that drought prone areas have also started considering the use of greywater, as an alternative water resource, and research has been conducted on the different use and treatment options that could be used to render the water fit for use. Van der Linde (1997) reported that the town of Hermanus has had to opt for a comprehensive water conservation programme due to the fact that the demand for water consistently outstrips the supply of town (Carden *et al.* 2007:2-23). Included in their 12-point conservation plan are *inter alia,* innovative tariff structures and the potential use of greywater for food gardening. Carden *et al.* (2007:2-12), reported that greywater irrigation in rural areas, where water consumption is at subsistence or near subsistence levels, has enabled yard crop production to take place on a modest scale. This has shown that greywater could be of critical importance for low-income agricultural purposes during periods of low rainfall. Murphy (2006:8), also indicated that in South Africa, greywater irrigation is being practiced amongst both poor and rich communities. Affluent areas also use greywater for irrigation in a bid to reduce municipal water bills. Users, who have to carry water home from a distant tap or water source, save water by re-using greywater, either in the home, or on subsistence crops (Alcock, 2002).

Carden *et al.* (2007:2-12), further points out that there have been very scientific investigations to date into the use of greywater for irrigation in South Africa. However, the use of greywater for irrigation of food crops poses certain health challenges, about which not enough is known at present. They reported one study by Beukes (2001) which showed that the use of greywater had a positive effect in plant growth and yields, specifically for tomatoes and beans over two seasons. It seemed that the soap present in the water provided benefits in terms of pest control and disease prevention.

In addition to this, the study by Alcock (2002), revealed that there is a lack of information on greywater as a specific resource and as an irrigation technique, especially for low-income households in South Africa. He did however conclude that greywater could be used for yard vegetable and fruit tree cultivation, provided that several precautions are strictly observed. In addition to this, Alcock, (2002) & Beukes (2001), indicated the beneficial use of greywater on the growth of beans and tomatoes over a short term in composed soil, on their study conducted on potted tomato plants and bean plants in a greenhouse. Murphy, (2006:40), also points out in this regard that wise management of greywater for irrigation is therefore required to reduce the negative effects of greywater irrigation. Greywater use for irrigation of plant growth was shown by the study of Salukazana *et al.* (2005), where they investigated plant growth and microbiological safety of plants that were irrigated with greywater from a low-income peri-urban community in Durban. Preliminary results have showed that greywater could represent a potentially important resource for food production in poor peri-urban communities and is of benefit both nutritionally and economically with minimal additional risks to health associated with consumption of the irrigated produce.

However the long term sustainability of the practice is at this stage unknown. In addition to this, in another study done by them, where two trials were conducted, the first trial representative vegetable used were aboveground crops (spinach and green pepper) and below ground tubers (potatoes and madumbes). In the second trial aboveground (spinach and green pepper) and belowground (beetroot and onions) were selected using tap water, hydroponic nutrient solution and greywater. The second trial results yielded significantly greater yields and overall plant growth for peppers, spinach and onion with greywater, than what was achieved with hydroponic nutrient solution for the first trial. The reason for the improvement in soil fertility and yield is not clear, nor is there yet evidence of potential deleterious effects of greywater on plant growth. They contemplated that negative factors that may accompany repeated greywater reuse must be controlled or ameliorated through research and appropriate guidelines. Englebrecht & Murhpy, (2006:1), also support the fact that greywater is used all over the world and in South Africa by the rich and poor, but not under a controlled system. They concluded in their study "what stops me from using greywater" that the reuse of water should be controlled and properly managed with the relevant knowledge and understanding.

According to (Alcock, 2002), the benefits of using greywater as a valuable irrigation supplement and plant nutrition resource for low income households has been realised by some participation programmes in South Africa (Murphy, 2006:37). Potential uses for greywater in South Africa include:

- For poor communities the irrigation of plants used for subsistence purposes (e.g. those that are fairly tolerant of elevated sodium in soil water, such as tomatoes and cabbages), security purpose, screening (i.e for domestic privacy), shade, animal fodder and compost, and
- For more wealthy communities the irrigation of flowers, shrubs, vines and lawns.

Amongst poor communities greywater is often reused for other purposes in the home (Alcock, 2002), such as the use of dish rinse water for washing dirty dishes, use of dirty dish water for washing pots, and the use of this greywater for compost (Murphy, 2006:37). Similarly, clothes' rinse water may be used for washing the next batch of dirty clothes, and clothes' wash water may be used for cleaning floors. It has been revealed that the extent of reuse depend on the cost and/or effort required to obtain source water. The greywater discharged from these homes can thus be expected to be of poor quality, and may only be suitable for compost or irrigating tolerant plants.

3.2.2 Other Countries

According to the Centre for the Study of the Built Environment, the reuse of greywater is being increasingly practiced in a number of countries, whose water crisis is less critical [Centre for the Study of the Built Environment (CSBE, 2003:6)]. A number of these countries have carried out assessments of greywater reuse practices and investigated the technical means of reuse, as well as the health and environmental implications. The following are some jurisdictions where information on greywater reuse has been found, and where greywater reuse is currently being practiced as stipulated in the CSBE:

- In the United States (US), no national guidelines exist, as individual states are responsible for their own regulation of water and plumbing. Several states have developed legislation to allow greywater reuse in different circumstances. California was the first state to study and permit the reuse of greywater. Greywater was being permitted in Santa Barbara as early as the 19th Century.

A pilot study into greywater reuse in the Los Angeles area was carried out in the 1980s. A Code to regulate the reuse of domestic greywater was issued in 1977 and is currently under revision.

In Arizona, greywater is permitted for use in household irrigation. Numerous trials, studies and assessments have been carried out, and reported. Guidelines for greywater reuse have also been prepared. A 2000 study showed that greywater reuse was common in Arizona for irrigation of shade and ornamental trees, even before legislation and guidance were available (Residential Greywater Reuse June 2000).

- Studies in Australia published in 1994 and 1997 (Jeppesen and Solley 1984; Anda and Matthew 1997) were carried out to assess the potential for greywater reuse there. The study concluded that significant water savings could be made from the responsible reuse of greywater, provided adequate safeguards were followed. No information regarding the degree for greywater reuse in Australia has been uncovered.

- Cyprus has initiated a subsidy program for households that wish to install greywater reuse systems for domestic landscaping and toilet flushing. There is also documentation of greywater reuse at certain hotels and at least one sports facility. Dual plumbing systems have also been introduced to allow the reuse of greywater in toilet flushing (Kambanellas 1999).

- Agencies in the United Kingdom (UK) (Environment Agency, CIRIA and BSIRIA) have published studies on greywater treatment and reuse for toilet flushing (CIRIA 2001). These studies investigated a number of operational pilot plants in various parts of the country, where greywater was captured and treated for use in toilet flushing. Filtration and disinfection were employed to raise the quality of the water to the desired standards. It is estimated that around 150 water savings could result, but cited issues of reliability and maintenance was needing to be overcome before greywater reuse could be promoted on a more widespread basis. The reports also cite lack of financial incentives due to the cost of greywater systems, and the low cost of water. It is clear that the level of complexity of treatment and operation of greywater systems, designed to produce water for toilet flushing, is considerably more complicated than for garden irrigation, and leads to increased operation and maintenance costs.

- Although legal in Germany, the use of greywater recycling systems has been limited. Instead, rainwater collection for toilet flushing is the favored option, due to the higher quality water available from this source.

- Greywater reuse is also practiced in Japan on a scale that ranges from the use of simple hand basin urinals in residential properties that flush the bowl using water from hand washing, to complex recycling systems in office blocks. In Tokyo, greywater recycling is mandatory for buildings with an area over 30,000 square meters or with potential reuse of 100 cubic meters/day (Hanson 1997).

- Pilot studies have also been carried out by the Islamic Network for Water Resource Demand Management (INWRDM) in Palestine and Lebanon, although greywater reuse in these countries is not thought to be widespread (see http://network.idrc.ca/ev.php).

Carden *et al.* (2007:2-21), also reported that many international studies show that using untreated wastewater as an irrigation resource for urban agriculture is common in the low-income countries of Asia and Africa. Such farming methods are clearly a health hazard and would not be accepted in the affluent countries of Europe and North America, but are an essential economic activity in poor countries, one that provides rice, vegetables and other foods to the urban poor, sometimes accounting for as much as 50% of urban vegetable supply. Despite all the potential and actual health problems with the use of untreated water, urban farming using waste water for irrigation creates employment and provides affordable food for some of the urban poor. For the farmers, the nutrients in the wastewater make it possible to minimize fertilizer costs while providing them with a constant supply of water they would otherwise not have. They state that there has been a reassessment of domestic water consumption in Israel in recent years, due to the fact that the costs and environmental impacts of desalination are so high. They further stipulate that greywater use initiatives, in most countries, are driven generally by limits on the water supply, either by high population densities or drought conditions.

Greywater is typically used for restricted irrigation or toilet flushing, usually with some form of pre-treatment units that were developed to help the rural poor in a case study in Jordan (Bino, 2004), where the quality of treated (generally anaerobic treatment) greywater was found to be suitable for restricted irrigation, i.e crops not directly consumed by humans.

Friedler and Galil (2003) evaluated the technological aspects of greywater recycling in multi-storey buildings (particularly for toilet flushing) with a view to providing sustainable solutions (Carden *et al.* 2007:2-21). There have also been agricultural initiatives in peri-urban areas in Palestine, examining the use of small trickling filters for the treatment of greywater, for use in home gardens (Mohammed, 1998).

Similarly, the opportunity for greywater to be reused, to irrigate gardens, is practised in Australia (Australian dept. of health, 2002: 1).This will reduce the demand on quality ground water and surface water supplies. Considering the dry environment in many parts of Western Australia, and the sometimes limited supply of available water, it is important that water is used efficiently and conserved wherever possible. Reuse of greywater is therefore supported and encouraged by Government to help conserve water.

On the global scene, Japan, the US and Australia maintain the highest profile in greywater reuse. Other countries involved in active greywater research and applications include Canada, the UK, Germany and Sweden (Al-Jayyousi, 2003:182). He reported that recent developments in technology, and changes in attitudes towards water reuse, suggest that there is potential for greywater reuse in the developing world. Greywater represents the largest potential source of water savings in domestic residence.

For example, the reuse of domestic greywater for landscape irrigation makes a significant contribution towards the reduction of potable water use. In Arizona, for example, it is documented that an average household can generate about 30,000 to 40,000 gallons of greywater per year. This illustrates the immense potential amounts of water that may be reutilized, especially in arid regions like the Middle East. Domestic greywater reuse offers an attractive option in arid and semi-arid regions due to severe water scarcity, rainfall fluctuation, and the rise in water pollution. Al-Jayyousi further stipulates that, to ensure sustainable water management, it is crucial to move towards the goal of efficient and appropriate water use. Greywater reuse contributes to promoting the preservation of high-quality fresh water, as well as reducing pollutants in the environment.

In addition to this, Winblad & Simpson-Herbet (2004), summarised the purpose of greywater treatment and disposal systems, within the context of ecological sanitation, as:

- To use greywater as a resource for plant growth etc.
- To avoid damage to buildings and surroundings areas from inundation and water logging.
- To avoid the creation of bad odours, stagnant water and breeding sites for mosquitoes and other insects.
- To prevent eutrophication of sensitive surface waters.
- To prevent contamination of groundwater and drinking water reservoirs.

Furthermore, greywater re-use for garden irrigation provides several beneficial results (Marshall, 1997: 1). It utilises a valuable on-site resource which is otherwise wasted, it conserves fresh water which can remain in natural ecosystems, and it reduces the load on wastewater disposal systems (both on-site and centralised). This is important as many on-site septic tank systems in Australia are failing, resulting in effluent surfacing in the leach field area.

This presents a significant health and environmental pollution risk for occupants and the local catchment. Direct greywater re-use for garden irrigation diverts much of the low-pollutant water load from a septic tank system, allowing the system to function under far less stress. Contrary to the above, CSBE, (2003:23), disapprove the use of greywater in that it should not be used for dust control, cooling, spray irrigation or any other use that would result in air-borne droplets or mist. As indicated in the guidelines by Australian Dept. of Health, (2002:1) greywater can contain pathogenic microorganisms including bacteria, protozoa, viruses and parasites in concentrations high enough to present a health risk. Therefore, a level of caution must be exercised with greywater reuse. This can be achieved by not allowing unnecessary human contact with greywater, or by treating the greywater to remove or destroy the microorganisms.

In light of the above, it is therefore imperative to know the quality and characteristics of greywater as outlined below.

3.3 Greywater quality

3.3.1 Composition of Household Greywater

Greywater constitutes kitchen, bathroom and laundry water. The composition will vary significantly in terms of both place and time, due to the variations in water consumption in relation to the discharged amounts of substances. Furthermore, there could be chemical and biological degradation of the chemical compounds, within the transportation network and during storage (Erikson *et al.* 2001:86). (NSWhealth, 2000:5) describes these different greywater streams as outlined below:

- **Kitchen greywater**

Kitchen wastewater is heavily polluted physically with food particles, oils, fats and other highly pollutant waste and is often more polluted than black water or raw sewage. It readily promotes and supports the growth of micro-organisms. Because of the solid food particles and because fats can solidify, kitchen wastewater may cause blockages in land application systems unless treated or removed from greywater. Microbiologically, extremely high concentrations of thermotolerant ($2x10^9$ cfu/100ml) have been found in kitchen greywater but the more usual concentrations appear to be in the range of less than 10 to 10^6 cfu/100ml. Such high levels are again indicative of raw sewage and on occasions kitchen greywater may be more contaminated with micro-organisms than raw sewage. The high thermotolerant coliform concentrations sometimes found in kitchen greywater is cause for concern and must be managed effectively to prevent disease transmission. Kitchen greywater is chemically polluted as it also contains detergents and cleaning agents and where dishwashers are used the greywater is very alkaline from the detergent. It may be harmful to soils by altering its characteristics in the longer run and can also cause the soil to become water repellent. It is therefore, for these reasons of health and environmental risk, that kitchen greywater is not to be reused nor diverted from sewer. However, where kitchen greywater is to be reused it must only be used after treatment in a greywater treatment system. CAT's free information service, (1995: 1) also supports the idea that one must refrain from re-using kitchen greywater, because it can be very dirty and may contain lots of undesirables such as grease, oil, and chemicals. As it is generally produced in small concentrated quantities it is best not to reuse it.

- **Bathroom greywater**

The bathroom (hand basin, shower and bath) generates about 38% of the household wastewater flow (55% of greywater) and is considered to be the least contaminated type of greywater. Microbiologically, thermotolerant coliform concentrations have been assessed in shower and bath water to be in the range of 10^4 to 10^6 cfu/100ml. As people often urinate in showers and bath water, concern is often expressed about the increased health aspects of inappropriate disposal. While urine in a healthy person is sterile, some bladder infections may pass micro organisms in urine. However, the potential for these organisms to survive and cause infection is considered remote. It also contains some faecal contamination (and the associated bacteria and viruses) through body washing. The ammonia in urine is beneficial to plants but may harm the environment if not adequately dispersed. Wastewater from hand basins is more polluted than bath or shower greywater. Soap is the most common chemical contaminant found in bathroom greywater and other common contaminants are from shampoo, hair dyes, toothpaste and cleaning chemicals. All of these contaminants are believed to adversely affect land application systems and are difficult to remove from the wastewater. Biocidal soaps have little effect on reducing the bacterial load in greywater.

- **Laundry greywater**

Laundry wastewater represents about 23% of household wastewater (34% of greywater). Greywater from the laundry improves in quality from wash water, to first rinse water, to second rinse water. Microbiologically, thermotolerant coliform loads varied from 10^7 cfu/100ml when nappies were washed to 25 cfu/100ml for second rinse water. In addition to this, laundry greywater can have faecal contamination with the associated bacteria and viruses, lint, oils, greases, chemicals, soaps, nutrients and other compounds (NSWhealth, 2000:5).

Wash cycle water contains higher chemical concentrations from soap powders and soiled clothes (sodium, phosphate, boron, surfactants, ammonia, nitrogen) and is high in suspended solids, lint, turbidity and oxygen demand. If applied to land, untreated, it can lead to environmental damage, as well as posing a threat to public health. First rinse and second rinse laundry greywater still contain a pollutant load and still pose a threat to public health, although greatly reduced.

Sometimes the laundry tub is also used in an irresponsible and illegal way to dispose of harmful substances such as plants, solvents, pesticides and herbicides and these residues further increase the pollutant potential. Domestic pets which may often be washed in the laundry tub are further sources of contamination. Furthermore, the relative mix of various types of greywater (kitchen, bathroom and laundry) will vary with time, thus averages of greywater characteristics must be used cautiously (Hrudey and Raninga, year unknown:138). Marshall, (1997: 2), also points out that greywater varies from house to house. For most houses it can contain soap, shampoo, toothpaste, shaving cream, food scraps, cooking oils, dishwashing detergents, laundry detergents, hair and lint. Normal use of these products appears to do no harm to garden soils and plants if greywater is used for garden irrigation. The content of metals and organic pollutants in greywater is generally low, but can increase due to addition of environmentally hazardous substances (Ridderstolpe, 2004:3). The levels of metals in greywater are for most substances approximately the same as in a mixed wastewater from a household, whereas for zinc and mercury the levels are lower (Vinneras, 2001). Metals in greywater originate from the water itself, from corrosion of the pipe system and from dust, cutlery, dyes and shampoos etc. used in the household. Most organic pollutants in the wastewater are found in the greywater fraction, hence the levels are in the same concentration range as in a mixed household wastewater. Organic pollutants are present in many of our ordinary household chemicals, e.g. shampoos, perfumes, preservatives, dyes and cleaners (Eriksson, 2002). They can also be found in furnishing fabrics, glue, detergents and floor coatings.

3.3.2 Characteristics of greywater

According to Erikson *et al.* (2001:86), the characteristics of grey wastewater depend firstly on the quality of the water supply, secondly on the type of distribution net for both drinking water and the grey wastewater (leaching from piping, chemical and biological processes in the biofilm on the piping walls) and thirdly from the activities in the household. The compounds present in the water vary from source to source, where the lifestyles, customs, installations and use of chemical household products will be of importance. Carden *et al.* (2007:7), also concurs with this, in that the quality of greywater generally contains high levels of pollution emanating particularly from the use of household chemicals and detergents. They point out that in general greywater contains lower levels of organic matter and nutrients compared with ordinary domestic wastewater, but heavy metals appear to be in the same concentration range. They further state that in South Africa there was absence of data on chemical and microbiological composition of greywater until the study by Alcock (2002) which considered the chemical composition of domestic greywater from a middle-class, sewered household in Stellenbosch. Household greywater was found to have high concentrations of chloride (Cl), sodium (Na) and potassium (K) with variable levels of nitrogen (N) and phosphorus (P). The greywater was generally alkaline and had a reasonable high sodium adsorption ratio (SAR). Subsequent to this, numerous studies were done regarding greywater quality in South Africa.

Carden *et al.* reported the results of the study that have been conducted in University of KwaZuluNatal (UKZN) plant trials with greywater from the Cato Manor area in Durban. The pH was found to be slightly acidic (5.8 – 6.3), conductivity was 144-148 millisiemens per meter (mS/m) while Total Kjeldahl Nitrogen (TKN) was 24-30mg/l. In addition to this, greywater from seven different households in Kwamathukuza township in Newcastle, Kwa-Zulu Natal (KZN) was monitored, where greywater was disposed onto the ground in front of the houses. The phosphate was found to be in the range of 0.29 – 18.89 milligram per litre (mg/l), Chemical Oxygen Demand (COD) 999-1625mg/l and SS 265.2 – 160.8 mg/l. Furthermore, a study by Pillay and Buckley (2001) on the impact of detergent phosphorus on eutrophication, reported that the South African detergent industry formulates with phosphorus builders and therefore uses the maximum amount of phosphorus (Carden *et, al.* 2007: 2-5). They reported that an investigation of the costs and benefits of eliminating detergent phosphorus altogether indicated that the costs outweighed the benefits, but Pillay and Buckley concluded that the cost of other systems which use reduced amounts of phosphorus should be investigated as they may still provide some benefit to the environment whilst being affordable.

Engelbrecht and Murphy, (2006:4), also added that the quality varies, depending on the volume of supply water consumed per person in a household, on the initial quality of the water supply, on the source of the greywater, and on chemicals used in the washing/bathing process. The volume of supply water consumed by a household depends on the scarcity/cost of supply water and on the water conservation measures being taken within the household. This is also in agreement with (Holtzhausen, 2005:11) in that the volumes of greywater vary enormously between households. Water consumption in poor areas can be as low as 15 to 20 L per person per day, while in more affluent urban areas people may generate more than ten times as much.

Due to the lack of information on the quality of greywater and in order to evaluate the fitness for use of greywater, Engelbrecht and Murphy decided to establish the greywater quality in relation to different social and economic settings. Eighteen individuals, staff members of the CSIR in Stellenbosch, were requested to bring samples of dishwater, bathwater and water from the source. The parameters done were Potassium, sodium, calcium, magnesium, ammonia, sulphate, chloride, alkalinity, nitrate plus nitrite, ortho phosphate, electrical conductivity, pH, sodium absorption ratio, boron, dissolved organic carbon, chemical oxygen demand (COD), kjeldahl nitrogen, total phosphorus, suspended solids, total dissolved solids, fats and oils, heterotrophic plate count, faecal coliform bacteria and Escherichia coli and the results were compared with the South African Water Quality Guidelines, Volume 4 Agricultural use of the Dept. of Water Affairs and Forestry. The results showed that that there were significant differences in quality between the different types of greywater, as well as between the different locations where greywater is produced. The results were found to be in comparison with the literature used, except for nitrogen which was found to be higher.

Salukazana *et al.* (2005: 3) also did physico-chemical and microbiological analyses prior to irrigation with greywater and hydroponic nutrient solution. The analyses included: alkalinity, conductivity, pH, free ammonia, Biochemical Oxygen Demand (BOD), COD, cadmium, calcium, chloride, chrome, copper, lead, magnesium, nickel, nitrate + nitrite, otho-phosphate, selenium, sulphate, total Kjeldahl nitrogen, total phosphate and zinc. Microbiological analysis included total coliforms, E.coli, coliphages and Ascaris spp. The results showed a variation and greywater irrigated plants showed the greatest plant heights throughout the entire crop cycle. In relation to this, Murphy, (2006: 13) reported the study done by Beukes (2001), on the impact of greywater irrigation on crops conducted at Infruitec-Nietvoorbij, Stellenbosch. Of all the chemical parameters measured, the sodium adsorption ratio and sodium concentration showed the greatest increases over the source water at levels indicating that sodium accumulation could occur in fine textured soils. Sodium was a major constituent of concern, however despite this, the production of beans and tomatoes in the pots irrigated with greywater were higher than those irrigated with municipal water.

In another study by Carden *et al.* (2006: 7) to develop a model to assess management options for greywater in the informal settlements of South Africa, the samples that were analysed indicated high levels of pollution emanating particularly from the use of household chemicals and detergents. Limited microbiological testing was conducted and generally showed high levels of faecal contamination in the greywater, thereby limiting the potential for reuse. Winter et al, (yr unknown) reported that the average values for greywater qualities for the settlements surveyed in each province - Western Cape (WC), Mpumalanga (MP), Limpopo (LIM), Eastern Cape (EC), KwaZuluNatal (KZN) and Gauteng (GP) indicated high levels of pollution emanating from the use of household chemicals and detergents and suggest that greywater is generally unfit for use except under controlled conditions. Levels of phosphorous and sodium were particularly high in certain cases and further investigation is required into the effect of detergent use on the quality of greywater and how this impacts on the use of the greywater as a resource.

A lot has been mentioned regarding the quality and characteristics of greywater. Given this status quo, it is also imperative to determine the quantity of greywater as outlined below.

3.4 Greywater volume

Greywater volume production from residence is generally not measured, and therefore needs to be estimated from alternative data sources (Murphy, 2006: 16). He points out that greywater volume production for private households may be estimated given the water consumption of a household, given some knowledge of how this water is used outside the house (e.g for the garden and swimming pool), whether the house has water-borne sanitation, whether water conservation measures are being practiced in the home and the cost of water, amongst other factors.

Carden, *et al.* (2007: 2-6), concurs with this, in that generation of greywater is directly related to the consumption of water in a household and is dependant on a number of factors including the level of service provision, tolerance of residents to pollution and the community's level of awareness of health and environmental risks. They point out that, it could be assumed that greywater accounts for virtually all water usage in non-sewered areas except for that which is used for drinking purposes, used for cooking and the water that remains on the surfaces of washed articles. They indicated that Wood, *et al.* (2001) noted that there is a general absence of data on the quantification of greywater in dense informal settlements, owing to the fact that generally there is no proper measurement in these areas and assumptions are made based on population estimates.

They reported that during the on site survey of their research, residents indicated water consumption figures ranging from 4.7 to 28L per capita per day, although in the general absence of metering, these figures do not accurately reflect the total water drawn from the system (i.e. leaks, under-reporting are not accounted for). Furthermore, the study by van Schalkwyk (1996), estimated the water used for dish washing, cleaning the house, clothes washing and personal hygiene varies from approximately 12 to 50l/c x d (Carden, *et al.* 2007: 2-6). Under such circumstances van Schalkwyk concluded that a greywater volume of 150L per household per day is possible, assuming a mean size of 6, and the fact that up to half of the water used or washing could be retained on surfaces. Murphy, (2006: 17), reported that, it is estimated that the average person in developing countries uses 60-150 liters per day [United Nations Environment Programme (UNEP, 2000)], and if 90% of this ends up as greywater, then between 55 and 135 litres of greywater per day would be produced per person. He further states that for households with a standpipe outside the house or tap in the home (not connected to a waterborne sewage system) is likely to be between 30 and 80 liters per day, where water has to be brought in from a source at least 250 meters away from the home, a consumption of 9-50 liters per person per day is likely. Greywater volumes may then be estimated from these figures.

Alcock, (1999a,b), reported that, there is likely little variation in demand for household water over the seasons for poor communities except where rainwater runoff is used to augment the household water supply, or unless source water is used for irrigating plants. The availability of rainwater in sufficient quantities, at home will result in a higher consumption, and therefore more greywater will be produced (Murphy, 2006: 18). (Carden, et *al* 2007: 2-7), indicated the ranges of typical domestic water consumption and greywater generation figures for the different levels of service (LOS) as quoted in the "Red Book" – Guidelines for human settlement planning and design [Council for Scientific and Industrial Research (CSIR, 2001)] as shown in table 3.1 below.

Table 3.1: Typical domestic water consumption figures and greywater volumes

Type of water supply	Typical consumption (l/p*d)	Range(l/p*d	Greywater generation (l/p*d)
Communal water point			
Well or standpipe at > 1000m distance	7	5-10	-
Well or standpipe at distance 250 – 1000m	12	10-15	-
Well or standpipe nearby < 250m	20	15-25	-
Domestic water consumption			
Standpipe within 200m	25	10-50	20-30*
Yard connection	55	50-100	30-60*
Yard connection with dry sanitation	55	30-60	
Yard connection with Low Flow On Site Sanitation System (LOFLOS)	55	45-75	
Yard connection with full-flush sanitation	55	60-100	

* Sanitation type – pit toilet; l/p*d – litres per person per day

In another study of developing a model to assess management options for greywater in the informal settlements of South Africa, Carden *et al.* (2006: 7), reported that, it was not possible to accurately measure the volumes of greywater being disposed of, in each community, but it was assumed that consumptive use of water (for drinking, cooking and that which remains on the surface of laundry) was relatively low, and that a large proportion (estimated as 75%) of the water used during any one day is discarded as greywater.

3.5 Greywater disposal

According to Carden *et al.* (2007: 5-1), there is currently a large portion of greywater generated from washing laundry, cleaning dishes and bathing that is disposed onto ground surfaces close to dwellings and thus any potential benefits through controlled use are being lost. They state that it is worth noting, that the water being used at dwellings is very often recycled before it gets disposed as greywater. They indicated in the "guidelines for human settlement planning design" (CSRI, 2001) the means for providing wide spaces between dwellings would result in far lower settlement densities and could create space for greywater disposal. These guidelines are:

- Low fire resistance buildings – 4.5m minimum distance to boundary and 9m minimum distance between buildings.
- Low fire resistance, but where units of houses are in groups of less than 20 buildings-2m minimum distance to boundary and 4m minimum distance between buildings.

They further state that it is worth noting, however, that the prescribed minimum distance between dwellings are seldom, if ever, adhered to in informal settlements. They contemplated that local authorities need to consider greywater disposal in their planning of settlements and must provide disposal systems for the greywater generated in densely-settled areas where on-site disposal is not possible. In areas where water and sanitation services have been privatized, the company responsible must take charge of greywater removal as part of the sanitation service. In addition to this, in another study of developing a model to assess management options for greywater in the informal settlements of South Africa, by Carden *et al.* (2006:7), they recommended an example of a "decision tree" for determining appropriate greywater management options, based on greywater generation rate, as follows:

- For a greywater generation rate of <500l/ha.day - On site disposal of the greywater is possible e.g. soakaway/ reuse options.
- For a greywater generation rate of 500 – 2500 l/ha.day - On site disposal can be considered, depending on:
    I. Soil/surface properties
    II. Slope
    III. Rainfall
    IV. Depth to water table
    V. Sensitive environments
    VI. Waste management
- For a greater generation of >2500l/ha.day – off site disposal of greywater is recommended.

Winter *et al.* (yr unkown:10), in their study on the problem of site and situation for the disposal of greywater in South Africa, also reported that most greywater is disposed onto surfaces as a matter of convenience and largely because the vast majority of interviewees reject the practice of reusing or recycling greywater. The reasons for this vary considerably, but the majority of the sample population felt that greywater is "dirty" and could not be reused. The study findings suggested that approximately 75% of all household water consumed is disposed of in the same manner. Hammel, (2006: 31), also reported the same manner of disposal in his research of investigation of soil properties, in relation to grey water management in South Africa, in that the responses to questions related to disposal of their greywater were relatively homogenous: in the absence of any piped drains or septic tanks, greywater was either poured directly onto their yard (5/12) or in dug drains (4/12) or on the street surface (4/12). These figures reflect that in some cases individual households used multiple methods for their greywater disposal. Jackson *et al.* (2006: 700), also in agreement with the same method of disposal, in their study, microbiological assessment of food crops irrigated with domestic greywater, reported that at the earliest stages of implementation of community upliftment, the feeling in the communities was that one of their highest priorities was to receive potable water; the aspect of sanitation came much further down on the list. This led to the situation where communities were receiving water but had no formal means of disposing of it after use. In many instances, water was thrown outside the door of the residence resulting in pooling and unsanitary conditions, including the breeding of mosquitoes.

Wood *et al.* (2001: 24) reported a good practice regarding greywater disposal in Paarl's densely populated informal settlements: They have established a temporary system to partially control and ease greywater problems by capturing greywater in soakaways, which gravitate through concrete trenches to the ex-river-stormwater channel. Litter and sewage get washed of the surfaces into the same trenches and accumulate in the channel, from where it gravitates, with the greywater, to the municipal sewage plant. In another instance the ground tanks supplied by Durban Metro, provide a maximum of 200l/day of potable water. This volume has been determined, by Metro water, to produce very little run-off and reduces greywater problems. Water is gravitated to the drip tank, directly connected to the house, at each household. A restriction valve allows use of limited amounts of water a day. They state that, in some sites, residents have utilised the minimal resources available, to route the drainage, in earth channels, between the dwellings.

In some instances additional standpipes are linked into the same channel. The final discharge point may be a watercourse outside the settlement. The greywater that is generated within the household, rather than at the standpipes and tanker, tends to de disposed directly to ground in the immediate vicinity of the shack. In the case of more developed informal and low cost settlements, where there is some garden area, the greywater will tend to be used as irrigation water. In the case of squatter areas and where the stand is dominated by back-yard shacks, there is limited area available for responsible disposal of the greywater and it then has to be discharged within the immediate vicinity of the shack in an ad-hoc manner. Wood *et al* also point out that limited volumes of greywater can be discharged to pit latrines and basic sanitation facilities without causing overloading, although some facilities, such as low-flush and compost units, do require some discharge of greywater to maintain an adequate moisture ratio. Murphy, (2006:18), reported that, for dwellings in peri-urban areas supplied by public standpipes, the final greywater was thrown on the vegetable patch, fruit trees or lawn.

As mentioned earlier, greywater has associated threats, which may result in negative impacts on health and the environment. This is outlined below as follows:

3.6 Potential health impacts

The health risks associated with greywater through, amongst others, direct contact, disposal and lack of sanitation, play an important role. Engelbrecht & Murphy, (2006: 4), reported that the health risk associated with greywater is related to the microbial quality of greywater at the point of irrigation, on how irrigation is carried out, and the type of crops being irrigated. Carden *et al.* (2007:1-1), points out in this regard that, the association between poor sanitation and ill health is well known, as demonstrated by World Health Organization (WHO, 1996) estimates that diarrheas are responsible for over a quarter of deaths of children in the world, and the fact that 80% of these deaths are reported as resulting from a lack of sanitation and water (Esrey, 1998). In South Africa, recent research has shown that 43 000 people, mainly children under the age of 5 years, die from diarrheas each year (Mara 2001). They further state that the links between health, sanitation and poverty have been demonstrated through initiatives such as Khayelitsha Water and Sanitation Programme (Stern *et al.* 2004) which highlighted the high rate of worm infestation and diarrhea amongst children in informal settlements, as a result of inadequate toilet facilities. This condition is further aggravated by highly polluted urban stormwater runoff, which is caused by, *inter alia,* greywater and solid waste disposal. In addition to this, the pollution from densely populated, and inadequately serviced, settlements also impairs in the downstream water resources for a variety of other users. Pollution from these settlements increase the health risks for recreational users of water bodies. Increase the risks for livestock, and impairs use of the water for irrigation purposes (DWAF, 1999:11).

Bacterial counts in greywater have an impact on the general health of the population and the ability of infectious agents to survive outside of their host (Carden *et al.* 2007:2-5). Since kitchen water contain high bacterial counts, compared to bathroom and laundry water (depends on whether there are babies), the risk is significant. The transmission of this bacteria is likely, if the disposal method is not managed properly. Furthermore, (Okun, 2000) indicated that, contrary to common belief, greywater is not a safe or harmless substance, since it contains bacteria, viruses and other potential pathogenic organisms, which are able to cause disease in humans or animals (Carden, *et al,* 2007: C-1). Consequently, the potential reuse of greywater is as much a public health issue as it is a water conservation issue.

A growing body of evidence indicates that the greatest risk of infection for enteric pathogens is borne by persons younger than 19 years (Nwachuku & Gerba, 2004:206). They indicate that, children are more likely to become ill from the consumption of contaminated water and from exposure via recreational activities.

This may be because their immunological, neurological and digestive systems are still developing and/or because they are environmentally more exposed. In addition, children are more exposed to pathogens in the environment because of poor, or lack of, sanitary habits. This is likely to be especially true of enteric pathogens, which are transmitted by the fecal-oral route through water, soil and food. Children and young ones have greater environmental exposure as they have not yet developed proper sanitary habits such as the use of toilet facilities and hand washing. Frequent hand-to-mouth and object-to-mouth contact is much greater among them than adults. Viruses and bacteria are readily transferred from contaminated objects (fomites) directly to the mouth or from a contaminated hand. They further point out that persons with compromised immune systems, or those who suffer from other health conditions, are also at increased risk.

Old people, pregnant women, patients suffering from HIV/AIDS, tuberculosis, malnutrition and other chronic diseases also fall into this category. Furthermore, eating edible crops, especially vegetables and fruits eaten raw, or after minimal processing, is unsafe. They contemplated that greywater emanating from non-sewered areas (and particularly densely populated informal settlements) is not suitable for the irrigation of edible crops, except in times of such severe food shortage, where the risk of disease becomes less than the risk attached to compromised food supplies (a very rare occurrence). There is also a large body of evidence showing bacterial transmission from greywater or other wastewater to food crops and livestock kept for slaughter (Petterson & Ashbolt, 2001; Fasciolo *et al.* 2002; Sadovski *et al.* 1978).

According to Carden *et al.* (2007: C-10), the reported cases of typhoid fever between 2000- 2005 in Benoni and Brakpan is 6 & 2 respectively. They indicated that attempts were made to try and obtain recent South African health clinic data on waterborne diseases or incidences of diarrhea, but it was only possible to get limited information at district level for typhoid and cholera cases. While these numbers certainly give an indication of the impacts of poor water supply and sanitation on these communities (as evidenced by the typhoid outbreak in Delmas in 2005), the specific impacts from greywater disposal, particularly in densely-populated areas, could not be determined.

There are still unanswered questions regarding the health risks associated with using greywater from impoverished communities (and particularly high-density settlements) to irrigate food products where community health and overall immunity to disease is severely compromised (Carden *et al.* 2007: 2-13). In addition to this, the impacts resulting from the poor management of greywater are felt more strongly by the poor than by the rich. This is primarily due to the health impacts related to greywater disposal; the poor are less likely to have resistance and a greater tendency to contract disease.

The implications of poor greywater disposal are therefore likely to be worse in low-income communities. They indicated that a lack of financial capacity in local authorities can also lead to increased risks of pollution in settlements, which in turn contributes to increased incidence of disease and consequent increased costs to all spheres of government. The risk of mosquito breeding and pathogen contamination, resulting from hand washing and laundry (including baby nappies) are often mentioned as factors exacerbating health hazard (Hamel, 2006:18). In addition to this, biogases such as carbon dioxide and methane are produced by the degradation of organic compounds of greywater, while sulphide production is responsible for unpleasant smells in areas with ponds (Ledin *et al.* 2001). Another risk to human health is eating raw vegetables irrigated with greywater, if the water is from a household where a child has diarrhea (Engelbrecht & Murphy, 2006:2). It is thus for reasons stipulated above that it is uncertain whether greywater use should be promoted or discouraged as a source of water for urban and peri-urban agriculture.

3.7 Potential environmental impacts

According to DWAF, (1999:11), the water quality problems are caused by the following:

- *Nutrients*, mainly phosphorus and nitrogen, which causes eutrophication and increase the costs of treating water to potable standards. These mostly come from human excreta and greywater, but may also be present in high concentrations in the stormwater runoff.
- *Solid waste* (litter) from public spaces and from household refuse, which causes ecological, aesthetic and health problems, and affects the functioning of stormwater and sewage services.
- *Sediment* from unpaved areas in the settlements, which accumulates in rivers and dams, affects aquatic habitats, and reduces storage of stormwater runoff.

- *Habitat destruction* mostly by building in the riparian zone which affects the natural functioning of river ecosystems, and allows waste to get into the rivers.

Carden *et al.* (2007: 2-8), indicated in the report by Ashton & Bhagwan (2001), that rapid growth of urban areas in South Africa has been accompanied by increased quantities of contaminated runoff from settlements, which has accelerated the degradation of water resources. They indicated that the impact low cost, high density urban land use has on catchments warrants urgent attention. Monitoring studies have, to date, often overlooked site-specific causes of contaminated runoff.

An emerging problem in this regard, which require attention, is the disposal of greywater, since it has the potential to cause severe pollution of water resources, as well as impacting local soils. According to Schoeman *et al.* (2001), greywater in itself is not considered to be a particular problem in terms of urban runoff, but could contribute to the total pollution load – the litter and faecal pollution associated with greywater from low cost, high density settlements is the main contributors to urban runoff (Carden *et al.* 2007:2-16). A study of groundwater contamination by Wright, (1999), revealed that all existing informal settlements, and particularly those that are poorly managed, should be considered as sources of contamination (Carden *et al.* 2007:2-17).

The groundwater from the acquifers around the study sites in Cape Town, Gauteng and Durban was found to be contaminated with nutrients, pathogenic micro-organisms and biodegradable organics at all of the sites studied. The major sources of groundwater pollution were found to be, amongst others, greywater disposal, on-site sanitation, seepage from garbage and communal water supply sites and stormwater drainage systems. Furthermore, if greywater does not percolate through soil, it can flow into creeks or other waterways untreated (Oasis design, 1999:11). While greywater may be a resource for maintaining a garden or lawn during periods when reticulated water is restricted, the detergents used in the laundry must be recognised as a salinity risk Patterson. (2007:248). The risk is associated mostly with powder detergents and the higher the dose of detergent recommended, the higher the potential risk. In laundry liquids there are more organic compounds that do not ionize to affect measured electrical conductivity (EC), yet may impinge upon soil properties and soil microbiological activity. They point out that biological systems prefer a range of pH 5.5 to 8.5, although many organisms live in extreme conditions. Highly acidic or highly alkaline greywater can change the solubility of soil minerals and affect any nutrient balance that may have existed before the greywater dispersal. In addition to this, high pH wastewater may also dissolve metals from the fittings and fixtures. Liquid detergents have a pH closer to neutral than the powders that are highly alkaline. Add to the high pH the total alkalinity (buffer capacity) and the powders in wash become even more environmentally hazardous.

Sodium can damage soil structure, reducing the air space, giving it a greasy texture and poor drainage capability. Products which use potassium salts or liquid concentrates should be used as they produce better quality, less saline greywater. Similarly, Marshall, (1997:2) points out in this regard that continual garden re-use of laundry water containing high salt, phosphorus-containing detergents can lead to salt accumulations in re-use areas. Regions with regular rainfall may not suffer salt build-ups due to leaching of salts from soil after rain.

CSBE, (2003:19), is also in agreement with the above in that most greywater is used to irrigate plants, so the most immediate risks of pollutant constituents in the greywater are related to plant health. It stipulates that, it is assumed that users will avoid the disposal of inappropriate substances (paints, antifreeze, solvents, mothballs, wastewater from oily rags, chemicals from photo-labs, etc) into the greywater. However, many greywater sources themselves will contain substances which may have harmful effects. Laundry products in particular use a variety of chemicals that can be harmful to plants. Most soaps and detergents - including baking soda - contain sodium compounds. High levels of sodium can cause discoloration and burning of leaves, and can contribute toward an alkaline soil condition. It further states that, high sodium can be toxic to certain plants and can prevent calcium from reaching the plants. A high sodium adsorption ration SAR (13 or above) will result in soils with reduced permeability and aeration, and a general degradation of the soil's structure. In addition to this, bleaches commonly contain chlorides, which can damage plants, particularly if the bleach water actually touches the foliage. The study done by Gross *et al.* (2005:1), to evaluate the environmental impact and health risks associated with the use of greywater on a small private farm, suggest that greywater may be of similar quality to wastewater in several parameters such as BOD and faecal coliforms. For some other variables such as boron and surfactants, greywater may even be of worse quality than wastewater.

Therefore long-term irrigation of arid loess soil with greywater may result in accumulation of salts, surfactants and boron in the soil, causing changes in soil properties and toxicity to plants. They concluded that treating greywater before using it for irrigation is recommended, even in places where this is not a requirement.

Murphy (2006:76), also indicated the potential negative effects of high sodium, and to some extent, raised chloride and boron concentrations in greywater used for irrigation, on crop/yields and on soils may be determined from the following statements derived from irrigation guidelines:

- High sodium, chloride and boron concentrations are toxic to crops on uptake through roots and especially leaves.
- High salinity (high concentrations of dissolved salts such as sodium, chlorides and sulphates) reduces crop yield, and can have a negative effect on the quality of harvested fruit.
- High soil pH reduces the bio-availability of certain plant micro-nutrients and has a potential negative effect on growth/health of many crops.
- High sodium concentrations can cause a reduction in soil infiltration rate, in soil hydraulic conductivity and can cause hard-setting when the soil dries out.

Furthermore, the most common risk for the environment, of grey water with a high COD content reaching a water body, is oxygen depletion. Fauna and flora equilibrium of the water body are consequently affected (Hamel, 2006:19).

4. METHODOLOGY

4.1 General approach

The following approach was used to conduct the study:
1. Survey and review of relevant literature
2. Identification and selection of four different, representative informal settlements as study sites through preliminary field visits and discussions with officials of the EMM eastern region
3. Reconnaissance site visits of the selected informal settlements to confirm suitability of site for research questions (field observations)
4. Selection of a total of 100 households in the four settlements, for conducting interviews on greywater generation, disposal and possible use
5. Conducting interviews with identified respondents, including observations on greywater related habits, infrastructure and problems
6. Sampling of greywater with distinctly different characteristics, at five selected sites, in the four settlements
7. Analyses of chemical and microbiological parameters of the sampled greywater
8. Evaluation and reporting of results

The different steps of the above are explained in more detail below:

4.2 Selection of study sites

The identification of the informal settlements of Springs (Gugulethu), Nigel (Soul City), and Brakpan (Mkhanca) was done with the assistance of officials of the EMM. There after reconnaissance was conducted in all the informal settlements. The residents were asked preliminary survey questions about the use and disposal of greywater, such as where the laundry is done, whether at stand pipes, in their yards, or on surfaces within the water resource – like the Blesbokspruit. Observations were made regarding the proximate distance of the informal settlements to adjacent water resources and the presence of ponding greywater and whitish patches caused by detergent residues, salts and fats contained in greywater in and around the informal settlements. Based on this, the following informal settlements were selected as study sites:

- Government employees are sometimes not trusted or accepted, due to the government's perceived lack of service delivery, by people awaiting houses and electricity. These people feel that they are being neglected while illegal immigrants fear repatriation. This created a great deal of uncertainty on the side of the interviewer.

The interviews were normally conducted in either Zulu or Sotho which are the most widely spoken languages in the study area. However there were few Tsonga speaking respondents who could not speak Zulu fluently.

Answers to the questionnaires were recorded on the questionnaire sheets during the interviews and were later entered into an Excel database. The design of the questionnaire is given below:

Section 1: Details of interview

1. Informal Settlement and house no
....
2. **Number of the interviewee**
....
3. Date and time
....
4. Duration
....

Section 2: Demographic details of respondent

1. Gender
....
2. Age
....
3. Race
....
4. Nationality
....
5. Income: personal/ family member
....
6. Education level
....

Section 3: Description of residence (shack)

1. How long residing in shack?
....
2. How many people in household:
Adults (16-65?),...............
Children (<16?)...............,
Elderly (>65?) ....

Section 4: Access to and sources of water

1. Where do you get your water from?
   - type of source.........................
   - distance..................................
2. How much water do you use?
   - buckets/ containers per day.....................
   - Container size and why?................................
   - Type of container: plastic, aluminum, other (specify) and why?
   ....

3. Would you like to use more water?
4. If yes, what prevents you from doing so?
   ………………………………………
5. Do you collect rainwater?
6. If no, why?…………………………………………
7. Do you get your water sometimes from other sources as well → streams, wetlands, vendors(supplier, retailor)……………………………..

Section 5: Sanitary situation

1. Describe sanitation and waster water facilities
   …………………………………………………
2. Where is the nearest toilet?
   …………………………….
3. What type of toilet is that?
   ………………………………
4. Is it used throughout the day/night
5. If not used at night time, what do they use?
   ……………………………………
   How do they dispose the waste?
   ……………………………………
6. Are there hand washing facilities nearby?
   ………Yes/No…………………………
7. Do you prepare water before or after toilet use?

Section 6: Water use

1. What do you use your water for? Estimate percentage:

Drinking	
Cooking	
Personal Hygiene	
Dish washing	
Laundry (clothes)	
Cleaning Tools House Vehicles	
Gardening	
Other (specify)	

2. Do you sometimes use other water sources such as rivers, wetlands for washing laundry, cleaning tools/ vehicles or bathing?
3. If yes, where and how often do you do this? ………………………………………………
4. How do you do your laundry/ dish washing: by hand, give to other people, machine, other (specify)……………………………………………………
5. If by hand: how do you do it (plastic bowels, bath tub………………)
   and where do you do it: inside house/ outside?
6. If outside: why…………………………………
   and where exactly → at river, wetland ……………………………
7. Do ever report any leaking taps or pipes to the municipality?
8. If not, why not…………………………………………………

Section 7: Generation of greywater

7.1 What type of chemicals comes in contact with your water:

	Brand	Purpose	Quantity per month/week	Price	Motivation
1. Soap					
2. Washing powder					
3. Dish washing liquids					
4. Household cleaners (e.g jik, handy –andy, vim etc)					
5. Washing softner/ Sta–soft					
6. Other (specify)					

7.2 How often do you do the following:

	1xd/w/m& why	2xd/w/m & why	3xd/w/m & why	Other& why
Wash dishes				
Wash clothes				
Clean the house				
Bath				
Clean vehicle				

d = day; w = week; m= month

Section 8: Disposal of waste water

1. What do you do with your waste water: discarding, gardening, cleaning, other specify...
2. Where do you dispose of your dirty water...?
3. Where do other people discard their waste water? ....
4. Are you bothered by waster water discarded by other people?
5. What is bothering you most: smell, pollution, possible health risk, attitude of dischargers, other (specify)..
6. Could you imagine preserving your waste water for cleaning/ re-use? If no, why...
7. What would you like to improve regarding the disposal of your waste water ....

4.5 Greywater sampling

4.5.1 Selection of sampling sites

To select the most appropriate sites to sample greywater for chemical and microbiological analyses, the following criteria were used:

Two households each, from two different informal settlements were chosen. In one settlement, Soul City, two households with laundry - nappies only - were chosen, to establish the feacal load. Here different types of soap were used. In Harry Gwala, two households, one with kids' clothing (including an adult) and one household with only one female resident, who also use different soaps, were chosen. In all of them laundry, dish water, bath water and the combined samples were taken. The study sites were selected because they had a visible environmental impact. In Harry Gwala most of them dispose greywater in the stormwater channel which flows into Leeupan, while in Soul City, the environmental impact due to ponding of greywater may create a health risk, due to smells and mosquito breeding, while groundwater contamination cannot be ruled out.

4.5.2 Sampling procedure

In each household, 2l of four different samples were obtained. The sites were abbreviated as follows:

- Soul City house no. 1: with nappies.
    - SB1 – bath water, use *sunlight soap*
    - SL1 – laundry, use *sunlight soap* – although during the interview she mentioned *maq*
    - SD1 – dish water, use *maq*
    - SC1 – combined i.e. laundry including rinse water with *sta soft* and bath water. There was not enough dish water to mix, 750ml of each was mixed then 2L was taken out of the constituents.
- Soul City house no. 2: with nappies.
    - SB2 –bath water, use *sunlight soap*
    - SL2– laundry, use *maq*
    - SD2 - dish water, use *maq*
    - SC2 – combined i.e laundry (rinse water without sta soft), bath water and dish water, 500ml of each was mixed to 2l.
- Ponding of greywater around the standpipe
    - SP – 2l Ponding of water in Soul City.
- Harry Gwala house no. 1: with 2 kids clothes (age 3 & 5) and 2 adults.
    - HB1 – bath water, use *sunlight soap* and *protex*
    - HL1 – laundry, use *sunlight soap*
    - HD1 - dish water, use *omo*
    - HC1 – combined i.e laundry including rinse water with sta soft, bath water, dish water, 500ml of each was mixed to 2l
- Harry Gwala house no. 2: one female only.
    - HB2 – bath water, use *sunlight soap*
    - HL2 – laundry, use *omo*
    - HD2 - dish water, use *sunlight soap*
    - HC2 – combined i.e laundry (rinse water without sta soft), bath water and dish water, 500ml of each was mixed to 2l.

Chemical and microbiological analyses of all the above was done. The results of greywater is attached in Table 6.2 and were compared with General standards of waster water or effluent published in the government gazette 18 May 1984 N0. 9225, Regulation N0. 991 18 May 1984.

4.6 Greywater analyses

All the analyses were done by ERWAT laboratory services, which is an accredited laboratory. Methods used for analyses are detailed in Appendix A. All ICP scanned metals have an error margin of approximately 5%.

5. CHARACTERISATION OF STUDY AREA (MAP ATTACHED IN APPENDIX B)

5.1 Background information to the study area

5.1.1 Natural conditions

Climate

According to EMM (2007:12) rainfall in the study area is typical of the Highveld summer rainfall where more than 80% occur from October to April. Average rainfall is 715mm to 735mm annually. Hail can be expected periodically and mild damage to fruit usually occurs in two out of three years, while severe damage occurs every two out of five years. According to the agricultural potential criteria of the National Department of Agriculture, the study area is suitable for rainfed crop production, provided that the crops are grown in areas with deep soil which stores water for use during dry periods in the growing season. Severe frost occurs frequently from mid-April to September. Temperatures below freezing are common in winter. Summers are mild with temperatures seldom above 30°C.

Northerly and north-westerly winds blow during winter and spring and north-easterly to north-north-easterly winds during summer. Winds are usually gentle, and strong winds are only experienced 15% of the time. Moderately high-speed winds occur from late winter to early spring. Wind damage to field crops is rare, but damage to deciduous fruit quite common.

Geology

Benoni – Harry Gwala is dominated by quartzite while most of the Benoni area is undermined. Springs - Gugulethu is dominated by quartzite even though most of the Springs area is also dolomite. Brakpan - Mkhanca is shale dominated while there are few areas in Brakpan that are undermined. In Nigel - Soul City is dominated by shale and a small amount of surface dolorite. According to (EMM, 2007:7) the geological stability of an area should be one of the key considerations when planning development. The possibility of sink hole formation or earth tremors should be taken into account when considering medium to long-term development projects. The potential negative effects that this may hold for development should in all cases be assessed before development is allowed in these areas. The above-mentioned report further stipulates that the remaining gold mines in the region pump large volume of semi-treated underground mine water into the Blesbokspruit, which is a major concern. In terms of ground stability of areas on cavernous dolomite, it is important to note that ponding water (incl. greywater) poses a particular risk for sinkhole formation (pers. commun. F. Winde).

Groundwater

According to the 1:500 000 Hydrogeological map series (Sheet Johannesburg) there are four main types of water-bearing interstices which are:

- CLASS A – Intergranular
- CLASS B – Fractured
- CLASS C – Karst
- CLASS D – Intergranular and Fractured

Most of the EMM falls into Class D. This aquifer type implies that water should be stored and transmitted through both aquifers. The intergranular aquifer consisting of loose unconsolidated material would serve as a primary storage function and water will infiltrate through the fractured aquifer. Significant quantities of water can be economically abstracted through fractures caused by drilled boreholes in the underlying fractured aquifer. The usage of groundwater / borehole around the study area is 22% (DWAF, 2008). Water quality data obtained is from 1995 to 2007 as indicated in table 5.1. Of interest is the Electrical conductivity (EC) which ranges from 24 - 258 mS/m, which indicate the level of salt contamination. It actually emanates from chloride (Cl) which ranges from 3.3 to – 610.59 mg/l, potassium (k), 1.8 - 19.48mg/l, Sodium (Na), 38.8 – 158.34 mg/l, Sulphate (SO_4) 4.4 – 314.8 mg/l.

Table 5.1: Chemical data analyses for groundwater

Sample Start	Ca-D	Cl-D	DMS-T	EC-P	F-Di	K-Di	Mg-	NH4-	NO3+	Na-D	PO4-F	SO4-	Si-Dis	TAL-	pH-D	Al-Dis	As-Di	B-Dis	Ba-Di	Cd-Diss-	Cr-Diss	Cu-Di	Fe-Dis	Mn-Di	Mo-Di	Ni-Di	Pb-Dis	Sr-Di	V-Diss
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1995/01/17	15	3	221	24	1	2	2	0.0	0.0	39	0.0	4	14	127	8														
2000/04/04	19	5	179	26	0.3	5	6	0.0	0.2	17	0.0	12	5	93	8														
2000/11/10	134	173	1063	145	0.4	15	74	0.0	6.3	60	0.0	116	24	397	8														
2001/10/02	138	298	1300	197	0.4	19	98	0.0	10.2	73	0.0	165	24	380	8														
2002/05/07	220	449	1712	258	0.3	19	132	0.0	11.5	104	0.0	298	21	361	8														
2002/10/16	292	611	2033	311	0.3	22	166	0.0	16.5	81	0.0	315	22	388	8														
2002/10/16																0.03	0.06	0.17	0.15	0.004	0.003	0.006	0.064	0	0.012	0.01	0.036	2.3	0.039
2003/05/06	179	315	1396	196	0.4	18	104	0.0	8.9	71	0.0	176	24	405	8														
2004/05/17	150	223	1168	168	0.4	16	80	0.1	6.3	66	0.0	127	22	392	8														
2004/10/18	159	233	1191	181	0.5	18	84	0.0	4.0	56	0.0	142	21	395	8														
2006/04/03	11	36	586	70	0.5	2	4	0.0	3.8	157	0.0	41	21	260	8														
2007/04/16	11	51	612	78	0.4	2	5	0.1	3.3	158	0.1	42	18	269	8														
2007/04/16				71											7														
2007/09/17	86	169	836	109	0.3	11	55	0.1	8.5	72	0.0	52	29	290	8														
n	12	12	12	13	12	12	12	12	12	12	12	12	12	12	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1
average	118	214	1027	141	0.4	12	68	0.04	7	79	0.03	124	21	313	8	0.03	0.06	0.17	0.15	0.00	0.00	0.01	0.06	0.00	0.01	0.01	0.04	2.30	0.04

The pH ranges from 7.32 – 8.34 which is acceptable. The nitrates and nitrites (NO_3 & NO_2) are 0.24 – 16.46 mg/l. of which the maximum value may affect infants, by causing methaemoglobinaemia, if this water is consumed, according to DWAF, (1996: 10). The guidelines stipulate that high concentrations of Aluminium (Al), as in this case is the highest 93.34 – 391.98 mg/l, may cause long term neurotoxic effects. There is quite low level concentration of metals, however Silicon (Si) is moderate 4.97 – 29.16 mg/l (it is not stipulated in any guideline series). In general the analyses therefore indicate the potential pollution of contaminants. The water level varies widely ranging from 2.1 to 48.77, which indicate the potential pollution that is likely to occur, considering the cumulative effects of the pollutants. Lastly the geology in Springs is dominated by dolomite, resulting in greywater potentially sinking easily into underlying aquifers, thus increasing the rate of groundwater contamination.

Surface water

The surface water system in the Eastern region is dominated by the Blesbokspruit wetlands and associated dams. According to DWAF (2004:3) the Blesbokspruit is a tributary of the Suikerbosrand, which in turn is a tributary of the Vaal River. The confluence of the Suikerbosrand with the Vaal River is downstream of the Vaal Dam but upstream of the Vaal Barrage. The Suikerbosrand is one of the main tributaries of the Vaal Barrage management unit. Other tributaries draining into the Barrage are the Rietspruit, Leeuspruit, Taaibosspruit and the Klip River. The Blesbokspruit/ Suikerbosrand catchment has a total catchment area of 3474 km^2. It is divided into three main sub-catchments namely:

- Upper Blesbokspruit catchment (Headwaters) of Brakpan, Springs, Benoni, Daveyton east and including the Cowles Dam. The Cowles Dam is situated in the Benoni Canal in the Blesbokspruit and is the last impoundment before the river enters the Blesbokspruit wetland. Cowles Dam comprises the main inflow to the wetland.
- Incremental Blesbokspruit catchment (Middle reaches) to Suikerbosrand confluence.
- Suikerbosrand river catchment (The lower Blesbokspruit).

The headwaters of the Blesbokspruit are situated in the Springs-Benoni-Daveyton area of the East Rand on a stream known as the Klein Blesbokspruit. The land use in the headwaters of the Blesbokspruit catchment consists of urban, industrial/commercial, mining and agricultural activities. About 30% of the catchment area is urbanized with informal, low cost housing and medium density developments. There are also tailings dams from gold mining activities in the area and some pans in the catchment.

There are a number of dams situated on the Klein Blesbokspruit catchment upstream of Cowles Dam with most of these dams being located in the Benoni area whereby Leeupan is amongst them. Urban and industrial development upstream of Cowles Dam outlet include Benoni, Brakpan, Springs, Tsakane and the Sappi paper mill are located upstream of this point.

The middle reaches of the Blesbokspruit are less developed, with less urban areas present than in the headwater region. This reach of the Blesbokspruit is characterized by extensive reed beds. The upper section is dominated by a large wetland which is recognized as a Ramsar site. The Marievale bird sanctuary is also situated in this section of the river. Grootvlei Gold mines is also situated in this section and presently releases underground water into the Blesbokspruit. There are also a number of tailings dams in the middle reaches of the Blesbokspruit, as well as a number of sewage treatment plants of ERWAT (East Rand Water Care Works) throughout, that discharge into the Blesbokspruit.

The lower Blesbokspruit catchment has urban developments which include Nigel and Heidelberg. The catchment of the Suikerbosrand River is largely undeveloped. The area upstream of its confluence with the Blesbokspruit is characterized by good quality water with low salinity. Balfour Dam is situated in the upper portion of the Suikerbosrand, which is the main source of water to the town of Balfour. Relevant to the study are the following figures, showing waterbodies that eventually lead to Blesbokspruit; namely Leeupan in Harry Gwala and Cowles dam near Gugulethu.

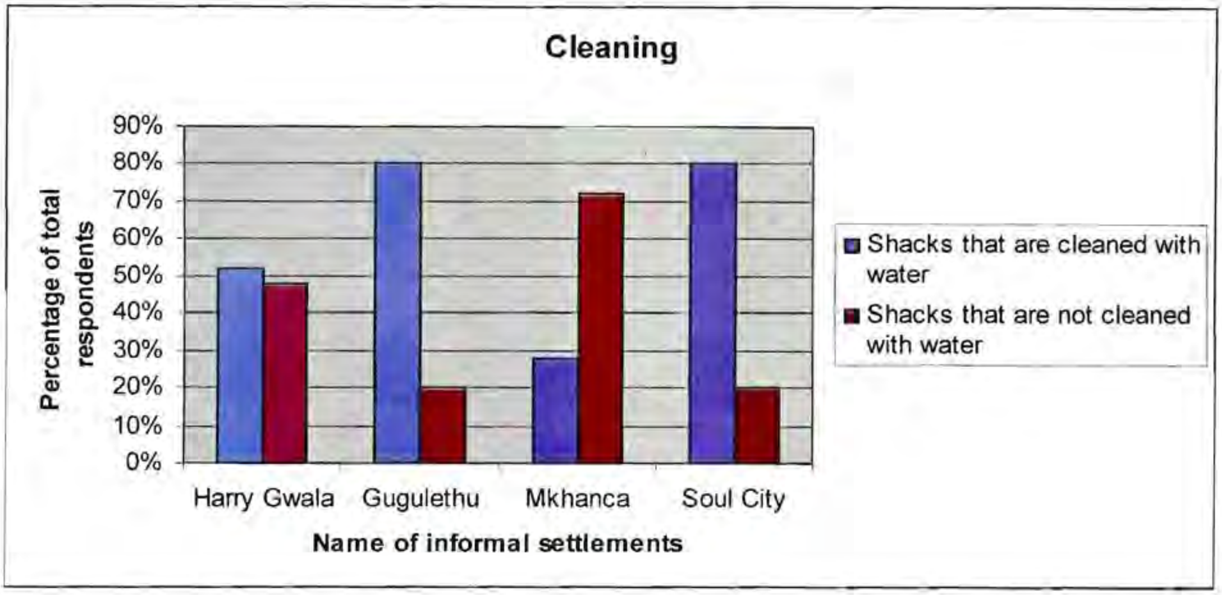

Figure 6.4 : Shacks that are cleaned with water

6.2.4 Access to and source of water

All the residents of the study area get their water from stand pipes, except in Harry Gwala where they have taps in their yards. This settlement was different from the others, in that all the stand pipes from the main line sources had been vandalized and illegal connections to the residents' yards had been made. About half of the number of respondents, who do not have connections in their yards, get water from their neighbor's taps. Most of the respondents, in all four sites, use 20L plastic containers for a number of varying reasons, such as that it is easy to carry, it fills enough for household needs and they believe that aluminum rusts, etc. Water is collected everyday in all three sites, except in Gugulethu, where water is fetched weekly and where the consumption is also the highest – on average they fetch 55 l/day (table 6.7). The author asserted that this is because there is only one tap in the area, prompting the people to get enough for the week, to avoid standing in long queues. This shows that with fewer infrastructures, the water consumption increases. In addition to this, the study revealed that the water fetched is related to gender (women to men ratio). For instance, in Mkhanca, the average water fetched is the lowest of all at 36 l/day. This is probably due to the fact that men use water only for basics, as opposed to women. When asked if they would like to use more water, most of the interviewees responded negatively. In addition to this, they do not collect rain water as they feel there is no need, because they have access to water. They also had the impression that rain water is dirty. The fact that almost all the interviewees responded that they do not like to have more water, means they are getting enough water. This illustrates that the municipality has succeeded in meeting the basic need of water supply of 25l/person per day, within 200m cartage distance, as stipulated in the White Paper on water supply and sanitation policy.

The findings indicated that people are not concerned about access to water, because they know it is readily available, which is also confirmed by them finding it unnecessary to collect rain water. Gugulethu was in contrast to the others in this regard, where most of them do collect rain water for laundry, probably due to the reason mentioned above – to avoid standing in long queues. This is also shown by the fact that most use on average 16l/day for their laundry. It would therefore be safe to say, since they collect rainwater because of their situation, should they have the advantage of having more stand pipes, rain water would also not be collected by them.

6.2.5 Sanitary situation

All of the residents have pit toilets (figures 6.5 & 6.6), mostly in their yards, except in Soul City where a bucket system, with collection twice a week by the municipality, are still in place for those that do not use a neighbor's toilet. Most of the females use the toilets only during the day, as they are too scared to go out at night, and then rather use the bucket. The bucket is disposed the following day, mostly in the toilet, sometimes in the stormwater channel and sometimes in the veld. People were ashamed to reveal their private conditions in terms of toilet use. For instance, in Mkhanca, the author was informed that respondents use the neighbor's toilet, which was not a true reflection of what was observed, since even though they all kept saying they use the neighbor's toilet, no toilets were ever seen. As a matter of fact, an anecdotal from a few people confirmed that residents use a nearby veld for toileting. In light of this, the statements made that the disposal, of buckets used at night, take place into a toilet, are questionable. This also applies to Soul City: When asked about the disposal of buckets used at night, if there are any feacal contents, respondents denied disposal. However, other people confirmed that it was. Anecdotal information from a few residents reveal that, sometimes, when the buckets are not collected, they are left with no choice but to discard them in the veld. In addition to this, a few people in Harry Gwala mentioned that they dispose their buckets, used at night, in the stormwater channel. This explains the high faecal coli, ammonia and phosphate levels found in monthly water analyses. Almost all respondents stated that they do wash their hands after toilet use, illustrating health consciousness.

Figure 6.5: Pit toilet in Mkhanca made of plastic

Figure 6.6: Pit toilet made next to the stormwater channel in Harry Gwala

Figure 6.7: Pit toilet made next to the stormwater channel in Harry Gwala

6.2.6 Water use

At all four the sites a minimal quantity is used for cooking and drinking, while Soul City use more water for dishes than the others, on average 14 l/day (table 6.6). Mkhanca and Harry Gwala have the lowest use for this purpose with an average of 9 l/day. For bathing, Gugulethu uses the highest volume amongst all, at an average of 15 l/day and Harry Gwala uses the least, at an average of 11 l/day. As mentioned earlier, not all the shacks are cleaned with water, the people in Mkhanca use the most for this purpose, with an average of 7 l/day, while Harry Gwala uses the least – on average 4 l/day. It is noticeable that more water is used for laundry, with Soul City having the highest use with an average of 28 l/day. Although Harry Gwala has the lowest average use of 12 l/day for laundry, it is the opinion of the author that it might not be a true reflection, since the availability of taps in their yards eliminate the need to collect water using containers, thus complicating an accurate estimation. This also applies to the amount of greywater generated. This is also supported by the high negative response when respondents were asked if they could preserve waste water, since they do not feel the need to do this, as they have easy access to water. In Mkhanca and Harry Gwala most of them use a plastic bath, while in Soul City and Gugulethu most use aluminum baths for their laundry. Residents' laundry are done outside, in all the areas, as they say it is dark inside, there is no space and to avoid untidiness. It was only respondents of Gugulethu who mentioned that they wash their blankets quarterly in the Blesbokspruit (wetland) or used to wash their laundry there, before they got taps.

During the 3 days that interviews were conducted in Soul City, there were always people doing their laundry at the stand pipes, resulting in ponding of greywater. Contrary to this, none of the interviewees stated that they do their laundry at the stand pipes. This contradicts what the author observed, and was also told by other residents. Similarity in behavior was noticeable in all four sites, like the fetching of water with the same size and type of containers and the doing of laundry outside shacks for the same reasons.

Out of 100 interviewed residents only one was found to keep a garden as a source of food. This was probably because it is an elderly /pensioner, who grew up in rural area and they are used to gardening. Most of the respondents mentioned that the reasons for not having a garden is because of limited space in their yards, laziness and that they will do it if they have proper housing (informal settlements is often seen as short term transitional residences). This shows that they are not bothered by the current living conditions and the main important thing to them is housing. Residents believe that having houses will change their living conditions. When asked if they do report broken pipes and taps, most of them said they never report it, since they feel it is the responsibility of the street committees to make sure it is fixed. Others mentioned that they sometimes donate money, (R 2–5) from each household, if needed for infrastructural purpose (e.g. broken taps and pipes). Residents do not have a sense of belonging because they are not sure if they are staying legally in the settlements, and they have fears of being evicted. This is especially true in Harry Gwala and this is probably also the reason why broken taps and pipes are not reported to the municipality.

6.2.7 Sources of greywater

Major sources of greywater are waste waters from the kitchen, bath, laundry and cleaning. It was observed that, in most of the four study sites, respondents cannot afford household detergents like handy-andy, jik (except Harry Gwala and Gugulethu) and sta soft (except in Harry Gwala and Soul City) although it was expected that Gugulethu might use a relatively luxurious product such as sta soft, because most of them are working (i.e. deriving a higher than average income). However, this outcome, in all four sites was to be expected, because they only live on the very basics. Washing powder is a necessity since respondents would always have laundry and most use sunlight powder, maq and omo, because they say it is the cheapest.
Sunlight soap is the soap most used for bathing, as expected, because respondents say it is cheaper, lasts longer and they are used to it from childhood. Lastly, when asked if they use vim, they all responded in the negative, without supplying reasons. The possibility exists that they are not acquainted with this product.

6.2.8 Greywater quality

a) Sampling sites

Sampling sites are shown in figure attached in appendix B

b) Analytical data

The water quality obtained (Table 6.2) have been compared with the General standards of waster water or effluent published in the government gazette 18 May 1984 N0. 9225, Regulation N0. 991 18 May 1984 (DWAF, 1984)

Table 6.2: Greywater

Sample name	HB1	HD1	HL1	HC1	HB2	HD2	HL2	HC2	SB1	SD1	SL1	SC1	SB2	SD2	SL2	SC2	SP	Waste Water general stds
Cond mS/m @ 25°C	216	156	116	183	42	40	[illegible]	[illegible]	44	[illegible]	38	39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	<75
TSS mg/L @ 105°C	1035	1368	1802	1894	472	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	<90
Cl mg/L Cl	26	53	168	199	34	33	103	60	25	34	28	31	610	122	44	255	210	
NH_3 mg/L N	66.7	6	14.3	33	1.2	0.1	[illegible]	[illegible]	[illegible]	0.7	0.6	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
PO_4 mg/L P	8.5	29.5	3.8	8.4	<0.1	[illegible]	[illegible]	[illegible]	<0.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
pH	9.3	7.3	9.2	8	9	9.5	[illegible]	[illegible]	7.3	9.4	9	8.3	7	6	[illegible]	7.3	9.2	5.5 – 9.5
COD mg/L O_2	7930	5780	10010	5130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	<75
OG mg/L	660	773	3035	4653	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	<2.5
Ecol MPN MPN/100 ml	19	10	[illegible]	42	[illegible]	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
TCMPN MPN/100 mL	4840	4840	4840	4840	42000	55000	34000	5000	173300	242000	242000	242000	24200000	24200000	435000	24200000	2700	
CaTot_ICP mg/L Ca	23.5	25.1	51.2	38.8	19.1	18.3	74.7	37.1	15.1	16.9	16.7	17.8	25	19.9	23.1	31.4	30	
MgTot_ICP mg/L Mg	8.8	9	14.3	11.5	6.4	6	16.5	9.8	6	6.1	7.3	7.5	8	10.4	6.7	9.9	10	
KTot_ICP mg/L K	77.8	10.8	23.4	28.2	6.4	4.2	17.4	9.6	8.6	4.8	3.7	5.6	256.3	22.9	4.6	92.1	16.3	
NaTot_ICP mg/L Na	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	76.8	[illegible]	75.1	85.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	<90
CdTot_ICP mg/L Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05
CrTot_ICP mg/L Cr	<0.07	<0.07	<0.07	[illegible]	<0.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
CoTot_ICP mg/L Co	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	
CuTot_ICP mg/L Cu	0.05	0.06	0.21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	[illegible]	<0.01	0.01	<0.01	[illegible]	0.01	[illegible]	[illegible]	0.02
FeTot_ICP mg/L Fe	4.77	6.44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.3
PbTot_ICP mg/L Pb	0.06	0.05	0.15	0.12	<0.01	<0.01	0.07	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	<0.01	<0.01	0.04	1
MnTot_ICP mg/L Mn	0.22	0.2	0.67	[illegible]	<0.01	<0.01	[illegible]	[illegible]	[illegible]	0.1	0.04	[illegible]	[illegible]	<0.01	[illegible]	[illegible]	[illegible]	0.1
NiTot_ICP mg/L Ni	0.03	0.02	0.07	0.07	0.01	0.02	0.08	0.04	<0.01	0.08	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.0	
ZnTot_ICP mg/L Zn	[illegible]	[illegible]	1.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.16	0.17	[illegible]	0.2	[illegible]	[illegible]	[illegible]	[illegible]	0.3
AlTot_ICP mg/L Al	9.75	7.63	25.31	17.77	1.08	1.2	9.44	4.09	3.04	3.48	0.97	1.64	1.65	4.4	47.26	2.85	25.08	
SiTot_ICP mg/L Si	9.28	3.38	37.78	31.66	2.19	1.96	2.37	35.49	3.41	28.93	3.02	3.2	2.7	34.34	47.26	34.77	51.56	
BTot_ICP mg/L B	0.08	0.11	0.11	0.11	<0.03	0.03	0.38	0.17	0.07	0.2	0.06	0.07	0.12	0.25	0.26	0.25	0.13	0.5
BaTot_ICP mg/L Ba					0.02	0.03	0.14	0.07										
HgTot_ICP mg/L Hg					<0.1	<0.1	<0.1	<0.1										0.02
MoTot_ICP mg/L Mo					<0.01	<0.01	<0.01	<0.01				<0.01	<0.01	<0.01	<0.01			
SrTot_ICP mg/L Sr					0.09	0.1	0.22	0.14				0.16	0.11	0.1	0.14			
VTot_ICP mg/L V					<0.02	0.02	0.02	<0.02				<0.02	0.02	<0.02	0.02			
AsTot_ICP mg/L As					<0.02	<0.02	0.05	0.04				<0.02	0.07	0.1	0.02			0.1
SeTot_ICP mg/L Se					<0.01	<0.01	[illegible]	<0.01				0.04	0.0	0.02	[illegible]			0.05

⬜ not provided by the standard limits
🟨 compliant
🟧 non-compliant

Chemical pollution

The results, as reported in table 6.2, vary in all the households. This corresponds with the literature that compounds present in greywater vary according to lifestyles, customs, installations, chemical household products and the number of occupants. This variation is also seen in the relative mix of various types of greywater (kitchen, bathroom and laundry). The high levels of ammonia and phosphate vary particularly from bath, laundry and dishes, respectively. This clearly indicates the nutrient pollution load that may emanate from non-sewered areas, as well as the environmental impact, which will eventually cause eutrophication in the water resources. The values of COD and oil & grease show a constant high range. These indicate the environmental impact on soils and water resources. The accumulation of these parameters on soil may result in scum. The impact of high COD in water resources may results in oxygen depletion. The sodium level varies, but is generally high. Although the metal concentrations are generally low, there are high levels of iron and aluminum at all four sites, while zinc is moderately high and a few peaks of manganese and boron exist at selected sites.

Microbial pollution

The results indicate high microbial pollution, as shown by the high total coli counts in all four sites. Although E. coli counts vary, it is exceptionally high in all samples taken in Soul City - including the ponding water sample taken at this site, while in the other selected sites (Harry Gwala) it was elevated in bath and laundry water. This clearly indicates the increased health risk to the community, especially kids who normally play around ponding greywater.

Inter-comparison of study sites

According to the literature reviewed, kitchen water is regarded as the most polluted. In this regard, the most polluted kitchen greywater is noticeable in HD1, SD2 with high suspended solids and followed by HD2 (which was unexpected as it was the greywater of only one occupant).In other samples, the suspended solids is high in laundry and bath water, i.e HL1, SB1 and SB2. In HL1 it is expected from the kids' clothing and in addition to this, the constituents of Harry Gwala 1 (H1) are all very high in suspended solids. HB1 is probably also due to kids' contribution, as they play in soil. High peaks of chloride are noticeable in laundry water, with Soul City 2 (S2) the highest shown in SD2 & SB2. It must be noted that Soul City 2 (S2) is the most polluted water and shows high peaks of constituents when compared to other selected sites. High ammonia is noticeable in bath & laundry water in all the sites, however in S2 it is noticeable in bath, laundry and dishwater. The COD is generally high in all selected sites, but exceptionally high in laundry water, HB1 & HL1 has the highest, followed by HL2 while the COD in Soul City is moderate. According to the literature, oil & grease is expected to be high in dishwater, this was found contradictory, as it is only high in SD2, while in other sites it is high in laundry water and generally high in all the samples. The hardness ions (Ca & Mg) were noticeably high in all selected sites in laundry water.

The pH of SD2 is slightly acidic, which is contrary to the literature, which states that it is normally alkaline, as it was found in the other samples. In bath water, there is high ammonia in SB2 and HB1 with the highest values in SB2. This conforms to the literature. The amount of ammonia varies, but in small quantities as compared to phosphate, which is higher but varies in all the samples. A high range of sodium is also seen in all the samples, especially in laundry as was expected according to the literature. Boron, which is toxic, as mentioned in the literature, is noticeable in the range of 0.1 to 0.4, but high in HL2 & SL2. In addition to this, high concentrations of metals, namely iron, aluminium and silicon are seen in all samples of greywater. Iron is quite high in laundry water of HL1, followed (probably due to soil from kids' clothing) by HL2, while it is noticeable in SD1 & SD2. Manganese is noticeably high in HL1 and generally low in other sites, also due to the same reason of kids' clothing. Zinc is also high in laundry water of all sites, except in SD2. Aluminium and silicon is high in laundry (especially in HL1 & SL2) water of three sites, except in SD1. Silicon is high in HL1 & SL2 and SD1 & SD2. Other metals are all present in low concentrations.

Regarding the ponding of greywater sample (SP), the following parameters are noticeably high: Chlorides, phosphate, COD, sodium, manganese, iron, zinc, aluminum, silicon, while microbial contamination is moderate, as compared to the other samples.

There is a high level of microbial contamination in all kitchen greywater from households (as expected, according to the literature), however SD2 has the highest - with TC and E coli, whereas in Harry Gwala it is only noticeable in HB2 and HL1 whereby in other constituents it is in small quantity to none respectively and it is minimal in SD1.

Bath water also indicate microbial contamination in all the samples taken. In laundry water high microbial contamination is seen in all samples, with the highest for those of nappies as expected. In addition to this total coli is high in all sites, with Soul City having the highest.

6.2.9 Greywater volume

According to van Schalkwyk (1996) a tap in the home (not connected to a waterborne sewage system) is likely to lead to water consumption rates of between 30 and 80 liters per day. In Harry Gwala, the only settlement where the majority of residents have access to inhouse taps, 24% of the households fall in this range while 3% are above (100 l/d) and 73% (i.e. almost three quarters) consume less than 30l/d (table 6.3) confirming that water consumption generally decreases by 2-3 times if people have to walk to fetch water (Carden et *al*, 2007: 4-11). Van Schalkwyk (1996), further indicated that, where water has to be brought in from a source that is at least 250 meters away from the home, a consumption of 9-50 liters per person per day is likely. This is largely confirmed in this study with 64% of all households in Gugulethu, 80% in Mkhanca, and 72% in Soul city falling into this range of water consumption.

Similarly, CSIR (2001) quoted that water consumption associated with yard connection is 50-100 l/d, which in the case of Harry Gwala, is 24% and for those with standpipes within 200m, the consumption is 10 – 50 l/d (which is 60% for Gugulethu, 80% Mkhanca and 76% Soul City). This conforms to the literature, except for Harry Gwala, where there might have been an underestimation as most of them fetch water directly from the taps in their yards when needed. The estimated water consumption of each household, given by the respondents, vary from 10-150 l/d. However, as indicated by Carden *et al.* (2007: 4-13), this does not reflect the total water delivered to the settlements since leaks, under-reporting/over-reporting are not accounted for, which was also found to be the case in this study. The quantity of greywater generated is directly linked to the water consumption by each household. Greywater is generated daily through washing dishes, bathing, cleaning and doing the laundry. It must be noted that, although the volume of waste water from cleaning was not gauged, it is included as part of the greywater generated. The estimated volumes given for bathing and washing dishes were multiplied by the frequency with which these activities are done, in order to give the true value of greywater generated for all four the sites. In addition to this, it must be noted that all the respondents were not sure about the quantity of bath water used by other family members in their households, thus only the interviewee's were given. Greywater generated for all four sites is shown in tables 6.3 to 6.6 & figures 6.7 to 6.10.

However, the (estimated) total volume of greywater generated at some of the four sites, add up to more than the total volume of water fetched (table 6.7: Mkhanca and Soul City) possibly indicating wrong estimates, either of the volume of water fetched or the volume of greywater generated. Where containers of a known size and quantity are used for fetching water the chances are that estimates of fetched water volumes will be more reliable than those for greywater generation for which no real benchmark exists. The resulting error margin is expressed in percentage of water fetched, with values above 100% indicating that more water was used for greywater creating activities than was available (table 6.7).

Figure 6.7 to 6.10 illustrate the average contribution of different water uses to total greywater generation, indicating that a third of all greywater originates from laundry, closely followed by bathing and dish washing together accounting for approx. half of the total greywater generated. Cleaning contributes to only 11% of the total greywater generation. While the exact proportions differ between the individual settlements, most do reflect the same general distribution pattern.

Table 6.3: Water consumption and greywater for Harry Gwala

Sampling	Water	Greywater generated								
Harry Gwala	fetched	dishes	bath	cleaning	laundry	laundry	Total	Average per greywater source	% of water fetched	Water left
unit	l/d	l/d	l/d	l/d	l/week	l/d	l/d	l/d		l/d
1	*	10	10	0	50	7	27	*7*		
2	10	6	20	0	30	4	30	*8*	303%	*-20*
3	100	10	10	5	30	4	29	*7*	29%	*71*
4	20	10	5	20	120	17	52	*13*	261%	*-32*
5	100	4	8	3	230	33	48	*12*	48%	*52*
6	25	5	10	0	75	11	26	*6*	103%	*-1*
7	20	10	20	10	300	43	83	*21*	414%	*-63*
8	20	5	5	0	60	9	19	*5*	93%	*1*
9	100	50	20	10	40	6	86	*21*	86%	*14*
10	40	4	10	20	25	4	38	*9*	94%	*2*
11	20	8	8	0	40	6	22	*5*	109%	*-2*
12	20	4	10	5	120	17	36	*9*	181%	*-16*
13	40	15	10	5	60	9	39	*10*	96%	*1*
14	50	4	10	5	20	3	22	*5*	44%	*28*
15	*	10	20	0	20	3	33	*8*		
16	100	15	10	5	50	7	37	*9*	37%	*63*
17	60	2	10	0	40	6	18	*4*	30%	*42*
18	29	18	18	0	100	14	50	*13*	173%	*-21*
19	20	5	10	0	40	6	21	*5*	104%	*-1*
20	20	2	4	5	40	7	18	*5*	90%	*2*
21	45	10		5	300	43	58	*19*	129%	*-13*
22	45	6	10	2,5	40	6	24	*6*	54%	*21*
23	20	2	4	0	80	11	17	*4*	87%	*3*
24	20	8	5	0	75	11	24	*6*	119%	*-4*
25	5	2	5	0	20	3	10	*2*	197%	*-5*
* Don't use container fetch water directly from the tap because is in the yard										
n	23	25	24	25	25	25	25	25		
av.	40	9	11	4	80	12	35	130		
min.	5	2	4	0	20	3	10	2		
max	100	50	20	20	300	43	86	21		
sum	929	225	252	101	2005	288	865	221		
% of Total greywater		26%	30%	11%		33%	100%			

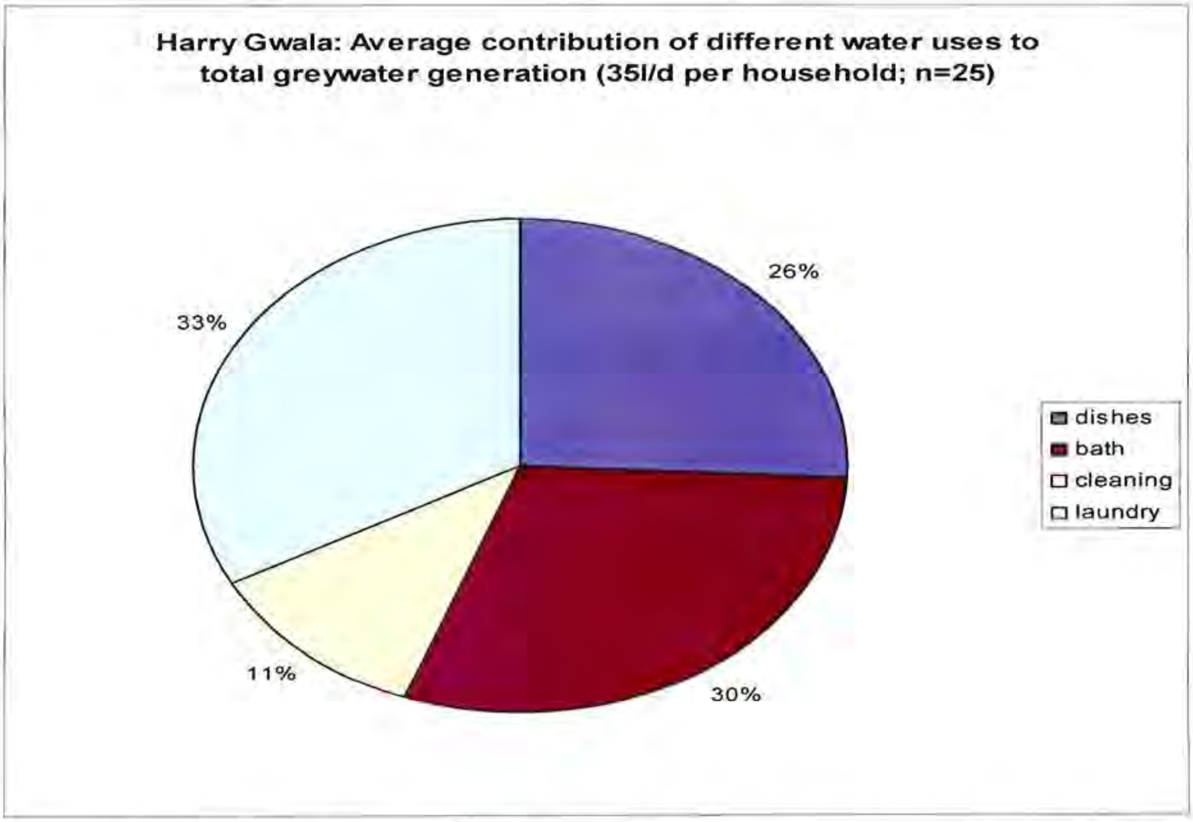

Figure 6.8: Average contribution of different uses to total greywater generation for Harry Gwala

Table 6.4: Water consumption and greywater generation for Gugulethu

Sampling	Water	Greywater generated								
Gugulethu	fetched	dishes	bath	cleaning	laundry	laundry	Total	Average per greywater source	% of water fetched	Water left
unit	l/d	l/d	l/d	l/d	l/week	l/d	l/d	l/d		l/d
1	26	6	5	3	300	43	57	14	219%	-31
2	96	6	5	1	150	21	33	8	35%	63
3	29	10	10	1	60	9	30	7	104%	-1
4	26	15	20	5	150	21	61	15	239%	-36
5	30	45	20	15	230	33	113	28	376%	-83
6	40	5	20	5	160	23	53	13	132%	-13
7	205	15	20	5	160	23	63	16	31%	142
8	22	10	20	10	50	7	47	12	213%	-25
9	9	3	4	4	120	17	28	7	328%	-20
10	25	10	20		150	21	51	17	206%	-26
11	100	5	5		100	14	24	8	24%	76
12	125	4	2	5	40	6	17	4	13%	108
13	120	10	10	5	120	17	42	11	35%	78
14	41	20	20	5	145	21	66	16	159%	-24
15	29	10	20	5	30	4	39	10	138%	-11
16	25	15	20		40	6	41	14	163%	-16
17	100	10	20	5	100	14	49	12	49%	51
18	80	10	10	10	100	14	44	11	55%	36
19	50	20	20	5	100	14	59	15	119%	-9
20	80	10	14	2,5	100	14	41	10	51%	39
21	24	5	10		75	11	26	9	106%	-1
22	60	10	20	5	80	11	46	12	77%	14
23	11	5	20		40	6	31	10	269%	-19
24	9	5	8	2	40	6	21	5	242%	-12
25	9	10	20	5	115	16	51	13	554%	-42
n	25	25	25	20	25	25	25	25		
av.	55	11	15	5	110	16	46	12		
min.	9	3	2	1	30	4	17	4		
max.	205	45	20	15	300	43	113	28		
sum	1371	274	363	104	2755	394	1134	298		
% of Total greywater		24%	31%	11%		34%	100%			

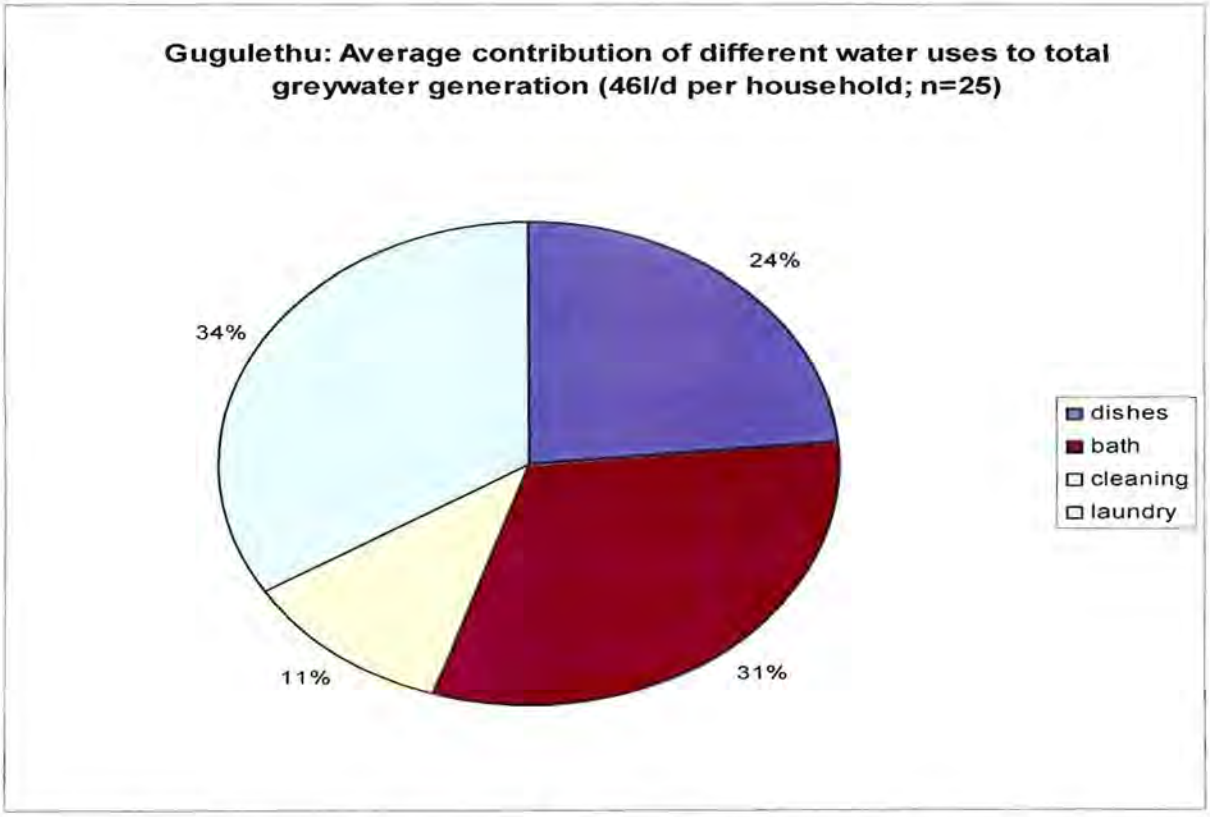

Figure 6.9: Average contribution of different water uses to total greywater generation for Gugulethu

Table 6.5: Water consumption and greywater generation for Mkhanca

Sampling	Water	Greywater generated								
Mkhanca	fetched	dishes	bath	cleaning	laundry	laundry	Total	Average per greywater source	% of water fetched	Water left
unit	l/d	l/d	l/d	l/d	l/week	l/d	l/d	l/d		l/d
1	60	30	60			60	150	50	250%	-90
2	20	2	5			3	10	3	50%	10
3	10	2	4			2	8	3	80%	2
4	3	2	5		20	3	10	3	329%	-7
5	40	10	6		80	11	27	9	69%	13
6	25	3.5	7		100	14	25	8	99%	0
7	5	2	4		10	1	7	2	149%	-2
8	9	10	10		60	9	29	10	317%	-20
9	26	4	8		240	34	46	15	178%	-20
10	100	9	10		75	11	30	10	30%	70
11	11	4	7.5	2	40	6	19	5	175%	-8
12	40	10	10		20	3	23	8	57%	17
13	40	10	10		350	50	70	23	175%	-30
14	20	10	10		350	50	70	23	350%	-50
15	100	20	30	5	450	64	119	30	119%	-19
16	11	10	20		100	14	44	15	403%	-33
17	50	15	20		200	29	64	21	127%	-14
18	14	1	6		200	29	36	12	254%	-22
19	30	20	10	20	30	4	54	14	181%	-24
20	80	18	12	5	180	26	61	15	76%	19
21	40	10	20	10	120	17	57	14	143%	-17
22	50	5	20	5	75	11	41	10	81%	9
23	20	10	20		200	29	59	20	293%	-39
24	80	9	20	4	120	17	50	13	63%	30
25	11	4	20		120	17	41	14	374%	-30
n	25	25	25	7	22	25	25	25		
av.	36	9	14	7	143	21	51	14		
min.	3	1	4	2	10	1	7	2		
max.	100	30	60	20	450	64	150	50		
sum	895	231	355	51	3140	514	1150	350		
% of Total greywater		18%	28%	14%		40%	100%			

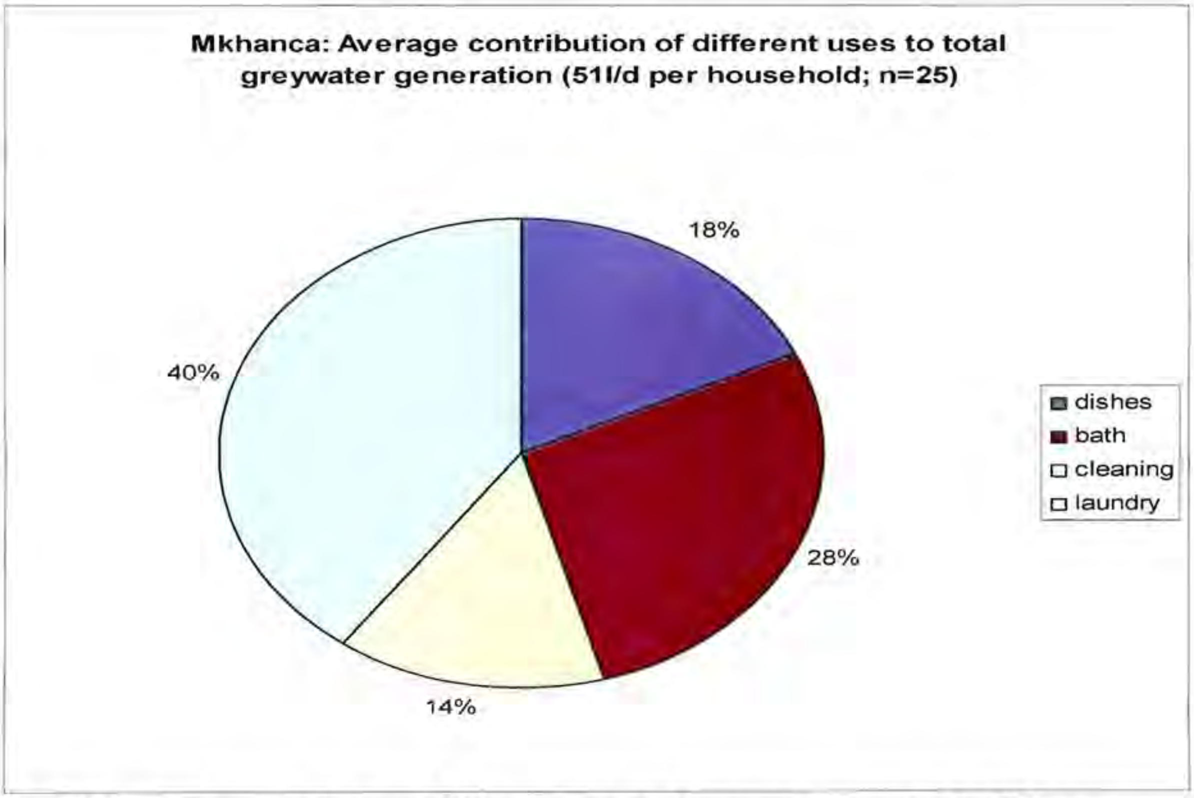

Figure 6.10: Average contribution of different uses to total greywater generation for Mkhanca

Table 6.6: Water consumption and greywater generation for Soul City

Sampling	Water	Greywater generated								
Soul City	fetched	dishes	bath	cleaning	laundry	laundry	Total	Average per greywater source	% of water fetched	Water left
unit	l/d	l/d	l/d	l/d	l/week	l/d	l/d	l/d		l/d
1	17	6	6		60	9	21	7	121%	-4
2	20		10		40	6	16	8	79%	4
3	20	8	8	5	100	14	35	9	178%	-15
4	40	5	8		100	14	27	9	68%	13
5	25	4	8	2	300	43	57	14	227%	-32
6	40	4	5	5	80	11	25	6	64%	15
7	20	5	9	5	60	9	28	7	138%	-8
8	100	30	12	4	780	111	157	39	157%	-57
9	10	9	5	3	20	3	20	5	199%	-10
10	60	10	10	2.5	80	11	34	8	57%	26
11	20	4	8	5	60	9	26	6	128%	-6
12	40	30	5	10	240	34	79	20	198%	-39
13	40	30	30	10	720	103	173	43	432%	-133
14	60	9	14		80	11	34	11	57%	26
15	40	30	10		240	34	74	25	186%	-34
16	75	10	10	10	?		30	10	40%	45
17	40	15	10	5	180	26	56	14	139%	-16
18	40	20	20	5	280	40	85	21	213%	-45
19	90	10	20		420	60	90	30	100%	0
20	75	30	50	10	525	75	165	41	220%	-90
21	40	15	10	5	60	9	39	10	96%	1
22	40	10	8	5	80	11	34	9	86%	6
23	40	8	5	5	100	14	32	8	81%	8
24	10	20	10	10	100	14	54	14	543%	-44
25	50	10	5	5	10	1	21	5	43%	29
n	25	24	25	19	24	24	25	25		
av.	**42**	**14**	**12**	6	**196**	**28**	**60**	**15**		
min.	10	4	5	2	10	1	16	5		
max	100	30	50	10	780	111	173	43		
sum	1052	332	296	112	4715	674	1413	380		
% of Total greywater		23%	20%	10%		47%	100%			

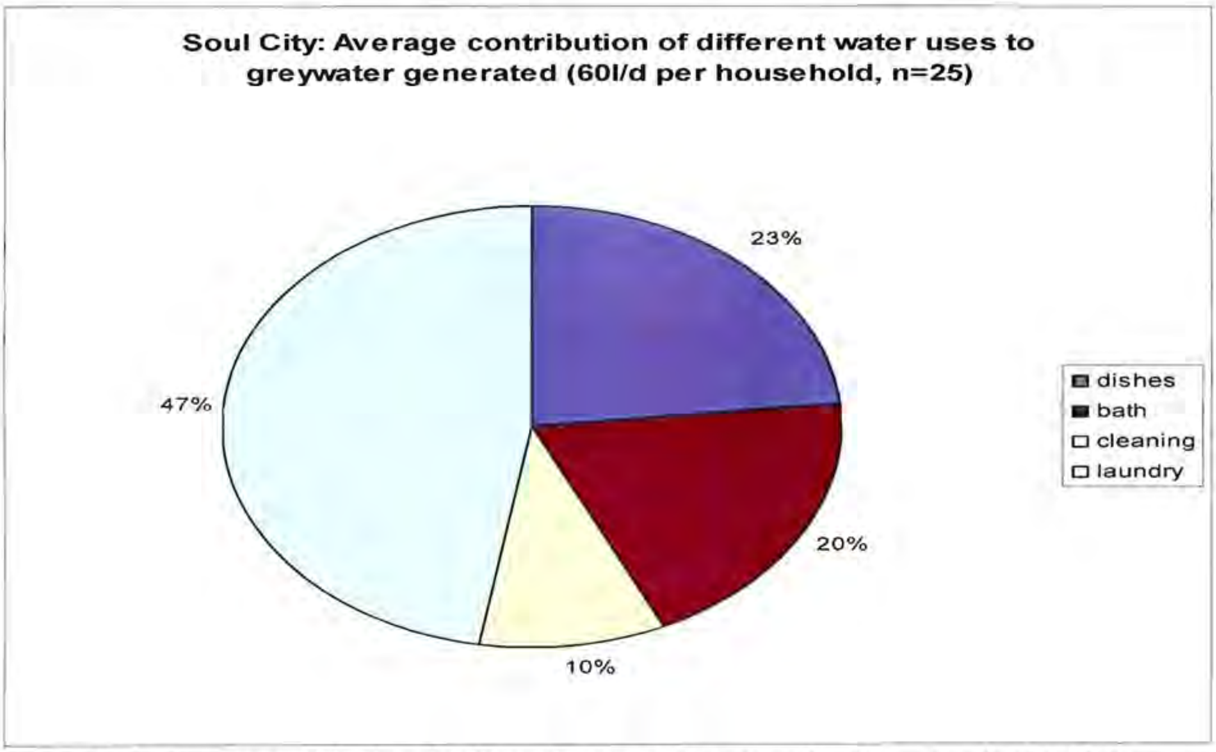

Figure 6.11: Average contribution of different water uses to greywater generation for Soul City

Table 6.7: Average comparison of total greywater generated and water fetched of the four sites

Name of setlement	Water fetched l/d	Total grewater generated l/d	Water left l/d	% of water fetched
Harry Gwala	40	35	5	88%
Gugulethu	55	46	9	84%
Mkhanca	36	51	-15	142%
Soul City	42	60	-18	143%
Total	173	192	-19	111%

6.2.10 Greywater disposal

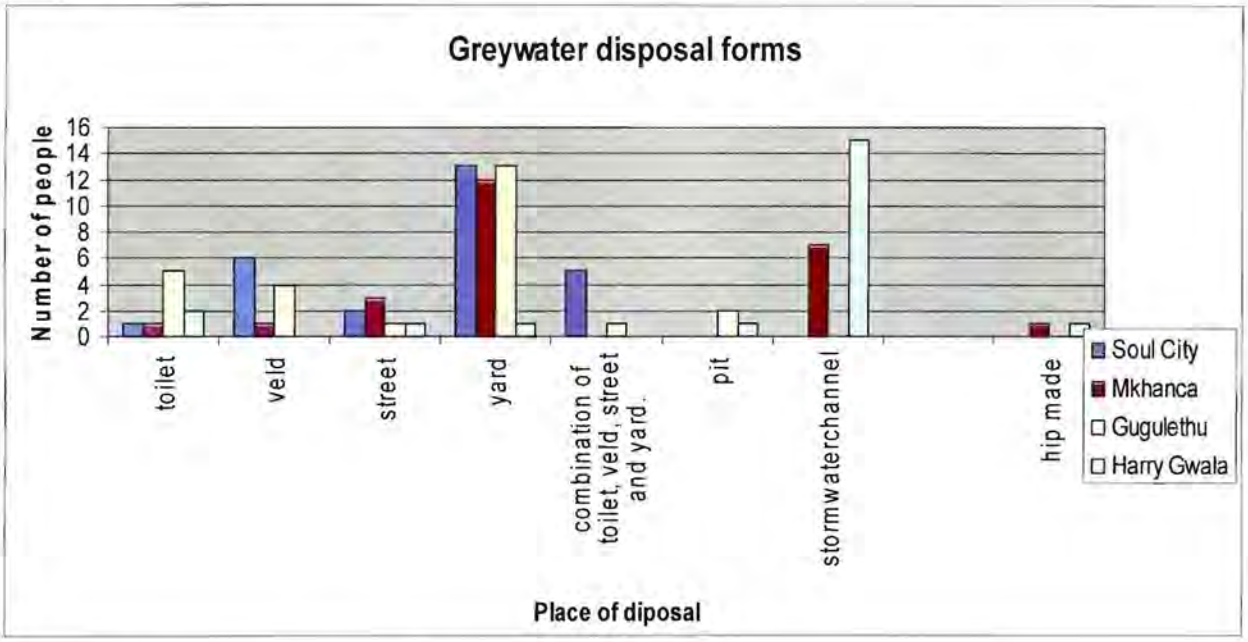

Figure 6.12: Greywater disposal forms

a) Harry Gwala

Most residents discard their waste water into the stormwater channel that leads to Leeupan. When asked about their neighbors, respondents mentioned that they also discard it in the stormwater channel. All respondents indicated that waste water discarded by people are of concern to them. Smell and pollution are the biggest concerns, while few of the respondents mentioned the health risk as a concern. Most of the respondents mentioned that they will never preserve waste water because it is dirty. When asked what it is that residents would like to improve regarding the disposal of waste water, most pointed out that there should be a purification plant in the area.

Figure 6.13: Channels made in the yard for disposal that leads to the main stormwater channel

b) Gugulethu

There was no visible greywater flowing or ponding in the streets. This was confirmed by the finding that most of the residents discard their waste water in their yards and a few in their toilets. When asked about their neighbors, they mentioned that the neighbours also discard it in their yards, while the most respondents said they do not know. Almost all of the respondents mentioned that they are bothered by the waste water discarded by people. Pollution is what is bothering them most. In addition to this, most of them have a notion of witchcraft. They believe that bath water should be respected; by not discarding it anywhere. They therefore opted to discard it in their yards, while others even went so far as discarding it at the back of their shacks, where it could not be seen. Other respondents indicated they would not step in the waste water as they would never know if people use "*muti*" to bath themselves, and they would therefore inherit other people's "*bad luck*". This is what bothers them most about seeing waste water flowing in the streets or from their neighbors' into their yards. Most of the respondents mentioned that they can preserve waste water by using laundry water for cleaning, rinse water to wash another load of laundry and bath water for gardening. When asked what it is that they would like improved regarding the disposal of waster water, most of them pointed out that there is nothing that can be done, although a few mentioned access to a proper drainage and sanitation system.

Figure 6.14: Greywater disposed in the yard

c) Mkhanca

Here there was also no visible greywater flowing or ponding on the streets. This was confirmed by the fact that most of the respondents discard their waste water in their yards. Most of them make infrastructural channels, in such a way that water can flow from one person's shack to the next (see figure 5.9 & 5.10). A few of these flow into the stormwater channel, which does not have an outlet, with the result that greywater eventually dries up. When asked about their neighbors' behavior, it emerged that it is equally disposed into the yard and the veld. Almost all of the respondents mentioned that they are bothered by the waste water discarded by people, whereas smell and pollution bothered them most. A few of them were concerned in the same way with witchcraft as was mentioned above. Most respondents mentioned that they can preserve waste water by using rinse water for cleaning or another load of laundry, while a few pointed out that they could do it if forced by law. When asked what it is that they would like improved regarding the disposal of waste water, most of them pointed out that there is nothing that can be done.

d) Soul City

Although most of the respondents mentioned that they dispose their waste water in their yards and a few mentioned in the veld, there were visible grey-whitish patches, resulting from greywater, present in the streets (figure 6.14 & 6.15)and also flowing and ponding greywater present at the stand pipes (figure 4.3 & 4.4). When asked about their neighbors, they also pointed out that the neighbors dispose in the veld, although a few said they do not know. However, on all the days that interviews were conducted, most women were seen doing their washing at the stand pipes and dumping their waste laundry water in the overflow from the stand pipes. Almost all of the respondents said they are bothered by the waste water discarded by people. Witchcraft seems to be the biggest concern in the same way as mentioned earlier, while a few mentioned pollution as their concern regarding greywater disposal. Most of them mentioned that they can preserve waste water by using rinse water for another load of laundry, bath water for cleaning and dish water for the garden while a few said they could reuse it if not dirty. When asked what it is that they would like to improve regarding the disposal of waster water, most of them pointed out that they would love to have proper sanitation and drainage systems.

Figure 6.15: Grey whitish patches of greywater as evidence of street disposal

Figure 6.16: Evidence of street disposal in Soul City

e) Greywater use

It must be noted that, out of 100 respondents, none of the respondents were found to be reusing greywater. However, when asked if they could reuse it, on average 65% responded positively, except in Harry Gwala where most of the respondents mentioned that they would not reuse greywater because it is dirty, except for some, who mentioned that they would reuse greywater because they fetch water from their neighbours and they cannot carry it, as it is heavy. They indicated that they would sometimes use rinse water for laundry and cleaning if water is not enough. Of those that responded that they would re-use greywater, most responded that they would re-use laundry water for cleaning purposes and rinse water for another batch of laundry. A few mentioned that they would use bath water for cleaning and gardening, and, if forced by law, bath water for laundry and cleaning, rinse water for cleaning and dish water for cleaning and gardening. They mentioned that they could do it, if they had the knowledge of how to do it and they will re-use it if it is not dirty.

f) Comparative summary on disposal forms at all four sites

It was observed that most of the residents dispose greywater in their yards, except in Harry Gwala where it is disposed in the stormwater channel that eventually flows into Leeupan. These findings conform to the literature review mentioned earlier, that the most convenient method of disposal is in their yards. A few respondents in Mkhanca mentioned that they dispose greywater into the stormwater channel which has no outflow and as a consequence the greywater eventually dries up. In addition to this, some individual households in Soul City and Gugulethu use multiple methods for their greywater disposal. The environmental impact is minimal for disposal in the veld (Soul City and Gugulethu) as they are few, however, a long term cumulative effect in Soul City cannot be ruled out. It is noticeable, in all the sites, that bath water is treated with dignity and respect, in that it is mostly disposed in their yards (others in the back yards). There is also a fear of being witchcrafted, as residents believe that people use "muti" to bath in and they do not want to step on greywater in the street. This is probably the reason why greywater is not disposed in the street, in most of the sites. However, greywater disposal was observed in the streets of Soul City, although most respondents denied this fact. This indicated a contradiction in terms of the information given and the observations made. Almost all of the respondents, in all four the sites, were bothered by discarded waste water, with the major concerns being smell and pollution. Most of them, in all four the sites, responded that their neighbors discard waste water in the same way as they do.

When asked if they would preserve their waste water, Gugulethu responded positively. Contrary to this, an unexpected response was received from Mkhanca and Soul City that they would preserve the waste water only by re-using the rinse water. Harry Gwala responded negatively, as was expected, because they have access to water (taps in their yards). The responses on greywater re-use was found to be contradictory to the way they responded about preserving water: When asked if they would use rain water, most responded that they would not, because it is dirty and there is no need because water is always available. It is therefore questionable as to whether they would reuse greywater.

7. CONCLUSIONS

This study aimed to characterise the extent and nature of greywater generation and disposal, in order to provide baseline information for improving the possible management thereof, including minimizing adverse impacts on human health and the environment.

In conducting the field research a range of methodological challenges had to be overcome. These included logistical problems (limited accessibility of informal settlements due to insufficient road infrastructure, lack of appropriate venues/conditions to physically conduct interviews), safety and security issues, socio-cultural obstacles in obtaining true answers on questions of rather intimate nature such as toilet use etc., language barriers and gender-related issues etc. The fact that the author, as black female, is proficient in several indigenous languages and familiar with cultural customs and peculiarities was found to be crucial for obtaining reliable information. Sanitation, for example, is a sensitive issue where people tend to be ashamed to admit to live in sub-standard conditions - making a proper assessment of the true situation in informal settlements difficult. These challenges need to be adequately addressed in larger-scale investigations as the deployment of untrained data clerks could seriously flaw such studies.

Furthermore, visits of governmental officials are either associated with fears of eviction or hope for improvement of living conditions regarding housing and employment. Both expectations are associated with implications for later interactions. Compared to employment and housing, access to water is not seen as crucial, resulting in little efforts to treat water as a precious resource not to mention exploring alternative water sources.

Greywater quality is largely determined by the source of greywater generation, where household chemicals largely determine the degree of chemical pollution, and usage type (dishes, washing, bathing etc.) largely controls the level of microbiological contamination. The results obtained clearly indicated that greywater quality varies. It conforms to the literature in that it varies according to the number of occupants in the household and the chemical constituents, water use efficiencies of appliances and fixtures, individual habits, and other site specific characteristics. Ammonia and phosphate is known to emanate from household detergents and chemicals. Despite HL1 and SL1 using the same brands of soap the ammonia concentration at both sites were found to be very different, indicating the existence of additional factors controlling ammonia levels. With phosphate concentration reflecting the same trend this confirms statements in literature that greywater quality is largely independent from the type of detergents used (Erikson *et al.* 2001:86; Engelbrecht and Murphy, 2006:4). The high microbial contamination (total coli) reported in literature was also found in this study except for bath water, which was found to be less contaminated than expected. In contrast to results confirming literature, the frequently cited prevalence of oil & grease in kitchen greywater was not apparent in this study and was only found in one sample. The extent to which household chemicals are used is mostly determined by income and availability.

The volumes of greywater found in this study generally confirm the order of magnitude reported in literature even though they tend to be somewhat lower. In view of the comparably large uncertainty associated with gathering volume data through questionnaires these deviations should not be overemphasized. With regard to the average contribution of different water uses to total greywater volumes, it was found that the single largest contribution comes from laundry, accounting for a third of the total greywater generated in informal settlements. This is followed by greywater originating from bathing and washing dishes both accounting for approx. a quarter of the total greywater volume.

In the absence of formal infrastructure, residents either create make-shift solutions to dispose of greywater (e.g. digging trenches) or use existing storm water canals and open field areas in the vicinity. This practice impacts adversely on nearby water courses, especially regarding microbiological pollution of natural surface and possible groundwater pollution. When asked about the disposal used by neighbors, respondents mentioned that they do likewise. They indicated the stormwater channel as the best means of disposal, as there will be no ponding of water in their yards and street, without considering the environmental impact.

Even though residents are aware of the unhealthy conditions created by waste water being discarded in this manner, and are bothered by the situation, they feel there is nothing they can do. Some are aware that at least something could be done to eliminate the greywater problem, by saying that there should be a purification plant – indicating that some prevailing reasoning is present, as noticed in Harry Gwala. In addition to this, there was a positive response in this regard from Soul City, as most of the respondents mentioned they would love to have proper sanitation and drainage systems. Together with the reluctance of residents to use 'dirty' greywater when clean water is readily available, this renders projects for use of greywater difficult to implement. This is further complicated by the low prevalence of gardening for food productions, as a potential field of greywater application. Owing to health concerns, these uses are anyway still controversial.

A common belief in witchcraft was notable at all four study sites. This is probably the reason why greywater was not visible in their streets, except in Soul City, because residents believe that they don't want to step on "muti", conversely they also fear that their bath water may also be taken for witchcraft if disposed carelessly.

The number of people affected by adverse health impacts associated with greywater is not known, even though pathogen values originating from feacal contamination and poorly treated waste water are reported. It was beyond the scope of this study to do that. Carden *et al.* (2007: C-10) reported that in Benoni and Brakpan 6 and 2 cases of Typhoid in 2000 - 2005 was reported respectively. There might be more cases that are not known or reported. The fact that people could come in contact with the contaminants became evident in this study, and a health risk is posed, especially to children, when playing on the ground where waste water (containing faecal contamination) is discarded. Although E.coli was expected in nappies only, it became apparent that almost all the waste water from bath, dishes, laundry and ponding contain E.coli.

This indicates a greater chance of human illness and infections developing through contact with the wastewater as stated in the literature.

It is therefore possible that greywater may have faecal contamination all the time. In Mkhanca greywater is disposed in the yards and the pit toilets (figure 4.8 & 6.5) which are not far from the houses, creating bad odours and attracting flies, thus creating a health risk. In addition to this, health impacts can be attributed by the toilet use in the veld at Mkhanca and the disposal of buckets in the veld at Soul City. In Gugulethu, the fact that they dispose the night use buckets in the veld, can also cause a health risk - , especially if it is raining and this waste is washed up by the rain water. Children are then especially at high risk because they like playing in rain water. Respondents also identified health problems, although limited response was received regarding the health risk. Most showed concern about smell and pollution while a few was concerned about mosquito infestation. This clearly indicated that at least they are aware of the risk, but that they have adapted and accepted their living conditions.

Apart from data gathered through the questionnaires, observations on site revealed behavioral patterns relevant to the generation and disposal of greywater. Regarding disposal sites it was observed that most respondents like doing their laundry outside the house owing to lack of lighting inside, splashing, limited space etc. In terms of water supply a widespread use of 20l containers was noticed, since this size is easy to carry while still holding enough water for household needs. The overall perception of the interviewed informal settlers is that they have enough water at their disposal, resulting in a general attitude that there is no need to collect rain water or repairing taps and pipes themselves.

The potential impact on the receiving environment i.e the Blesbokspruit is evident in Harry Gwala where most of the greywater is discarded into a stormwater channel that leads to Leeupan. The adverse impact of this disposal, on the water quality in Leeupan, is confirmed by monthly analyses showing frequently high peaks of E-coli, ammonia and phosphate. In addition to this most pit toilets are located next to the channel. Comparatively few respondents mentioned that they dispose their night use buckets into the stormwater channel, further adding to the pollution of Leeupan.

High phosphate and ammonia levels found in the greywater samples indicate the potential for causing eutrophication in affected water bodies, followed by algal bloom and the associated aesthetical deterioration. In Gugulethu the environmental impact is smaller as most greywater is disposed of in toilets. Some respondents mentioned that, prior to the installation of stand pipes, laundry was washed in the nearby stream (Blesbokspruit). One person even mentioned that she uses the Blesbokspruit for toileting. In addition to this night buckets disposed of in the nearby veld may also add to stream pollution through subsequent rainwater runoff.

8. RECOMMENDATIONS

8.1 Proposed interventions by local authorities

In the short-term

- Stop stormwater channel disposal.
- Drain the ponding greywater.
- Inform residents of health risks.

In the medium-term

- Communities must be encouraged to have gardens, trees and shrubs where they can dispose greywater, but since usage as plant food is still a controversial issue, the risk factor need to be considered if not used under control and good management.
- Some form of technological and strategic interventions must be implemented in existing settlements which impact on the water resource, like Harry Gwala, as it was indicated in the study findings that it is the course of pollution at Leeupan.
- Seeing that vandalizing and stealing of taps are rife, specialized stainless steel, push-button automatic taps should be welded. Although this is expensive, it would save the cost of repairs and prevent contamination in the water supply as well as reducing greywater ponding.

- Provision of catchpits / greywater disposal points at standpipes, for drainage into the municipal sewer and encouragement of communities to do washing activities at these points. (Carden et *al,* 2007: 5-2).

For the long-term:

Local authorities should embark on programs to raise awareness about environmental pollution and associated health risks in affected communities, to gradually change improper behavior and improve community hygiene and waste water management.

8.2 Future management recommendations

- There should be cooperative governance amongst the departments; this entails the development of an integrated working strategy with the Departments of Water Services, Housing and Health. Housing should consult Water Services before people are placed in any land/area so that it will be established if people are placed in environmentally sensitive areas. In addition to this, housing should address the overpopulation of informal settlements by not exceeding the design service capacity.
- Including greywater management plans/strategies into the Water Service Plan (WSP).

8.3 Identified research needs

Future research could concentrate on the following aspects:

- Possible means and ways of greywater use.
- Associated health risks and benefits of using greywater.
- Use of greywater as demand management tool.
- Groundwater pollution associated with uncontrolled disposal of greywater.
- Effects of detergent pollution load in relation to the chemical components to the environmental and health impact
- Quantifying the proportion of water supply becoming greywater for different categories of water supply, different seasons (wet and dry) and during times of water shortages.

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Appendix A

Chemical and microbiological methods used for analyses

Table 4.1: Chemical and microbiological methods used for analyses

Parameter	Analytical Procedure	Concentration units	Measurement range	Method reference	Error
Cond	Conductimetric	mS/m	1 –	SM 2510	Not done yet
TSS	Gravimetric	mg/L	> 10	SM 2540 D	Not done yet
Cl	Colorimetric (Silver Nitrate)	mg/L Cl^-	2 – 400	SM 407 A	Not done yet
NH_3	Colorimetric FIA (Salicylate)	mg/L N	0.1 – 100	EPA 350.1	Not done yet
PO_4	Colorimetric FIA (sb. potassium tartrate/ ammonium molybdate)	mg/L P	0.1 - 40	EPA 365.1	Not done yet
pH	Electrometric	pH units	-	SM 4500 H^+ B	Not done yet
COD	Colorimetric (potassium chromate)	mg/L O_2	HR 100 – 2 000 LR 10 - 150	SM 5220 D and Hach method 8116	Not done yet
OG	Gravimetric (petroleum ether)	mg/L oil & grease	>10	SM 5520	Not done yet
Ca	ICP - OES Manual	mg/L Ca	0.1-100.0	*	Not done yet
Mg	ICP - OES Manual	mg/L Mg	0.1-100.0	*	Not done yet
K	ICP - OES Manual	mg/L K	0.1-50.0	*	Not done yet
Na	ICP - OES Manual	mg/L Na	0.1-250.0	*	Not done yet
Cd	ICP - OES Manual	mg/L Cd	0.02-10.00	0,007:0,02 = 35%	Total uncertainty 0.007ppm Expanded uncertainty @ 0.014 pm at 95% confidence level
Cr	ICP - OES Manual	mg/L Cr	0.07-10.00	*8,6%	Total uncertainty 0.006ppm Expanded uncertainty @ 0.011 pm at 95% confidence level
Co	ICP - OES Manual	mg/L Co	0.04-10.00	*15%	Total uncertainty 0.006ppm Expanded uncertainty @ 0.012 pm at 95% confidence level
Cu	ICP - OES Manual	mg/L Cu	0.01-10.00	*60%	Total uncertainty 0.006ppm Expanded uncertainty @ 0.012 pm at 95% confidence level
Fe	ICP - OES Manual	mg/L Fe	0.01-10.00	*440%	Total uncertainty 0.044ppm Expanded uncertainty @ 0.087 pm at 95% confidence level
Pb	ICP - OES Manual	mg/L Pb	0.01-10.00	*101%	Total uncertainty 0.005ppm Expanded uncertainty @ 0.010 pm at 95% confidence level

Mn	ICP - OES Manual	mg/L Mn	0.01-10.00	*50%	Total uncertainty 0.005ppm Expanded uncertainty @ 0.011 pm at 95% confidence level
Ni	ICP - OES Manual	mg/L Ni	0.01-10.00	*60%	Total uncertainty 0.006ppm Expanded uncertainty @ 0.011 pm at 95% confidence level
Zn	ICP - OES Manual	mg/L Zn	0.07-10.00	*13%	Total uncertainty 0.009 ppm Expanded uncertainty @ 0.017 pm at 95% confidence level
Al	ICP - OES Manual	mg/L Al	0.07-10.00	*20%	Total uncertainty 0.014 ppm Expanded uncertainty @ 0.028 pm at 95% confidence level
Si	ICP - OES Manual	mg/L Si	0.01-10.0	*110%	Total uncertainty 0.011 ppm Expanded uncertainty @ 0.022 pm at 95% confidence level
B	ICP - OES Manual	mg/L B	0.03-10.00	*93%	Total uncertainty 0.028 ppm Expanded uncertainty @ 0.436 pm at 95% confidence level
Ba	ICP - OES Manual	mg/L Ba	0.01-10.0	*120%	Total uncertainty 0.012 ppm Expanded uncertainty @ 0.023 pm at 95% confidence level
Hg	ICP - OES Manual	mg/L Hg	0.1-10.00	*180%	Total uncertainty 0.180 ppm Expanded uncertainty @ 0.359 pm at 95% confidence level
Mo	ICP - OES Manual	mg/L Mo	0.01-10.00	*	Not done yet
Sr	ICP - OES Manual	mg/L Sr	0.01-10.0	*130%	Total uncertainty 0.013 ppm Expanded uncertainty @ 0.026 pm at 95% confidence level
V	ICP - OES Manual	mg/L V	0.02-10.00	*55%	Total uncertainty 0.011 ppm Expanded uncertainty @ 0.022 pm at 95% confidence level
As	ICP - OES Manual	mg/L As	0.02-5.00	*575%	Total uncertainty 0.115 ppm Expanded uncertainty @ 0.230 pm at 95% confidence level
Se	ICP - OES Manual	mg/L Se	0.01-5.00	*	Not done yet
Ecol MPN	MPN Substrate	CFU/100ml		SM 9223 A+B	**
TC MPN	Membrane	CFU/100ml		SM 9222	**

filtration B

* 1. AMERICAN PUBLIC HEALTH ASSOCIATION - AMERICAN WATER WORKS ASSOCIATION – WATER ENVIRONMENTAL FEDERATION (1995). Standard methods for the examination of water and wastewater 19th Edition, Washington DC

*2. PERKIN ELMER, Optima 5000 series ICP Optical emission, operator's manual.

SM-Standard Methods for the Examination of Water and Waste Water, 19thEdition (1995).

EPA- US Environmental Protection Agency, Methods for Chemical Analysis of water and wastes (1983)

Detection limit used for printing of final result sheets / certificates - Blue

** Expanded Unceratinty for Microbiology Laboratory 2008 E.colMPN (Water)

Relative Standard Deviation (RSD) average (rc) 0.01879 Minimum RSD reproducibility (r) 0.00493, Maximum RSD r 0.0396 k = +/-2

Sample count c1000 Expanded UM = log10 C +/- k. RSD rc, Uncertainty of count -2.96242+3.03758 Antilog of count 917+1090

Expanded Uncertainty for Microbiology Laboratory 2008

TCMPN (Water), RSD rc 0.01046 Minimum RSD r0.00496 Maximum RSD r 0.01582 k = +/-2Sample count c 1000

Expanded UM = log10 C +/- k. RSD rc Uncertainty of count -2.97908 + 3.02092 Antilog of count -953 +1049

Appendix B

Overview of the Eastern region map of EMM

Harry Gwala – indicated beneath ward 30 next to Beach front in Benoni, Gugulethu is indicated in Payneville extension 3, Mkhanca – indicated as Ergo squatters next to ward 74 in Brakpan, Soul City is part of Masechaba view between ward 86 & 87 in Duduza

Appendix C

Demographic details of the respondents

Table 6.1: Demographic details of respondents

	Gender			Race (South African)								Foreign languages			Nationality									Employment		Income per household	Education			
Name of settlement	Female	Male	Age	Zulu	S.Sotho	N. Sotho	Xhosa	Ndebele	Xhosa	Tswana	Venda	Tsonga	Shona	Swati	MP	KZN	OFS	GP	Limpopo	EC	NW	Mozambique	Zimbabwe	Employment	Unemployed		matric	Gr 8-11	Gr 1-7	none
Harry Gwala	15	10	34	9	3	5	4	0	0	1	0	2	0	1	1	6	2	4	5	4	1	2	0	9	16	1160	6	11	6	2
Gugulethu	19	6	34	8	2	7	2	3	0	0	0	1	0	2	8	1	2	3	8	3	0	0	0	15	10	964	4	14	3	4
Mkhanca	12	13	31	5	3	3	2	1	0	5	1	3	1	1	2	5	2	0	7	3	5	0	1	10	15	1555	3	13	6	3
Soul City	21	4	35	13	7	1	4	0	0	0	0	0	0	0	0	5	5	14	0	1	0	0	0	5	20	833	4	8	6	7
Total	**67**	**33**		**35**	**15**	**16**	**12**	**4**	**0**	**6**	**1**	**6**	**1**	**4**	**11**	**17**	**11**	**21**	**20**	**11**	**6**	**2**	**1**	**39**	**61**	**1128**	**17**	**46**	**21**	**16**