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Characterisation of Greywater from peri-urban areas in Nakuru, Kenya

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Nakushukuru sana!

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Abbreviations & Acronyms

BOD	Biochemical Oxygen Demand
CBO	Community Based Organizations
DO	Dissolved Oxygen
EC	Electrical Conductivity
Ecosan	Ecological sanitation
FAO	Food and Agricultural Organization
FC	Faecal Coliforms
GPS	Global Positioning System
Ksh	Kenyan Schilling
MCN	Municipal Council of Nakuru
MDG	Millennium Development Goals
ROSA	Resource-Oriented Sanitation concepts for peri-urban areas in Africa
SRP	Soluble Reactive Phosphorus
SS	Suspended Solids
TDS	Total Dissolved Solids
TP	Total Phosphorus
TSS	Total Suspended Solids
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children’s Fund
WHO	World Health Organization

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Zusammenfassung

Kenia ist wie viele andere afrikanische Länder mit ernsthaften Problemen in den Bereichen Trinkwasserversorgung, Abwasserentsorgung und Ernährungssicherheit konfrontiert. Aufgrund des hohen Bevölkerungswachstums und der steigenden Nachfrage nach Wasser werden dringend alternative Wasserressourcen benötigt.

Das ROSA (Resource Oriented Sanitation for peri-urban areas of Africa) Konzept empfiehlt daher, Abwasser zur Bewässerung und Düngung in der Landwirtschaft zu nutzen. Um eine effektive Behandlung und Wiederverwendung zu gewährleisten wird das Abwasser in verschieden Ströme getrennt (Urin, Fäkalien und Grauwasser).

Grauwasser ist Abwasser, das aus Küche, Bad und vom Waschen der Kleidung stammt, aber kein WC-Abwasser enthält. Die Wiederverwendung für die Bewässerung im Garten oder in der Landwirtschaft vermindert die Nachfrage nach Trinkwasser, schont die Wasserressourcen und verbessert die Ernährungssicherheit, weil die Pflanzen ganzjährig bewässert werden können.

Da es in den Randgebieten von Nakuru in Kenia keine Kanalisation gibt, wird das Grauwasser unbehandelt auf der Straße entsorgt. Daraus entsteht eine schwerwiegende Gefahr für Umwelt und Gesundheit.

Vor diesem Hintergrund ist das Ziel dieser Arbeit, die Grauwassermenge abzuschätzen und eine Qualitätsbestimmung vorzunehmen. Dafür wurden Grauwasserproben aus verschiedenen Haushalten in Nakuru und aus unterschiedlichen Quellen untersucht: Grauwasser aus der Küche, das beim Wäschewaschen entstandene Grauwasser und gemischtes Grauwasser.

Zur Einschätzung des Risikos für Gesundheit und Umwelt und der Möglichkeiten zur Wiederverwendung von Grauwasser wurden verschiedene physikalisch-chemische und mikrobiologische Eigenschaften bestimmt. Die Grauwassermenge wurde mit Hilfe der Ergebnisse eines Fragebogens berechnet.

Stichwörter: Grauwassercharakteristik, Grauwassermenge, Grauwasserqualität, Grauwasserwiederverwendung, Grauwasserentsorgung

Abstract

Kenya, as many other African countries, is confronted with serious problems in sanitation, water and food security. High population growth causes a rapidly increasing demand for water and creates an urgent need for alternative water sources. The ROSA (Resource Oriented Sanitation for peri-urban areas of Africa) concept is recognizing wastewater as a sustainable source for irrigation and fertilizing in agriculture. Therefore waste water is separated in different streams (urine, faeces and greywater) to ensure most effective treatment and reuse.

Greywater is wastewater from the kitchen, laundry and bath but excluding toilet wastewater. Its reuse for irrigation in horticulture reduces the demand of freshwater, mitigates the stress on water resources and improves food security as plants can be irrigated during the whole year. Nevertheless in the peri-urban areas of Nakuru, Kenya there is no sewer connection and therefore greywater is mainly disposed untreated on the road where it creates serious problems for the environment and public health.

With this background the aim of this thesis was to estimate greywater quantity and determining its quality by sampling greywater from different households and different sources (kitchen, laundry and combined) in the low and middle income areas of Nakuru. To characterize greywater quality a variety of different physicochemical and microbial parameters were chosen to assess the risk for the environment and health, further to explore the possibility of reusing it for irrigation. Greywater quantity was calculated by the results of a questionnaire done by the ROSA team in Nakuru.

Keywords: greywater characteristics, greywater quantity, greywater quality, greywater reuse, greywater disposal

1. Introduction

As stated in the latest United Nations World Water Development Report (2009): “Water in a Changing world”, there are 884 million humans (13%) without any access to drinking water, 340 million people of those in Africa (UNESCO, 2009). Furthermore there is a population growth of 80 million people yearly which causes an additional water demand of 64 million m³ water.

2.6 billion people do not have access to any type of improved sanitation. Reducing these numbers by half, by the year 2015, is currently the focus of international efforts as part of the Millennium Development Goals (MDGs). According to the latest figures released by the UN this goal will not be achieved (NZZ, 2009).

Most of all world-wide countries with a high percentage of death due to inadequate water and sanitation are in Africa, for example Uganda 15,8%; Ethiopia 15% and in Kenya 9,9% (WHO, 2008). Ecological sanitation offers an alternative to conventional sanitation and avoids its disadvantages like high costs and high water consumption. It is different from conventional approaches: human excreta and greywater from households are recognised as a resource which should be reused mainly for irrigation and fertilizing in agriculture (ROSA, 2006). According to WHO (2006a), greywater is water from the kitchen, bath and laundry, which generally does not contain significant concentrations of excreta.

A recent FAO report (2000) states, approximately 85% of water is used for agriculture purpose in Africa. To provide food for a growing world population it is necessary to enlarge irrigated farm land without tightening the water crisis (TANJI and KIELEN, 2002). Therefore water resource development is crucial for food security and sustainable agricultural production. Greywater reuse reduces the demand for freshwater, mitigates the stress on water resources and has the potential to influence poverty positively (WHO, 2006a).

Purpose of this study

The limited amount of data on greywater compositions shows a high variability in greywater quality (VAN STRAATEN, 2008). Though greywater is generally less polluted than domestic blackwater or industrial wastewater, it may still contain high levels of pathogenic microorganisms, suspended solids and substances such as oil, fat, soaps, detergents, and other household chemicals (MOREL and DIENER, 2006). Hence it is fundamental to assess the quality of greywater before reusing it, as poor quality can have a negative impact on the environment, on crop yields and also on human health (MURPHY, 2006).

In general there is a lack of data on greywater composition. This is also true for the study site Nakuru in Kenya, a pilot city in the ROSA project. Therefore in this study the main objective is to characterize type and content of greywater pollutants from different households and different sources (kitchen, laundry and combined) in the peri-urban areas of Nakuru Municipality. Therefore the following physicochemical and microbiological parameters were monitored.

1) Physicochemical parameters (onsite and sum parameters)

Temperature: T (°C)

Total suspended solids: TSS (mg/l)

pH value

Electrical conductivity EC: (µS/cm)

Salinity (g/l)

Total dissolved solids: TDS (mg/l)

Dissolved oxygen: DO (mg/l)

Biological oxygen demand: BOD (mg/l)

2) Physicochemical parameters (nutrients)

Total phosphorus: TP (mg/l)

Soluble reactive phosphorus: SRP (mg/l)

Nitrate nitrogen: NO_3-N (mg/l)

Nitrite nitrogen: NO_2-N (mg/l)

Ammonium nitrogen: NH_4-N (mg/l)

3) Microbiological parameter

Faecal coliforms (cfu/100ml)

Furthermore the collected data will be used in another study for designing an adequate treatment system (constructed wetland) for these areas as there is no sewer connection available.

2. Background

Providing access to sufficient quantities of safe water and the provision of facilities for sanitary disposal is of paramount importance to reduce the burden of disease (WHO/UNICEF, 2004). Africa stays behind every other region in coping with sanitation services (STEDMAN, 2008).

The ROSA (Resource-Oriented Sanitation concepts for peri-urban areas in Africa) project suggests resource-oriented sanitation concepts as a possibility of sustainable sanitation and to meet the UN MDGs (ROSA, 2006). These concepts shall be applied in four cities in East Africa, called Arba Minch (Ethiopia), Nakuru (Kenya), Arusha (Tanzania) and Kitgum (Uganda). All pilot cities have common problems like a lack of water and high population growth rates combined with inadequate sanitation and water supply.

2.1. Resource oriented or ecological sanitation systems

According to the Description of Work for the Project "Resource-Oriented Sanitation concepts for peri-urban areas in Africa" (ROSA, 2006), ecological sanitation (ecosan) is different from conventional approaches, as human excreta and greywater from households are recognised as a resource which should be reused mainly for irrigation and fertilizing in agriculture (figure 1).

By theses means, ecological sanitation helps to restore soil fertility, conserve freshwater and protect surface and ground water (ROSA, 2006). To assure the most effective treatment and an efficient reuse, the wastewater is separated in different streams (urine, faeces and greywater) which differ in terms of pathogens, nutrient content and benefits to soils and plants (ESREY et al., 2001).

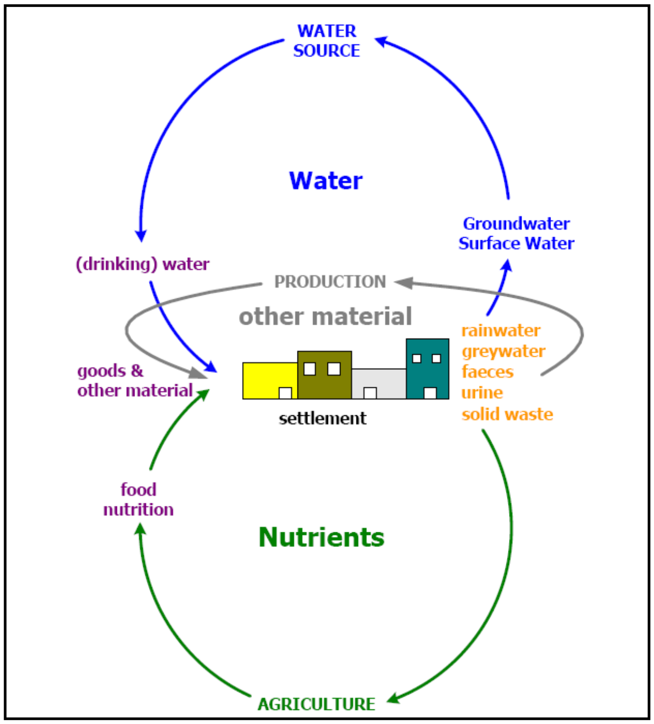

Figure 1: Resource-oriented or ecological sanitation systems (LANGERGRABER AND MÜLLEGGER, 2005)

2.2. Background information about Nakuru

2.2.1. General

Nakuru is located 160 km north-west of Nairobi (and about 30km south from the equator at a sea level of 1900m) in the Great Rift Valley, next to Lake Nakuru National Park. Nakuru is headquarter oft Rift Valley Province and acts as a political, administrative and economic centre. The climate is semi-arid and characterized by two rain seasons. An average rainfall of 800-900 mm per year and an average temperature of 24 to 29°C are recorded across the town (ROSA NAKURU, 2007).

The soil is mainly volcanic loose soil and the town is characterized by young volcanic rocks and localized faulting (MCN et al., 1999). According to OTIENO (2005) the water table ranges between 60 and 130 m depth. Nakuru is the fourth largest city in Kenya with approximately 500 000 inhabitants and a considerable annual population growth rate of 7% (ROSA NAKURU, 2007). Resulting from this the demand for water, sanitation, housing and food is sharply increasing.

2.2.2. Water supply

The UNESCO (2006) reports about 650 m^3/year available water per capita in Kenya but also prognoses a drop to 359m^3 as a result of population growth. The baseline study (ROSA NAKURU, 2007), which was conducted by the Nakuru ROSA team in 2007, asserted that water supply is a major problem in Nakuru, especially in the low-income areas. It was estimated that more than 50% of town residents do not have adequate water supply. Due to very limited water supply there are areas in the town where water is scheduled at specific hours each day while other areas receive water twice a week or are only sporadically provided with water. Access to water and frequency of water supply in Nakuru town is shown in figure 2. However rationing highly affects the poor in the low-income areas due to the low number of access points and also lack of storage facilities (ROSA NAKURU, 2007).

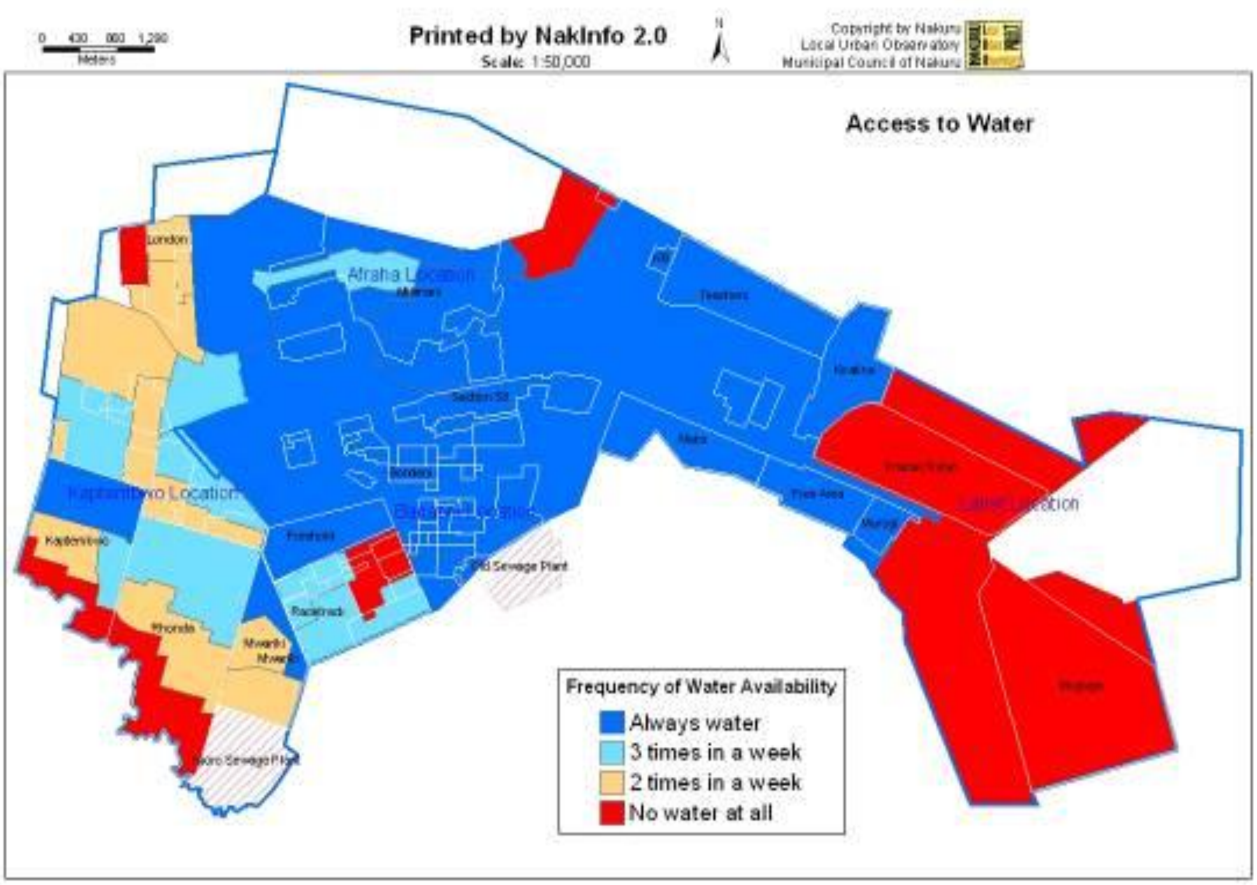

Figure 2: Accesses to Water and Frequency of Water Supply in Nakuru Town (ROSA NAKURU, 2007)

The town gets water from both surface and groundwater sources. Other water sources include private vendors, wells and rainwater catchment. Water supply in peri-urban areas is mainly organized by private initiatives such as water vendors who are the main alternative source of water (ROSA NAKURU, 2007).

There are three water kiosks in operation, which are managed by local Community Based Organisations (CBOs) and run by volunteers. The water is currently sold for Ksh. 4 for every 20 liter container in the kiosks and vendors charge between Ksh. 10 and 30 depending on distance and season. There is average water consumption per household of 65 l/d per capita (ROSA NAKURU, 2007).

2.2.3. Sanitation

In Nakuru only 13 km^2 of a 240km^2 area has a sewer system and this only serves the middle and high income areas. For these areas the town has two sewerage treatment plants with a total installed capacity of 16 200 m^3/day (ROSA NAKURU, 2007).

In other parts without a sewer connection mainly pit latrines (85%) and septic tanks (11%) are used (OTIENO, 2005). The use of pit latrines causes problems especially in the high populated peri-urban areas due to groundwater contamination and lack of space as in general the full pit latrine is abandoned and the new one is built next to it. In these areas it is also common that latrines are shared by 15 or more people especially in rented houses with toilets in the yard (OTIENO, 2005).

According to the baseline study (ROSA NAKURU, 2007) a high number of people (36% in Kwa Rhonda and 20% in Lake View) are not able to use their latrines in the night due to security concerns thus there is also a problem with open defecation. Furthermore there are one public toilet managed by the Municipal Council of Nakuru and three by a CBO which charges Ksh. 5 for normal usage and Ksh. 20 for showering and laundry services (ROSA NAKURU, 2007).

2.2.4. Greywater management

The highest percentage of household wastewater in Kwa Rhonda and Kaptembwo is greywater (OTIENO, 2005). The baseline study from ROSA NAKURU (2007) also observed that greywater separation is already in practice, for example it is sometimes used for irrigating vegetable gardens. According to inquiries there is a broad acceptance to consume vegetables irrigated by greywater. This is common in low density settlements where agricultural activities are high, for example in the Milimani area. In contrast to that, greywater is discharged onto the road or into open drainage systems in high-density settlements without sewer connection like Kaptembwo.

2.2.5. Urban agriculture

Information on urban agriculture has been largely drawn from a study titled “Urban Farmers in Nakuru, Kenya“ by FOEKEN and OWUOR (2000). According to this study 75% of households in Nakuru practice farming. Furthermore 35% of the households exercise farming within town boundaries, 27% of which cultivate crops while 20% keep livestock (table 1), hence there is great potential for reusing greywater for irrigation.

Table 1: Urban agriculture in Nakuru town (FOEKEN and OWUOR, 2000)

Type of urban agriculture	Percentage of households (Survey n= 594)	Estimated number of households
Farming in town	35.2	25 000
Cultivating crops in town	26.9	19 000
Keeping livestock in town	20.4	14 000

2.3. Greywater

Greywater is water from kitchen, bath and laundry, and generally does not contain significant concentrations of excreta and makes up the largest volume of the wastewater flow from households and is characterized by low nutrient and pathogen content (WHO, 2006a).

Treated greywater can be used for infiltration into soil (groundwater recharge), discharged into surface water or reused in agriculture. This depends on the local situation as well as on the greywater treatment method (MOREL and DIENER, 2006).

2.3.1. Treatment and reuse of greywater

There are a lot of different treatment systems available for greywater (figure 3). Corresponding to the WHO (2006a), greywater contains only low amounts of nutrients and pathogens. Therefore simple greywater management systems such as constructed wetlands, gravel filters or soil infiltration may reduce pathogens to meet the WHO health-based targets. Pre-treatment is necessary to remove solids and other rejects as well as oil and grease to prevent secondary treatment facilities from clogging, whereas secondary treatment is used for the removal of organic matter and the reduction of pathogens and nutrients (MOREL and DIENER, 2006).

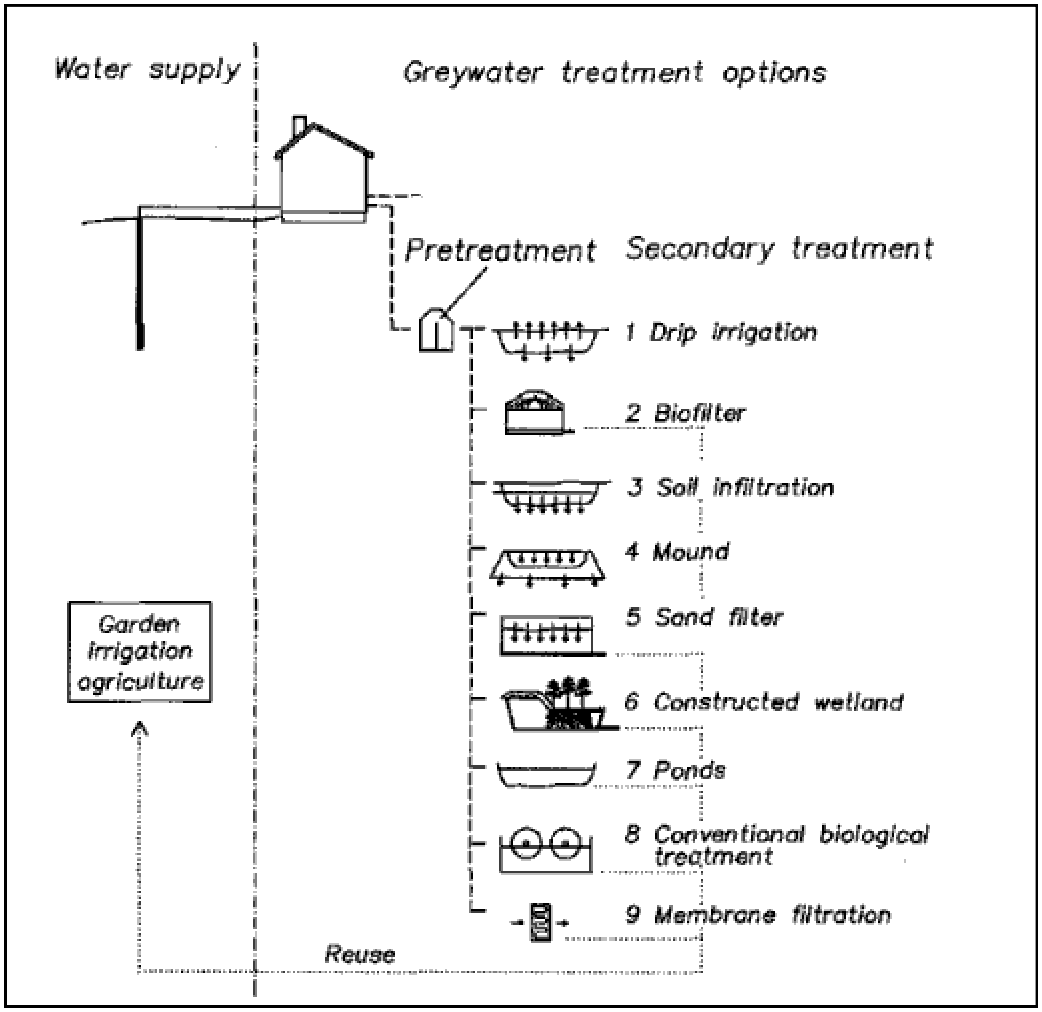

Figure 3: Greywater treatment options (WHO, 2006a)

Nevertheless one of the most effective ways to reduce greywater pollution is source control (MOREL and DIENER, 2006). This is linked to the use of environmental friendly household chemicals and the avoidance of faecal cross-contamination (WHO, 2006a). After treatment, greywater is infiltrated into soil for groundwater recharge or used in garden irrigation or agriculture.

According to the FAO (2000), the highest amount of water is used for agriculture purposes, as shown in figure 4, in Africa approximately 85 % of water withdrawals is used for agriculture. To provide food for a growing world population it is necessary to enlarge irrigated agriculture without tightening the water crisis (TANJI and KIELEN, 2002).

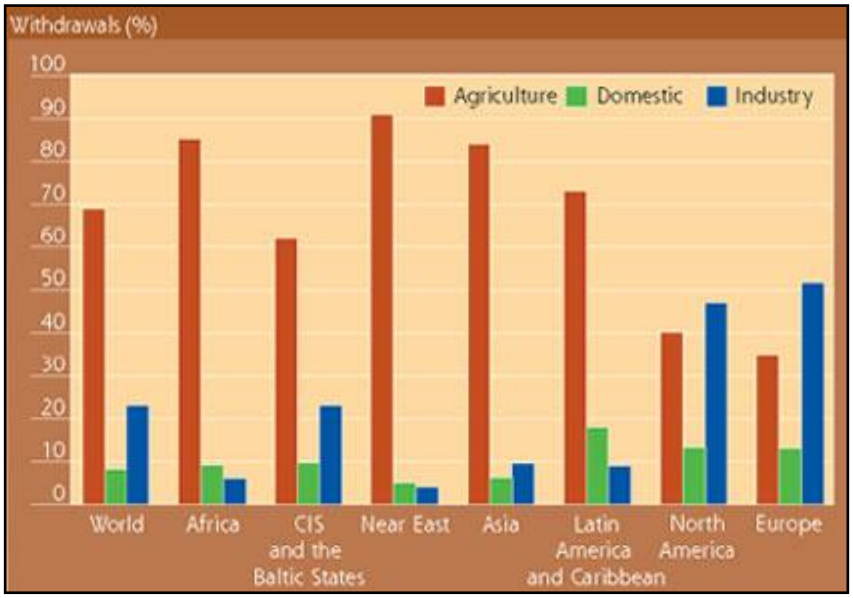

Figure 4: Water withdrawals by region and by sector (FAO, 2000)

The FAO (2000) is reporting both a rapidly growing demand of water and an increase in water pollution. Therefore water resource development is crucial for food security and sustainable agricultural production. As stated by HOLZHAUSEN (2005), greywater can be an important water resource for irrigation in agriculture and has the potential to increase food security instead of adding to pollution.

Corresponding to the WHO (2006a), greywater reuse reduces the demand for freshwater, mitigates the stress on water resources and is likely to have a positive impact on poor households:

1) Reduction of malnutrition due to higher food security and food variety as greywater is a reliable water source even during the dry season.

2) It contains plant nutrients which are readily available and can help to reduce the use of commercial fertilizer. The money saved can be used in other ways such as education or health care.

3) Greywater used in irrigation may allow to grow crops around the year. The additional yields can be sold on local markets increasing household income.

Poverty has for long been identified as one of the chief obstacles to sustainable development. Therefore, according to the WHO (2006a), the reuse of greywater and excreta in agriculture is a key development issue.

2.3.2. Quantity of greywater

Greywater volume available for irrigation determines the types of crops which can be cultivated and the irrigation method used (WHO, 2006b). Furthermore due to the dilution factor the volume of water used for washing, cooking and bathing is important to evaluate greywater quality. Thus knowledge of the quantity of fresh water used per capita and per household should be sufficient to obtain a first estimate of the characteristics of greywater in a given region (MURPHY, 2006). The best methods to account the amount of water used and how it is used are onsite surveys and field observations (VAN STRAATEN, 2008).

2.3.3. Greywater quality

The reuse potential and appropriate treatment method of greywater are affected by several factors. Most important are quantity, source (kitchen, bathroom or laundry) and the cleansing material used (MOREL and DIENER, 2006).

Furthermore the chemical quality of the fresh water and the water reuse within the household before its disposal are of importance (MURPHY, 2006). Mainly in low-income households without tapped water in the vicinity of the house, greywater from washing the laundry is reused, fpr example to clean the floor.

If greywater is reused poor quality can have a negative impact on the environment, on crop yields and also on human health (MURPHY, 2006). Greywater quality also determines which irrigation technique can be used for agricultural purposes. For example when greywater is characterized by a high salinity it is not recommended to use sprinkler irrigation as sodium and chloride can cause leaf damage (WHO, 2006b).

2.3.3.1. Physicochemical parameters (onsite and sum parameters)

Temperature

The temperature of greywater might be higher than the temperature of consumed fresh water because for laundry, bathing or cooking warm water is used (MOREL and DIENER, 2006). According to KLEE (1998) it is important to measure temperature in water samples as the solubility of gases, microbiological activities and the speed of reactions are strongly influenced by temperature. MOREL and DIENER (2006) refer to rather high temperatures with a range from 18 to 30°C which can cause enhanced bacterial growth.

pH

The pH of a solution is defined as the negative decimal logarithm of the hydrogen ion concentration (KLEE, 1998). The pH scale ranges from 0 to 14 with pH 7 as the neutral point. From pH 7 to 0 greywater becomes increasingly acidic and from pH 7 to 14 it is turning more alkaline (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996).

Greywater pH is mainly influenced by water supply and the cleansing products used (MOREL and DIENER, 2006). Especially laundry detergents can cause alkaline greywater that has a potentially negative effect on crops and fruit (MURPHY, 2006). According to AYERS and WESTCOTT (1994) pH itself is seldom a problem. However irrigation water with a pH outside the normal range (pH 6. 5 to 8. 5) may affect nutrient balance or may contain toxic substances. The greatest direct hazard of water with an abnormal pH value is the impact on components used in irrigation equipment such as corrosion and encrustation (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996).

Most effects of pH on plants are indirect through availability of certain plant nutrients and heavy metals in the soil. The majority of micro-nutrients and heavy metals are unavailable for plant uptake at high soil pH, but available at lower pH levels and then can be absorbed by crops and contaminate water bodies (WHO, 2006b). However except for extreme conditions irrigation greywater will only change the soil pH very slowly due to the fact that soil is buffered more strongly against changes in pH than water (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996).

To avoid negative effects on soil, plants, fruits and irrigation equipment a pH in the range from 5 to 8 is defined by the WHO guidelines for water quality for irrigation (Appendix, table 24).

<u>Electrical conductivity (EC), salinity and total dissolved solids (TDS)</u>

The electrical conductivity is a method to determine the ability of water to conduct an electrical current (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). As stated by KLEE (1998), pure water is unable to conduct an electrical current. It is only able to conduct the electrical current if electrically charged particles (ions) are present. Hence this ability is higher when more ions like carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium are in the water (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). Thus electrical conductivity is a criterion for the salinity as well as for the totally dissolved solids which are defined according to the DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1996) as the quantity of various inorganic salts.

Salinity is one of the most important parameters in determining the suitability of greywater to be used for irrigation (U.S. EPA, 2004). When greywater is used for irrigation the ions of primary concern are sodium, chloride and boron as these ions are toxic for plants (WHO, 2006a). Household detergents like sodium based soaps and washing powder are the main source of these salts (MOREL and DIENER, 2006). High salt concentrations in greywater used for irrigation increase salinity in soil and thus affect plant growth, unless the salts are regularly leached out. According to WHO (2006b) this is the main negative impact on the environment caused by greywater irrigation. Salinity effects soil quality in different ways: it makes the soil structure collapse enhancing diagonal drainage and soil erosion. Moreover, oxygen concentration and root growth are diminished, hence plant growth is limited or stopped (WHO, 2006b).

Due to high salinity the osmotic potential of the soil is reduced and therefore water uptake in plants is hindered. This results in less energy for plant growth as more energy is needed to adapt to receive enough water (U.S. EPA, 2004).

In arid or semi-arid areas this problem is more profound, because a relatively high amount of water is needed by the plants due to evaporation. Dissolved salts can accumulate on the soil surface especially when sprinkler irrigation is used (MOREL and DIENER, 2006). Most problems with salinity occur with seedlings because during this state plants are very sensitive even for low salt concentrations (U.S. EPA, 2004). The restriction on the use of greywater with high EC can be found in the WHO guidelines for interpretation of water quality for irrigation (Appendix, table 23).

Biological oxygen demand (BOD) and dissolved oxygen (DO)

The biological oxygen demand (BOD) measures the amount of oxygen needed by bacteria to degrade organic substances in water samples over a 5 day period at 20 °C (BOD_5) (MOREL and DIENER, 2006). Hence the oxygen demand is an indirect way to measure the organic pollution of water samples (KLEE, 1998). According to MOREL and DIENER (2006) the major organic substances in greywater are proteins, sugar, fats and oils as well as surfactants, which are biodegradable to a lower extent.

As shown in figure 5 greywater contains more than half of the BOD load compared to the total load in domestic wastewater. The amount of BOD and therefore also the biodegradability of greywater mainly depend on the water volume and on the products that are used as detergents, soaps oils and fats (MOREL and DIENER, 2006). Due to the use of cooking oil the organic substances in the kitchen greywater are very high and hence must be treated separately (WHO, 2006a). High amounts of easily degradable organic matter in greywater results in oxygen depletion when it is discharged into surface water (MOREL and DIENER, 2006). Therefore the oxygen is no longer available to other aquatic organisms, if the concentration of oxygen is too low, fish mortality may reach alarming proportions.

Total suspended solids (TSS)

The total suspended solids (TSS) are defined as the particulate matter consisting of inorganic and organic matter retained on a glass fibre filter (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). Fine suspended material derived from food, oil, soap, dirt or laundry fibres can cause turbidity and clogging of the treatment system (MOREL and DIENER, 2006). Furthermore seedlings are inhibited from sprouting as the soil surface is encrusted and on the other side water is prevented from infiltrating due to high amounts of formerly suspended solids. However if suspended solids have a high percentage of organic matter, soil texture, fertility and the microbiological activity in the soil might be improved (WHO, 2006b).

2.3.3.2. Physicochemical parameters (nutrients)

Plants and animals need basic elements and compounds such as phosphorus, nitrogen and potassium for growing. Problems with these nutrients occur when they are washed out into surface water or groundwater (MOREL and DIENER, 2006).

In natural aquatic environments phosphorus is the limiting factor for primary production growth, therefore excess nutrients in surface water lead to eutrophication because of a higher primary production (MURPHY, 2006). Furthermore some nutrients will have a toxic effect on organism if present in high concentrations (MOREL and DIENER, 2006). Greywater normally contains low levels of nutrients hence the main positive aspect of greywater is water recycling rather than nutrient supply (WHO, 2006a). Figure 5 shows that greywater might contain high levels on phosphorus depending mainly on the cleansing products used.

According to MOREL and DIENER (2006), greywater contains up to two thirds of the phosphorus load of total wastewater if phosphate containing detergents are used.

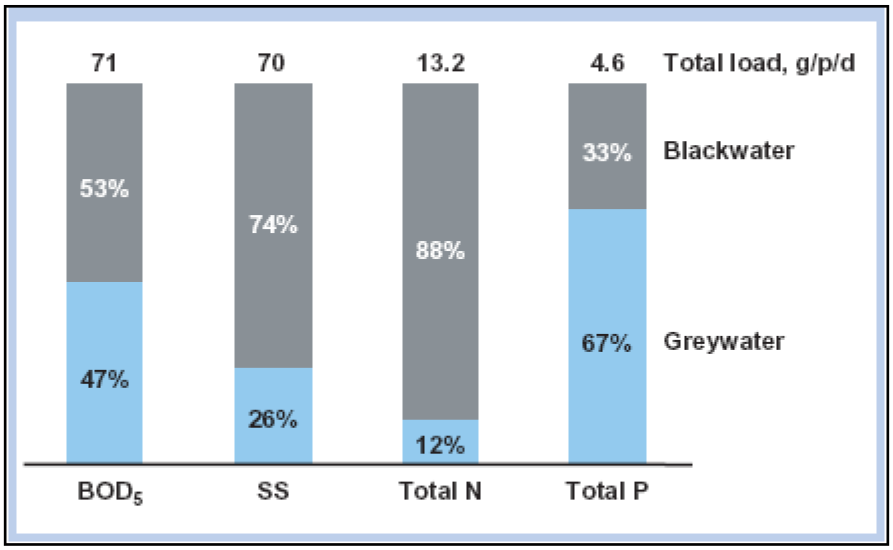

Figure 5: Average pollution loads in greywater compare to total loads in domestic wastewater (MOREL and DIENER, 2006)

<u>Total phosphorus</u>

Total phosphorus (TP (mg/l)) consists of dissolved and particulate phosphorus.

The major source of phosphorus in greywater is phosphoric household detergents such as laundry and dishwashing detergents (MOREL and DIENER, 2006); particularly in countries where phosphorous-containing detergents have not been banned.

As mentioned above phosphorus is essential for plant growth and mined phosphates are commonly used as fertilizer to increase agricultural productivity (WHO, 2006b).

THIESSEN (1995) argues that too little phosphorous is used in Africa where a major effect on food production could be achieved by using it. Furthermore population growth is anticipated to increase mainly in urban and peri-urban areas of Africa and Asia (WHO, 2006a). This will result in higher demand in food and phosphorus. According to STEEN and AGRO (1998), reserves of phosphate carrying rocks are about to deplete in 60-130 years. Furthermore phosphate mining leads to environmental damage such as land and water degradation. According to THIESSEN (1995) 25% of minded phosphorus ends up in aquatic environments leading to eutrophication. Thus, recycling phosphorus by greywater irrigation is a method to reduce demand of mined phosphorus, minimizing the environmental impact of phosphate mining and additionally enhancing food security by increasing agriculture productivity.

Ammonia (NH_4), nitrite (NO_2) and nitrate (NO_3)

Total nitrogen is the sum of organic nitrogen, ammonia (NH_4), nitrite (NO_2) and nitrate (NO_3). Nitrogen, like phosphorus, is one of the essential macro-plant nutrients and in general has a positive effect on plant growth unless excessively applied (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996).

According to MOREL and DIENER (2006) greywater from bath and laundry usually contains low nitrogen whereas kitchen greywater is the main nitrogen source in household greywater. Nitrogen in greywater results from ammonia containing household products and from food proteins. Generally the concentration of total nitrogen in greywater is relatively low (figure 5) therefore problems may more likely occur due to the nitrogen deficit (MOREL and DIENER, 2006). Because of the fact that nitrogen is also an important nutrient for microorganisms nitrogen deficits limit microbial processes. Therefore organic matter (soaps, oils, fats) may accumulate and clog soil or filter beds (MOREL and DIENER, 2006).

However high concentrations of nitrogen may cause negative effects on crop yield and quality as well as on ground- and surface water (Appendix: table 24 and 25). Nitrogen demand of crops depends on the growth stage (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). At early stages, crops need high amounts of nitrogen in contrary to the flowering and fruit stages, when high concentrations may cause yield or quality loss.

The amount of nitrogen leached out depends on the irrigation rate and hydraulic load due to rain, soil type, the uptake by plants, the total load of nitrogen in irrigation water and the nitrogen concentration in soils (WHO, 2006a).

Nitrate is only very weakly bound in the soil due to the fact that it is an anion and therefore it is not affected by an exchange reaction (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). Furthermore it is also highly water-soluble and for these reasons it is easily leached out especially when applied in high concentrations. Therefore it can easily reach groundwater and contaminate it. Nitrates are stable in groundwater and can reach concentrations that might contribute to methaemoglobinaemia (blue-baby syndrome) in bottle-fed infants if this water is used to prepare baby food (WHO, 2004).

Through surface runoff, especially by greywater, nitrogen can end up in aquatic environments where it stimulates algae and aquatic plant growth (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). Furthermore ammonia is oxidized into nitrite by microorganisms and as this process (nitrification) needs a high amount of oxygen, oxygen deficiency may occur in the water (KLEE, 1998).

There is also a high risk that ammonia turns into ammoniac when pH and temperature are high. This raises a problem as ammoniac is very toxic for aquatic life, especially fish (KLEE, 1998).

2.3.3.3. Microbial characteristics

According to WHO (2006a), the danger from pathogens in greywater results from direct contact, contaminated potable water, inhalation of aerosols and consumption of contaminated fruit when greywater is used for irrigation.

The direct detection of pathogens is difficult, time-consuming and expensive. Therefore indicator organisms are commonly used to determine pathogens and faecal cross-contamination (DEPARTMENT OF WATER AND FORESTRY, 1996). Faecal coliforms are harmless and characteristic for the intestines of warm-blooded animals including humans and therefore also found in faeces (MURPHY, 2006). That is the reason why these bacteria are commonly used as an indicator for the presence of faecal pathogens and to evaluate microbial water quality.

According to MOREL and DIENER (2006) faecal contamination is common in households with young children or babies because of washing the nappies and child care. Furthermore showering and anal cleansing can cause faecal cross contamination (WHO, 2006a). Contaminated food represents another possibility of faecal contamination via the kitchen sink (OTTOSSON, 2003). Hence the microbiological contamination of kitchen greywater is in general higher than in the other sources (MURPHY, 2006). Nevertheless as kitchen greywater contains a high amount of easily degradable organic compounds, there is also a high regrowth rate for E.coli and other coliforms (OTTOSSON and STENSTROM, 2003). Therefore these numbers may lead to an overestimation of faecal loads and thus the risk they expose WHO (2006a).

3. Material and methods

3.1. Sampling sites

59 greywater samples, containing 24 samples from kitchen, 25 samples from laundry, 10 samples from combined greywater and also five source water samples were taken. The sampling areas were Kaptembwo, Kwa Rhonda, Lake View and Mbugua. These areas are not connected to a sewer and water is not available throughout. The map below shows the 27 chosen households as for every sampling point the GPS data were noticed and used for the creation of this map in Arc View.

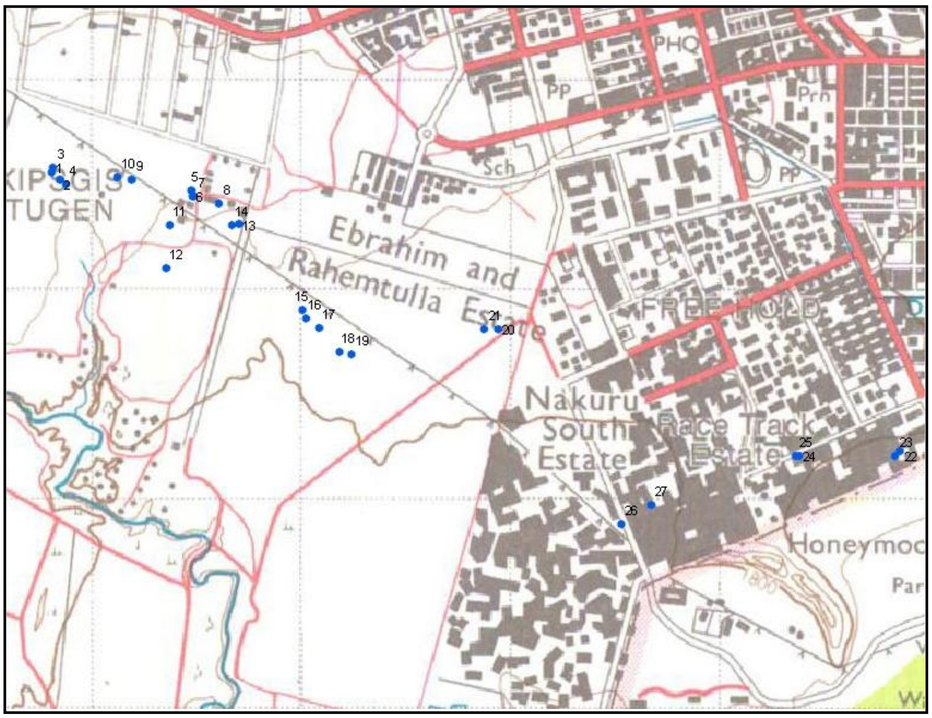

Figure 6: Sampling areas and households

Greywater samples for nutrients analysis were collected in 1 litre polyethylene bottles which were rinsed with distilled water beforehand; the samples for the microbiological parameter were collected in 500 ml sterile polyethylene containers. All containers were filled to their maximum capacity, so that no air was left inside. For transport, all containers were placed in a refrigerator box to minimise any change in the parameters.

Faecal coliforms, biological oxygen demand and total suspended solids were determined immediately after return to the laboratory. Then the samples were filtered and stored in the fridge at a temperature of 4°C. All remaining parameters were determined within 48 hours after sampling.

Greywater analyses have been carried out at the laboratory of the Biological Department at Egerton University- Njoro, Kenya. All methods used for the greywater analyses and mentioned below were according to the Manual for Water Quality Analysis, Egerton University- Njoro, Kenya (ODUOR, 2008).

3.2. Greywater quantity

For the calculation of the greywater quantity as well as for general information about water costs, awareness and reuse potential in the sampling areas, secondary data from a questionnaire was used. The questionnaire on sanitation survey in Nakuru Municipality was carried out by the ROSA Nakuru team in February 2007. The objective of the questionnaire was to get an overview about type, quantity and composition of wastewater as well as finance and settlement in the peri-urban areas of Nakuru. During the survey 120 households were selected from the low and middle income areas in the municipality.

3.3. Greywater quality

3.3.1. Sample collection

Within the sampling period of three month (November 2008 to January 2009), greywater samples were taken from two different households in the peri-urban areas of Nakuru every week. The sampling time was on Mondays between eight and ten o'clock in the morning. The households were randomly chosen within the five sampling areas.

Different challenges were faced during the sampling activities. First there were mistrust and lack of understanding. On the one hand the people feared to give the greywater samples because they could not understand the reasons of analysing this water. On the other hand they were ashamed for the water, tried to influence results by dilution or were not willing to give it to strangers at all as they feared the results. These social problems were solved by a sociologist who was accompanying the sampling and informed the people about the study aims and the reasons for the greywater sampling.

Second there were practical problems as it was difficult to get all sources of greywater especially for greywater from bathrooms and combined greywater. It was not possible to get bathroom greywater because normally it is poured in the shower and then it is directly infiltrating into the soil. The same happens to combined greywater which is the poured greywater from one household and normally contains all sources. The only possibility to get combined greywater was a blocked drainage within the household compound or a place where greywater is poured regularly therefore not infiltras into the soil and forms a puddle. Hence the greywater might not be fresh and maybe mixed with rainwater which may influence the analysed parameters.

There was no problem to get greywater samples from kitchen and laundry during the rainy season because the washing is normally done in basins and afterwards the greywater is poured. Hence if there is enough water available the people were generally willing to give the amount of greywater needed for the analysis. However during dry season it was also a challenge to get samples at all as water was scarce and the access was limited to certain days of the week. Therefore the water was often reused, for example laundry greywater was used to sweep the floor and the people were not willing to give it away.

Figure 7: Greywater sampling in Kaptembwo

3.3.2. Physicochemical parameters (onsite and sum parameters)

Dissolved oxygen, pH, temperature, electrical conductivity and salinity were measured on-site using the WTW Multi 340i meter. As problems occur with the WTW Multi 340i meter after the 6th sampling, other meters (VWR DO 200 and VWR EC300) were used for determining dissolved oxygen, electrical conductivity, total dissolved solids and salinity (figure 8).

Figure 8: On-site measurements in laundry (left) and kitchen greywater (right)

Temperature (T)

Temperature was determined by using a temperature sensor. The temperature was always measured in combination with other parameters like EC or DO. The probe was plunged partly in the greywater sample and the value shown on the meter was recorded.

pH

The pH was determined by using a portable meter (WTW Multi 340i) with a glass electrode. The method is based on the diffusion of H^+ ions across the glass membrane, in a flux proportional to the difference between the H^+ concentration fixed inside and outside the glass bulb. The glass electrode was used in conjunction with a standard Hg/Hg_2Cl_2 reference electrode.

Dissolved oxygen concentrations (DO)

The dissolved oxygen was measured with the help of an electrode probe (VWR DO 200) which was dipped in the water at a specific depth. The DO concentration was then shown on the meter display. The calibration was performed in water vapour-saturated air by using the OxiCal-SL calibration vessel.

Electrical conductivity (EC) and total dissolved solids (TDS)

The EC was determined with a cell consisting of two parallel platinum plates (VWR EC300) in a Wheatstone bridge. There is an electric current between the two electrodes and the more dissolved salt (cations and anions) the stronger the current flow and the higher the EC. The EC meter was calibrated by using a standard 0.01 mol/l KCl solution (conductivity 1430 µS/cm at 25 °C) the temperature dependency of the EC was compensated automatically by the meter. The EC also gives a rough estimation of TDS and the salinity presented in the water sample. The values of TDS and salinity were also shown on the EC meter display.

Biological Oxygen Demand (BOD)

BOD samples have been incubated for 5 days without any chemical inhibitor. The analysis of the BOD should be done immediately after sampling and a temperature of 20°C should be obtained.

Material:

- Winkler bottles (250ml)
- Aluminium foil
- Oxygen probe
- Stirrer

Procedure:

5 ml of samples were diluted up to 500ml with tap water to get the dilution factor 1:100. Afterwards the samples and the dilution water (blind) were carefully filled into Winkler bottles to avoid air bubbles followed by measuring the dissolved oxygen using an oxygen probe and a stirrer. The bottles were wrapped with aluminium foil and then put into a dark chamber for 5 days. After this, the dissolved oxygen was measured again and the BOD_5 was calculated according the formula below.

$$BOD = (Em - Ed) \cdot \frac{1000}{v} + Ed \quad (1)$$

BOD: biological oxygen demand [mg/l]

Em: oxygen demand of mixture [mg/l]

Ed: oxygen demand of dilution water [mg/l]

v = volume of sample [ml]

Total suspended solids (TSS)

To determine the amount of total suspended solids in greywater samples a gravimetric method was used. The samples were filtered using a filtration unit and glass fibre filters (Whatman GFC, pore size: 45 µm) as shown in figure 9.

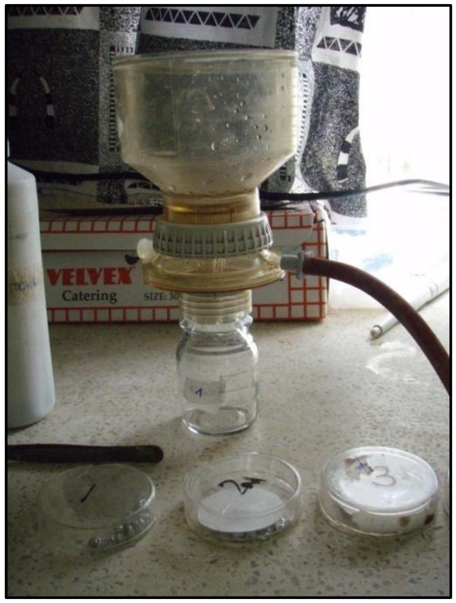

Figure 9: Filtration unit and glass fibre filters

The filters were dried at 500 °C for 2 hours and weighed before filtering a defined volume of sample. Afterwards the filters were placed in an oven and dried at 95°C for 3 hours. The dried filters were weighed again and the TSS was calculated using the following formula.

$$TSS\,[mg/l] = \frac{(Wc - Wf) \cdot 10^6}{V} \quad (2)$$

TSS = total suspended solids [mg/l]

Wc = weight of empty filter+residue [g]

Wf = weight of empty filter [g]

V = volume of sample [ml]

Organic and inorganic contents:

The inorganic content was determined by burning the filters used for TSS in a furnace at 500°C for 2 hours. Finally the filters were weighed again and the inorganic and organic content can be determined according to the formulas below.

$$inorganic \quad content \; [mg/l] = \frac{(AFDW - Wf) \cdot 10^6}{V} \tag{3}$$

AFDW= ash free dry weight [g]

Wf = weight of empty filter [g]

V = volume of sample [ml]

$$organic \quad content \; [mg/l] = \frac{(Wc - AFDW) \cdot 10^6}{V} \tag{4}$$

AFDW= ash free dry weight [g]

Wc = weight of empty filter+residue [g]

V = volume of sample [ml]

3.3.3. Physicochemical parameters (nutrients)

3.3.3.1. Introduction

Photometry is a method of estimating concentrations by using the light absorbance of the sample solution. The sample absorbance was determined with a spectrophotometer where the sample was placed in a cuvette and then penetrated by monochromatic light. Monochromatic light is light of a separated wavelength for example 578 nm. The light beam is partly absorbed by the substances in the solution hence the intensity of the emergent light is lower than that of the incident light. The reduced radiation is measured by a detector. Thus the light absorption can be determinated and this is related to the concentration of the absorbent material in the solution. This proportionality is described by the Law of Lambert-Beer:

$$A = \varepsilon \cdot c \cdot d \tag{5}$$

A= absorbance [-]

ε = molar extinction coefficient [$L \cdot mol^{-1} \cdot cm^{-1}$]

d = path length [cm]

c = molar concentration [mol/ L]

According to the Law of Lambert-Beer the light extinction caused by a solution is proportional to its concentration. Hence the concentration of a substance can be estimated through its extinction. This relation was shown with a calibration curve where the extinction of standard series of known concentrations was measured and plotted against concentration on a millimetre graph paper. The concentration of the sample was then estimated graphically through linear regression.

For the use of the photometric measurement it is usually necessary to add some reagents to form a coloured compound. To ensure that only a specific component is measured the reaction should be selective and stable.

Blanks and references:

To consider the impurities of glassware and reagents it is important to use blanks to get a correction factor. Blanks were only containing distilled water and all the used reagents but no sample. The light extinction of the blanks was measured and then the extinction of the sample was corrected by this value. Only distilled water is used as reference which was taken as the zero value.

Material:

- Spectrophotometer
- Filtration unit
- Glass-fibre filters
- Reagents

Figure 10: Spectrophotometer (4053 Ultrospec K)

Spectrophotometer (4053 Ultrospec K)

According to the Ultrospec K Instruction Manual (BIOCHROM, 1987), the spectrophotometer used for the nutrients analyses is working with visible and ultra-violet light. It is designed to carry out a comprehensive range of spectrophotometry measurements. It can perform absorbance, transmittance, concentration, rate kinetics and standard curve determination at wavelengths from 200 to 900 nm.

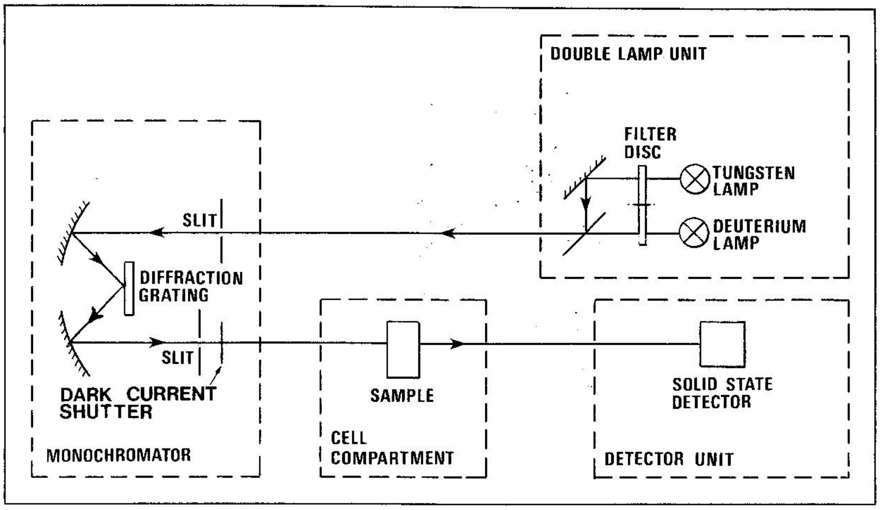

Figure 11: Optical system of spectrophotometer (BIOCHROM,1987)

As shown in figure 11 lights which are produced by the tungsten and deuterium lamps pass a rotating disc which has holes and filters hence only light from a selected source pass through. Afterwards the two light sources are combined and this light beam enters the monocromator. The monocromator is of a Czerny-Turner configuration with a 1200 lines/mm diffraction grating generating a narrow band of wavelengths. After the monocromator the light beam passes through the cuvette and then to the detector which is a single solid-state silicon photocell.

3.3.3.2. Nutrients analysis

For the nutrients analysis all samples were filtered with a filtration unit through glass fibre filters (Whatman GFC, 45 µm) to avoid light absorbance caused by particles. Only for the estimation of total phosphorus, unfiltered samples were used. To avoid particle interference greywater samples had been diluted. Analyses had to be done as soon as possible and the samples were stored in the fridge (4°C in the dark). Glassware which was used for the analyses had been washed with 10 % sulphuric acid (H_2SO_4) and rinsed with distilled water.

Soluble reactive phosphorus (SRP):
SRP was measured via the ascorbic acid method (APHA, 1995).

Standard calibration curve:

For the calibration curve 5.623g of dried (24h, 70 °C) potassium hydrogen phosphate (K_2HPO_4) salt was dissolved in 1 litre of distilled water to get a stock solution with a concentration of 1 g/l. 10ml of this stock solution were diluted furthermore to 1 litre with distilled water to get an intermediate solution of 10 mg/l. To get a working solution with a concentration of 0.5 mg/l, 25 ml intermediate solution were diluted to 500 ml with distilled water. The standard series was prepared by taking the volumes shown on the table below. Triplicate samples were taken for each concentration.

Conc. (mg/l)	0	0.01	0.02	0.05	0.1	0.2	0.4	0.5
Working solution (ml)	0	0.5	1.0	2.5	5.0	10.0	20.0	25.0
Vol. dist. Water (ml)	25.0	24.5	24.0	22.5	20.0	15.0	5.0	0.0

Reagents:

A) Ammonium molybdate solution.

15 g $(NH_4)_6MO_7O_{24}$ x 4 H_2O) in 500 ml distilled water

B) Sulphuric acid:

140 ml concentrated sulphuric acid was diluted up to 1000 ml with distilled water

C) Ascorbic acid:

2.7 g ascorbic acid was dissolved in 50 ml distilled water. This was freshly prepared since the acidic solution is highly unstable and must be used within 24 hrs.

D) Potassium-Antimonyltartrate-Solution:

0.34 g K-Antimonyltartrate was dissolved in 250 ml distilled water

Procedure:

The four reagents were mixed according to these ratios:

A: B: C: D = 2: 5: 2: 1

To 25 ml of each filtered samples 2.5 ml of the mixed reagents were added and after 15 minutes the absorbance of the samples was measured at a wavelength of 885 nm with distilled water as a reference.

Total Phosphorus (TP):

To measure TP unfiltered greywater samples were used. It was necessary to reduce the phosphorus in the water samples into free ortho-phosphate (SRP) by using persulphate digestion.

Standard calibration curve:

The calibration curve was made by the same standard solutions used for SRP but underwent the persulphate digestion first.

Persulphate digestion:

Reagents:

Potassium persulphate $K_2S_2O_8$

12g of $K_2S_2O_8$ was dissolved in 100 ml of distilled water under heating for about half an hour.

Procedure:

1 ml of warm potassium persulphate solution was added to 25 ml of all samples. Afterwards the weight of all bottles was noted then the bottles were closed (not too tightly) and autoclaved for 90 minutes (120 °C, 1.2 atm.). Further on the bottles were weighed again after cooling and the amount of water lost through evaporation was replaced by distilled water. After the digestion process the same method as for SRP was used to estimate the amount of total phosphorus.

Nitrate-nitrogen (NO_3-N):

Nitrate-nitrogen was determined by the sodium saliycilate method (APHA,1995).

Standard calibration curve:

6.067g of sodium nitrate ($NaNO_3$) were dissolved in 1 litre of distilled water to get a solution with a concentration of 1000 mg/l. From this solution 5 ml were diluted in 1 litre to get a concentration of 5 mg/l. The standard series was made by using the concentrations given in the following table. Triplicate samples for each concentration was made.

Conc. (mg/l)	0	0.25	0.5	1.0	2.5	5.0
Working solution (ml)	0	1.0	2.0	4.0	10.0	20.0
Vol. dist. Water (ml)	20	19.0	18.0	16.0	10.0	0.0

Reagents:

A) Sodiumsalicylate-solution:

0.5 g Na-Salicylate were dissolved in 100 ml distilled water. This solution was stable for 1 day only.

B) Concentrated sulphuric acid

C) Potassium-sodium tartarate solution:

400 g NaOH were dissolved in 1 litre distilled water, together with 50 g K-Na-Tartarate

Procedure:

20 ml of the filtered greywater samples were put in evaporation bottles and then 1 ml of the freshly prepared sodium salycilate solution was added. To dry the samples, the bottles were placed in the oven at a temperature of 95 °C over night. After drying, the residue of the samples was dissolved by using 1 ml of concentrated sulphuric acid (H_2SO_4) the bottles were swirled while they were still warm. Thereafter 40 ml of distilled water were added and mixed, followed by 7 ml of potassium-sodium hydroxide- tartarate solution. The absorbance of the samples was measured at a wavelength of 420 nm.

Nitrite-nitrogen (NO_2-N):

The reaction between sulfanilamid and N-Naphthyl-(1)-ethylendiamin-dihydrochlorid was used for the estimation of nitrite-nitrogen in the greywater samples.

Standard calibration curve:

1.2322 g sodium nitrite ($NaNO_2$) with a molar weight of 69 g were dissolved in 250 ml distilled water to get the concentration of 1 g/l. Furthermore 5 ml of this solution were diluted to 500 ml using distilled water to get a solution with 10 mg/l. Finally 50 ml of the solution were diluted in 1 litre distilled water to get the working solution having a concentration of 0.5 mg/l. The standard series was prepared according to the table below. Triplicate samples for each concentration were made.

Conc. (mg/l)	0	0.02	0.05	0.1	0.2	0.5
Working solution (ml)	0	1.0	2.5	5.0	10.0	25.0
Vol. dist. Water (ml)	25.0	24.0	22.5	20.0	15.0	0.0

A) Sulfanilamid solution:

25 ml Conc. HCl (37%) were diluted to 150 ml with distilled water. To this dilute acid, 2.5g of sulphanilamide were added. The solution was then further diluted up to 250 ml with distilled water.

B) N-Naphthyl-(1)-ethylendiamin-dihydrochlorid solution:

0.25 g of N-Naphthyl-(1)-ethylendiamin-dihydrochlorid were mixed in 250 ml with distilled water.

Procedure:

1 ml of reagent A was added to 25 ml of the filtered samples and 2-8 minutes later, 1 ml of reagent B was added and mixed. After 10 minutes the absorbance of the samples was measured at a wavelength of 543 nm.

Ammonium- nitrogen (NH_4-N):

Standard calibration curve

Ammonium chloride (NH_4Cl) with molecular weight of 53.492 g was dissolved in 250 ml distilled water to get a solution with a concentration of 1 g/l. 10 ml of this dilution was diluted with distilled water to 1 litre to get a concentration of 10 mg/l. By taking 25 ml of this solution and diluting it up to 1 litre a concentration of 0.25 mg/l was achieved. To get the standard series the volumes of the table below were used. Triplicate samples for each concentration were used to determine the calibration curve.

Conc. (mg/l)	0	0.01	0.02	0.05	0.1	0.25
Working solution (ml)	0	1.0	2.0	5.0	10.0	25.0
Vol. dist. water (ml)	25.0	24.0	23.0	20.0	15.0	0.0

A) Sodium salicylate solution:

130 g of sodium salicylate and 130 g of trisodium–dihydrate were mixed in 800 ml of distilled water. 0.97 g of sodium nitroprussid were then added to this solution. The solution was filled up to 1000 ml using distilled water. This solution has a bench life of two months.

B) Hypochlorid solution

0.2 g of sodium dichloroisocynurate which should always be freshly prepared was added and mixed with 100 ml of NaOH solution. The NaOH solution, made by dissolving 32 g NaOH in 1000 ml distilled water can be prepared in advance because it has a bench life of two months.

Procedure:

2.5 ml of reagent A were added to 25 ml of the filtered samples, followed immediately by adding reagent B. After this the samples were placed in the dark at a temperature of 25°C for 90 minutes. The absorbance was determined at a wavelength of 655 nm.

3.3.4. Microbiological analysis

The microbiological analysis was carried out in accordance with the Manual of Parasitological and Bacteriological Techniques published by the World Health Organisation, 1996.

3.3.4.1. Membrane filtration method

Faecal coliforms can be cultivated on membrane filters topped on a specific culture medium. These filters were placed on an adequate growth medium for example membrane lauryl sulfat broth. The nutrients of the medium were diffusing through the filter and hence the bacteria colonies were able to grow on the surface of the membrane filter. Coliforms were used as indicators for faecal cross-contamination in greywater.

A known amount of sample was filtered using a membrane filtration unit and membrane filters with 0.45 μm pore size to keep all faecal coliforms on it as shown in figure 12.

Figure 12: Membrane filtration for faecal coliforms

Afterwards the membrane filter was put on an absorbent pat placed in a petri dish and soaked with a faecal coliform growth medium. Finally the filters were incubated for 24 hours at a temperature of 44 °C (figure 13).

Figure 13: Incubator with samples

Theoretically each faecal coliform bacterium is forming a yellow colony which is counted after 24 hours incubation. The yellow colour is developed as faecal coliforms produce acid from the lactose in the medium and this acid changes the colour of the phenol red pH-indicator as shown in figure 14.

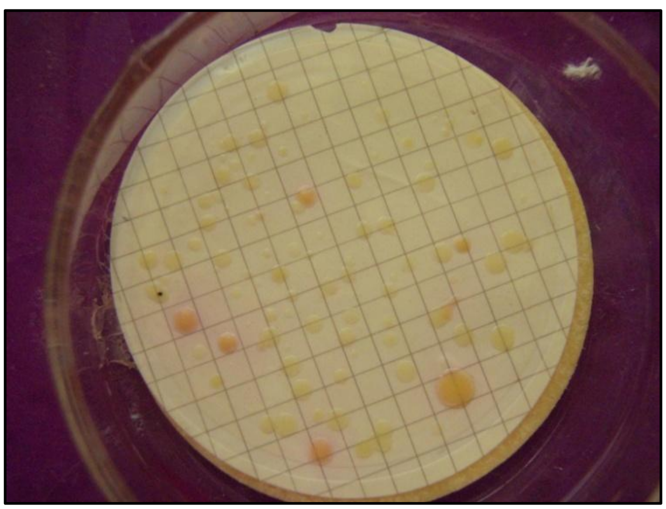

Figure 14: Yellow colonies on membrane filter

Equipment:

- forceps
- petri dishes (60 mm diameter, glass)
- membrane filtration unit
- 10 ml and 1 ml blow out pipettes
- vacuum pump (electrical)
- Bunsen burner
- incubator
- pressure cooker
- balance

Consumables:

- membrane filters (0,45 µm pore size, 47 mm diameter)
- absorbent pad (47 mm diameter)
- membrane lauryl sulfat broth
- quarter-strength Ringer´s solution (8.5 NaCl in 1 litre distilled water)
- ethanol

Dilutions:

As the concentration of faecal coliforms was high in greywater samples it was necessary to dilute.

1) 1 ml of sample was added to 9 ml of sterile water to get a 1:10 dilution. This was mixed thoroughly.

2) Using a fresh sterile 1 ml pipette, 1ml of the 1:10 dilution was put in another 9 ml of sterile water and mixed. This was a 1:100 solution.

3) To get higher dilutions step 2 was repeated by always using 1 ml of the last dilution and 9 ml of sterile water

The dilutions used in the study are shown in the Appendix, table 36 (Determination of feacal coliforms).

Procedure:

A sterilised forceps was used to place the absorbent pad into the sterile petri dish. With a sterile pipette 1.8 ml of sterilised membrane lauryl sulphate broth was put on the pad. The sterile membrane filter was put in the filtration unit 20 ml of sterile quarter-strength Ringer´s solution and further 5 ml of the diluted sample was added using a sterile pipette. Using the vacuum pump the sample was filtered through the membrane filter. Afterwards the filter was placed on the absorbent pad and finally the petri dish was put upside down in the incubator at 44 °C for 24 hours.

After incubation the numbers of yellow colonies were counted and the faecal coliform count per 100 ml was calculated according to the formula below

$$Cs = \frac{Z}{A} Vs \qquad (7)$$

Cs: number of colony forming units/ 100ml

Z: sum of all counted colonies of all dilutions

A: original sample volume [ml]

Vs: reference volume (= 100ml)

$$A = n_1 \cdot V_1 \cdot d_1 \qquad (8)$$

A: original sample volume [ml]

n1, n2...ni: amount of filters used and evaluated

d1, d2...di: dilution

4. Results and Discussion

4.1. Results of the questionnaire

4.1.1. Water and Population

The questionnaire on sanitation survey in Nakuru Municipality was carried out by the ROSA Nakuru team in February 2007. According to this quationnaire there is an average of five household members in all sampling areas. In Kaptembwo and Mwariki, the main water sources are communal taps and water kiosks while in Lake View and Kwa Rhonda water is mainly piped into the respondent's yard. The distance from the households to the water source varies between 0 and 2000 meters in Kaptembwo, 10 to 1500 meters in Kwa Rhonda, 0 to 100 meters in Mwariki and 0 to 20 meters in Lake View. The cost of water per 20 litre jerry can is between 3 and 30 Ksh. in all sampling areas. While in all areas water is mostly available for only two days a week, in Lake View water is mainly available for over 18 hours, in all other areas it is less than 6 hours. In the sampling areas 80.2 % of the households have problems associated with water supply. Main problems in all areas are water shortage (63.6%), rationing (14.3%) and disconnection (9.1%).

4.1.2. Greywater quantity

According to CARDEN K. et al. (2007) the amount of greywater produced per day is calculated with the amount of water used per day and multiplied by a factor of 0.75. Estimated from the questionnaire on sanitation survey in Nakuru Municipality (February 2007) the amount of water used per household and day ranges from 20 l/d to 200 l/d in the different sampling areas. The mean values for all areas are shown in figure 15 below and the calculated amount of produced greywater in table 2.

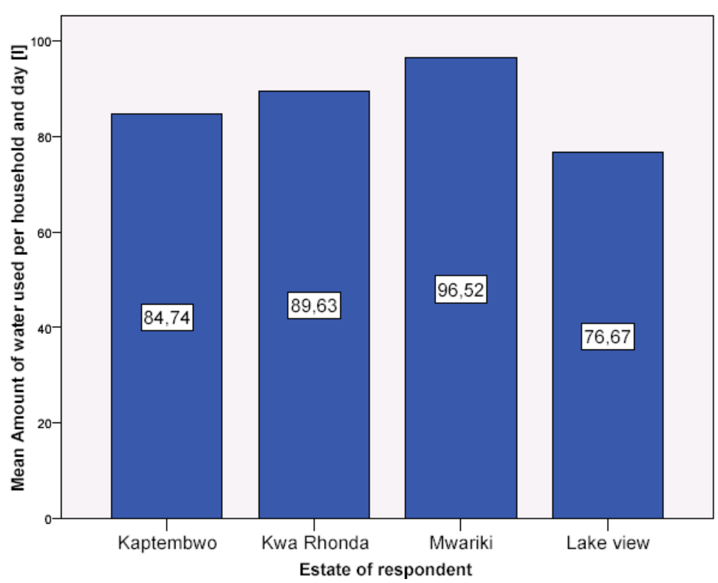

Figure 15: Mean amount of water used per household and day

Table 2: Calculated amount of produced greywater per household

Sampling area	Daily water use [l/d]	Greywater produced [l/d]
Kaptembwo	85	64
Kwa Rhonda	90	67
Mwariki	97	72
Lake View	77	57

According to the questionnaire the activity which requires the highest amount of water in all four areas is bathing and laundry (85.7%) followed by kitchen (8.6%) and 5.7 % of the amount of water used per household and day are used for other purposes. With this information it is possible to calculate the amount of greywater which is produced per source (table 3).

Table 3: Estimated amount of greywater produced from different sources (average values) per household

Sampling area	Kitchen greywater [l/d]	Laundry and bath greywater [l/d]	Combined greywater [l/d]
Kaptembwo	5	54	64
Kwa Rhonda	6	58	67
Mwariki	6	62	72
Lake View	5	49	57

Table 4: Approximate percentage of generated wastewater/household (WHO, 2006c)

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

4.1.3. Greywater disposal

Most of the people in Kaptembwo (66%), Kwa Rhonda (44%), Mwariki (68%) and Lake View (67%) pour their greywater into any empty space in their compound or on the road (figure 16). Other possibilities of greywater disposal are pouring physically into sewage, septic tanks or pit latrines which is done by 30% in all areas or using it for cleaning toilets (4%). In all sampling areas the majority of households are combining hard soaps and washing powder for cleaning their clothes.

Figure 16: Greywater disposal in the sampling areas

4.1.4. Awareness

Awareness of problems connected to greywater disposal as shown in table 5 differs. In Kaptembwo 45.5 % of the people think it is a big problem while in all other areas the majority of people say it is not a problem at all. This might be due to the fact that in Kaptembwo the housing density is higher and there is no space to pour greywater in the compound hence most of the greywater is disposed on the road. Furthermore the questionnaire was done on sanitation in general and therefore people are more aware of the problems connected with blackwater than with greywater.

Table 5: Challenges faced in disposing greywater

Estate of respondent			Percent
Kaptembwo	Valid	Not a problem	20.5
		Small problem	27.3
		Big problem	45.5
		Very big problem	6.8
Kwa Rhonda	Valid	Not a problem	44.8
		Small problem	27.6
		Big problem	27.6
Mwariki	Valid	Not a problem	52.0
		Small problem	12.0
		Big problem	28.0
		Very big problem	8.0
Lake View	Valid	Not a problem	83.3
		Big problem	16.7

4.1.5. Urban agriculture and possibilities of greywater reuse

There are 30.7 % of people who grow crops in their compound in Kaptembwo, 50 % in Kwa Rhonda and even 62.5 % in Mwariki while in Lake View none of the chosen households were growing crops .Therefore the reuse potential might be different for this area. The main crops growing in these areas are vegetables (30.8%), maize (23.1%), bananas (23.1%) and 15.4 % kales (*Brassica acephala).*

Only 3.1 % of crops are irrigated by tap water and 2.8 % by the use of untreated waste water while 67.6 % are only watered through the rain or grow naturally (26.5%). Hence there is a high potential for increasing the crop production by the use of greywater.

4.2. Greywater quality

4.2.1. Sample collection

Within the sampling period of three months (November 2008 to January 2009), 27 different households in four estates (Kaptembwo, Kwa Rhonda, Lake View and Mwariki) in the peri urban areas of Nakuru Municipality have been visited for sampling.

59 greywater samples, containing 24 samples from kitchen, 25 samples from laundry, 10 samples from combined greywater and also five source water samples were taken. The sampling time was on Monday between eight and ten o'clock in the morning.

The results of the different parameters according to their source are listed in the Appendix table 29 to table 33. All the results are also presented graphically in figures 17 to 34 for better demonstration of the differences. Beside the mean values of the respective parameter there are also the minimums, the maximums and the empiric standard deviation of the single measurement shown in the graph. Furthermore n is showing the amount of samples which were analysed for the presented parameter according to the different sources.

The quality of greywater is different from household to household and also from greywater source to greywater source. It was very difficult to get comparable samples as the parameters are influenced by so many things. First of all the amount of water which is used in kitchen or for laundry has a great influence on the greywater quality as in fewer amounts of water proportionally higher concentrations are found in the samples (MOREL and DIENER, 2006). Furthermore it is also influenced by the source water, the amount and type of detergents used for washing and how often the greywater was reused (MURPHY, 2006).

The quality is even changing daily within the households as it is depending on the activities of the household´s occupants like cooking habits (WHO, 2006c). Additionally it is also depending on the kind of people living in one household so if there are children or sick people within the household especially the microbiological quality is influenced (MURPHY, 2006). Also if greywater is stored the parameters are highly changing, for example thermo tolerant coliforms are multiplying between 10 and 100 times during the first 24 to 48 hours of storage (WHO, 2006c). This explains the highly different results from this study as it was not possible to control or to influence this reasons when samples were taken.

To improve the results in further studies it would be advisable to combine the samplings with a short questionnaire were this additional information is collected.

4.2.2. Temperature

As shown in the figure 17 below the temperature of kitchen greywater has a mean value of 21.7 °C and a median of 20.7 °C. The temperatures range from 15.5 °C to 33.5 °C and the standard deviation is 3.9 °C.

Temperature of laundry greywater is conspicuously high for one sample with the maximum temperature of 36.7 °C but there is also a very low temperature of 12.5°C. The mean temperature is 21 °C, the median 20 °C and the standard deviation is 4.9 °C.

The results for combined greywater samples are between 16 °C and 31°C. The mean is 19.4 °C, the median 18.3 °C and the standard deviation is 4.3 °C.

For source water the maximum temperature was 26.4 °C and the minimum 21.9 °C. The mean value is 24 °C, the median 23.4 °C and the standard deviation 2.2 °C.

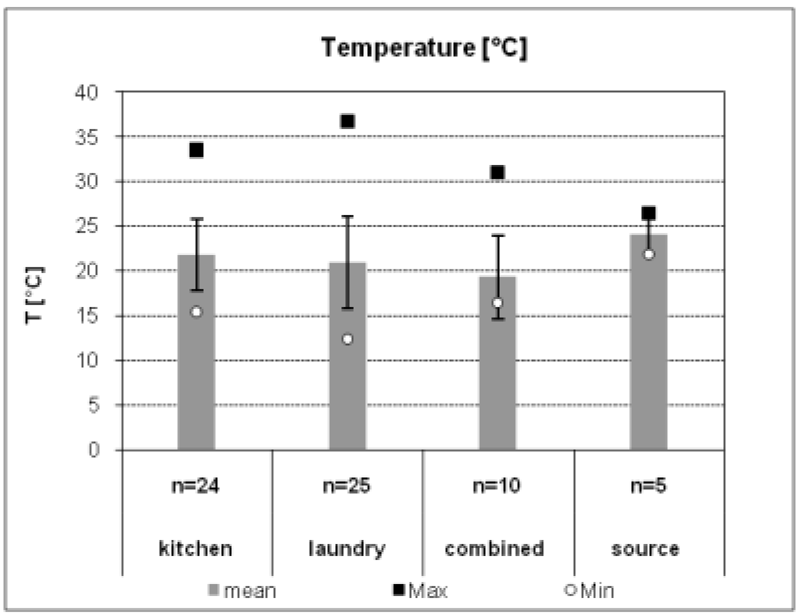

Figure 17: Average values, standard deviation, and minimum and maximum value of the temperature for different sources of greywater and source water

According to a previously published article (MOREL and DIENER, 2006), a higher temperature is expected in the greywater compared to the source water, as heated water is used for washing. From the results of this study it appears that the greywater means as well as the medians are all lower than the source water mean and median (table 6). That might be due to the fact that the water is normally stored in the house for some time before it is used as the water is not available every day. However there are also cases where the temperature reaches very high values over 30 °C and especially in kitchen and laundry greywater. This might be due to the fact that heated water was used for cleaning.

MOREL and DIENER (2006) refer to a temperature range between 18 to 30 °C which is not a problem if greywater is treated biologically. Nevertheless as stated by OTTOSSON (2003) higher temperatures can favour bacterial growth.

Table 6: Statistic values for temperature (°C) in greywater and source water

Sample	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	21.7	20.7	3.9	15.5	33.5
Laundry	25	21.0	20.0	4.9	12.5	36.7
Combined	10	19.4	18.3	4.3	16.0	31.0
Source water	5	24.0	23.4	2.2	21.9	26.4

4.2.3. pH

Figure 18 shows the pH of kitchen greywater with a minimum at pH 4.40 and a maximum of pH 9.9. The mean is a pH of 7.8, median pH 8.1 and the standard deviation is 1.7.

All results show an increased pH in the laundry greywater compared to the source water with a range from pH 7.3 to 10.1. The mean pH 9.1 is the highest compared to the other sources, the median is pH 9.4 and the standard deviation 0.8.

Like with kitchen water the pH in combined greywater was higher as well as lower than in the source water, the minimum of the combined greywater is pH 4.5 and the maximum is pH 8.7. The mean of combined is pH 7.1, the median pH 8.4 and standard deviation 1.5.

The mean pH in the source water is 7.1 with a minimum of 6.9 and a maximum of 7.3. The median is pH 7.0 and the standard deviation pH 0.2.

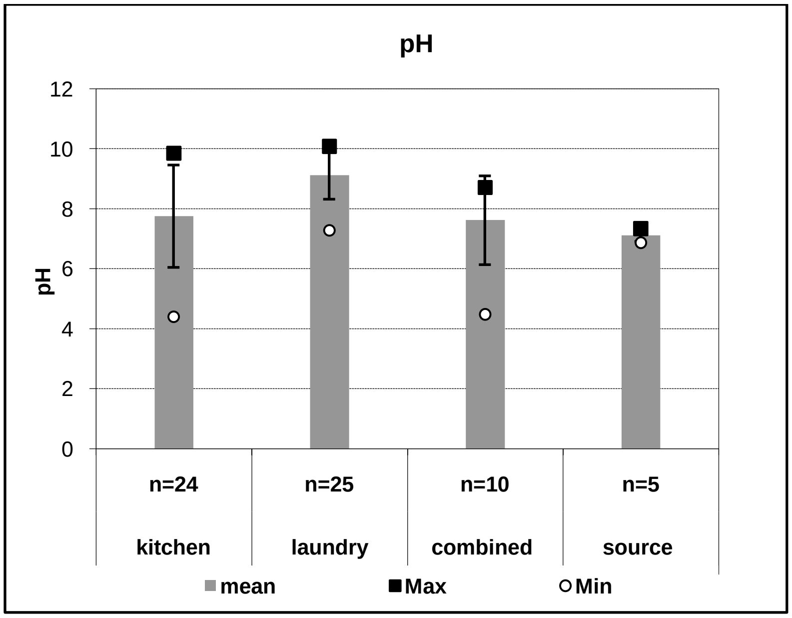

Figure 18: Average values, standard deviation, and minimum and maximum value of pH for different sources of greywater and source water

From results it is shown that the pH in kitchen as well as in combined greywater can be higher as well as lower than in the source water. As stated by MURPHY (2006) and also proved within this study the results of laundry greywater show an increased pH which is due to the used laundry detergents. Laundry greywater has a median of pH 9.4 while kitchen and combined greywater are more in the neutral range with a median of 8.1 for kitchen and 8.4 for combined. The source water might not be influencing the pH of the greywater as the results are always around pH 7 and hence neutral (table 7).

Compared to results found in literature (table 8) it is interesting to note that the pH for kitchen and combined greywater is lower and for laundry higher. The high alkalinity especially from laundry greywater (pH higher than 8.4) increases problems with foliar damage which can result in decreased yield or damage to fruit (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). However the results from this study are comparable with the literature results.

Table 7: Statistic values for pH in greywater and source water

	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	7.8	8.1	1.7	4.4	9.9
Laundry	25	9.1	9.4	0.8	7.3	10.1
combined	10	7.6	8.4	1.5	4.5	8.7
Source	5	7.1	7.0	0.2	6.9	7.3

Table 8: pH in greywater from different studies (CSBE, 2003)

Reference	Source	pH
Jeppesen & Solly (1994)	combined greywater	6.6 - 8.7
Christova – Boal et. al (1995)	Bathroom	6.4 – 8.1
Christova – Boal et. al (1995)	Laundry	6.3 – 9.5

To avoid negative effects on soil, plants, fruits and irrigation equipment should have a pH in range of 6. 5 – 8.0 as set by the WHO guidelines (Appendix: table 23). Soil pH is very important because it affects soil properties and plant growth in different ways like nutrient availability, elemental toxicity and microbial activity. The majority of micro-nutrients and heavy metals are unavailable for plant uptake at high soil pH and available at lower pH levels. Therefore they can be absorbed by crops and contaminate water bodies (WHO, 2006b).

Before a nutrient can be used by plants it must be dissolved in the soil solution. As it is shown in figure 19, plant nutrients generally show the highest availability in the pH range from 5.5 to 7. 0, which is also a good range for beneficial soil bacteria (CSBE, 2003). This figure also presents that nutrients such as nitrates, phosphates and potassium become less available to plants below a pH of 5. When the pH is 8 or higher, iron magnesium and zinc become less available to plants.

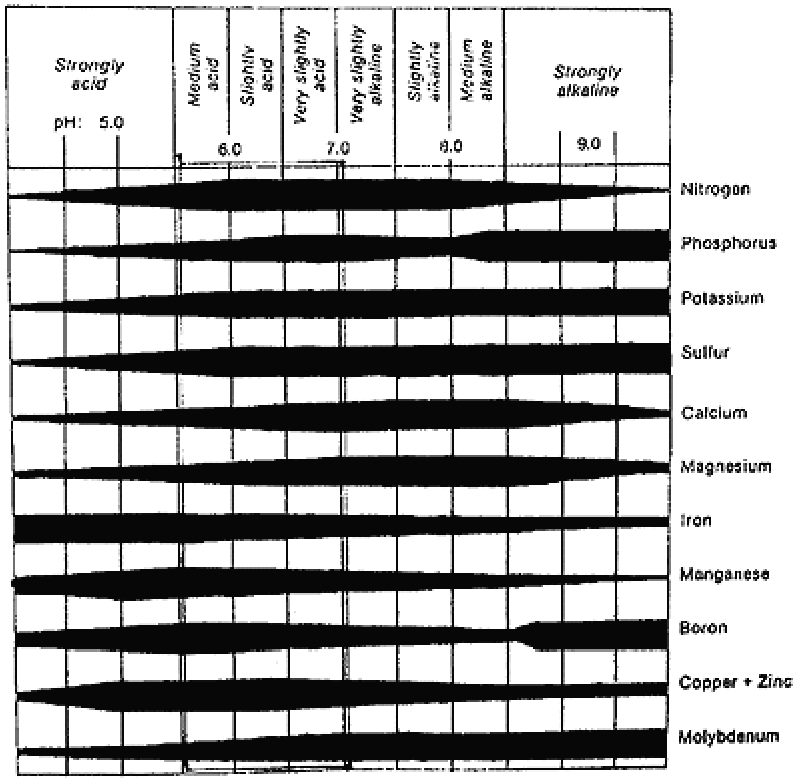

Figure 19: The effect of soil pH on availability of plant nutrients (SPRAGUE, 1964)

The majority of food crops prefer basic soil pH or slightly acidic. Some plants however prefer more acidic or alkaline conditions. Apart from extreme conditions irrigation greywater will change the soil pH only very slowly due to the fact that soil is much more strongly buffered against changes in pH than is water (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). The effects of pH on crops, soil and irrigation equipment are also shown in table 9.

Table 9: Effects of pH on Crop Yield and Quality, Sustainability of the Soil and Irrigation Equipment (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996)

pH Range	Crop Yield and Quality	Sustainability	Irrigation Equipment
< 6.5	Increasing problems with foliar damage when crop foliage is wet. This could give rise to yield reduction or a decrease in the quality of marketable materials	Increasing problems with the availability of several micro- and macro-nutrients in toxic concentrations are experienced in this range over the long term	Increasing problems with corrosion of metal and concrete in irrigation equipment are experienced in this range Practically no problems experienced with clogging of drip irrigation systems
Target Water Quality Range 6.5 - 8.4	***Even when crop foliage is wetted, this should not cause foliar damage in plants which will result in a yield reduction or a decrease in the quality of marketable products.***	***Soil pH within this range does not present major problems with either unavailability of plant nutrients or toxic levels of elements.***	***Mostly no major problem with either corrosion or encrustation of irrigation equipment is experienced within this range (see Total Hardness).*** ***Slight to moderate problems with the clogging of drip irrigation systems.***
> 8.4	Increasing problems with foliar damage affecting yield or decrease in visual quality of visual marketable products are experienced in this range.	Increasing problems with the unavailability of several micro- and macro-nutrients are experienced within this range over the long term.	Increasing problems with encrustation of irrigation pipes and clogging of drip irrigation systems are experienced in this range.

Mitigation of damages:

There is a possibility to treat the pH of greywater directly, although seldom used, an alkali or acid can be added to prevent soil, crops and irrigation material from damage (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). Another more common way is to correct the soil pH by adding lime when pH is acidic and sulphur or gypsum to correct a high soil pH (AYERS and WESTCOTT, 1994). The Department of Water Affairs and Forestry (1996) indicates that the negative effects of extreme pH are connected with damage due to wetting, hence foliar damage can be avoided by using a method of irrigation that will not allow greywater contact with leaves or fruits. Mitigation can also result from choosing the right crops or plants which are tolerant to the greywater pH used for irrigation. Furthermore one of the effective ways of mitigation is source control such as avoidance of very high pH detergents for washing laundry (MOREL and DIENER, 2006).

4.2.4. Dissolved oxygen

In almost all samples the amount of dissolved oxygen is lower in the kitchen greywater samples than the mean concentration of the source water (3.87 mg/l), but there are two samples where the amount of DO (7.50 mg/l and 6.78mg/l) is significantly higher. The minimum of 0.07 mg/l is represented by two samples. The mean concentration is 2.31 mg/l, the median 2.17 mg/l and the standard deviation 1.93 mg/l.

The amount of DO differs from sample to sample. In laundry greywater the concentrations of sample 14 (0.12 mg/l) and sample 15 with a minimum of 0.07 mg/l are extraordinary low. The samples have a concentration ranging from 0.07 mg/l to 8.20 mg/l while the mean concentration of 4.12 mg/l, a median of 3.98 mg/l and a standard deviation of 1.89 mg/l.

The minimum concentration is 0.08 mg/l and the maximum concentration 3.11 mg/l in the combined greywater. The mean for combined is 1,33 mg/l, the median 1,16 mg/l and the standard deviation is 1,24 mg/l.

The source water ranges from 3.47 mg/l to 4.87 mg/l with a mean of 3.87mg/l, a median of 3.50 mg/l and a standard deviation of 0.60 (figure 20) .

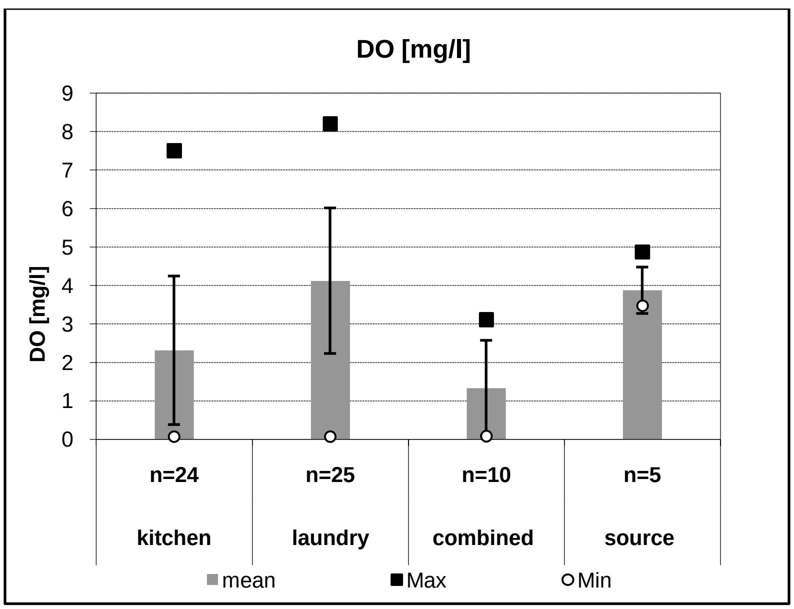

Figure 20: Average values, standard deviation, and minimum and maximum value of DO for different sources of greywater and source water

According to WHO (2006a) greywater contains at least 50 % of organic matter in household sewage however the results can be highly variable as they depend on the amounts of detergents as well as on the kind of oil and grease that is used for food preparation. When high amounts of organic matter enter a water body, algae growing will lead to eutrophication hence have a negative impact on aquatic organisms (WHO 2006a).

In Nakuru, almost all kitchen greywater samples show a lower amount of dissolved oxygen than the source water (3.87 mg/l). Comparing the means it is shown that laundry greywater has the highest amount of dissolved oxygen (4.12 mg/l) which is even higher than the source water mean. The combined greywater always has a lower mean concentration of dissolved oxygen than the source water (table 10).

Table 10: Statistic values for dissolved oxygen (mg/l) in greywater and source water

	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	2.31	2.17	1.93	0.07	7.50
Laundry	25	4.12	3.98	1.89	0.07	8.20
Combined	10	1.33	1.16	1.24	0.08	3.11
Source	5	3.87	3.50	0.60	3.47	4.87

4.2.5. Biological oxygen demand (BOD)

For the greywater samples the results for the first sampling are missing as at that time there were no BOD bottles available and therefore it was not possible to determine this parameter.

It appears that the concentration for BOD in all greywater samples mainly range from 400 to 500 mg/l. There is a maximum of 596 mg/l and a minimum of 340 mg/l in kitchen greywater. The mean is 456 mg/l, the median 445 mg/l and the standard deviation for BOD in kitchen greywater is 56 mg/l.

The highest concentration for laundry greywater is 600 mg/l is the while the minimum is 308 mg/l. The mean is 459 mg/l, the median 449 mg/l and the standard deviation 56 mg/l.

The minimum concentration for combined is 431 mg/l while the maximum is 501 mg/l. The mean concentration is 460 mg/l, the median is 455 mg/l and the standard deviation is 25.

The source water ranges from 7 mg/l to 14 mg/l. The mean for source water is 11 mg/l, the median is 13 mg/l and the standard deviation is 3 mg/l.

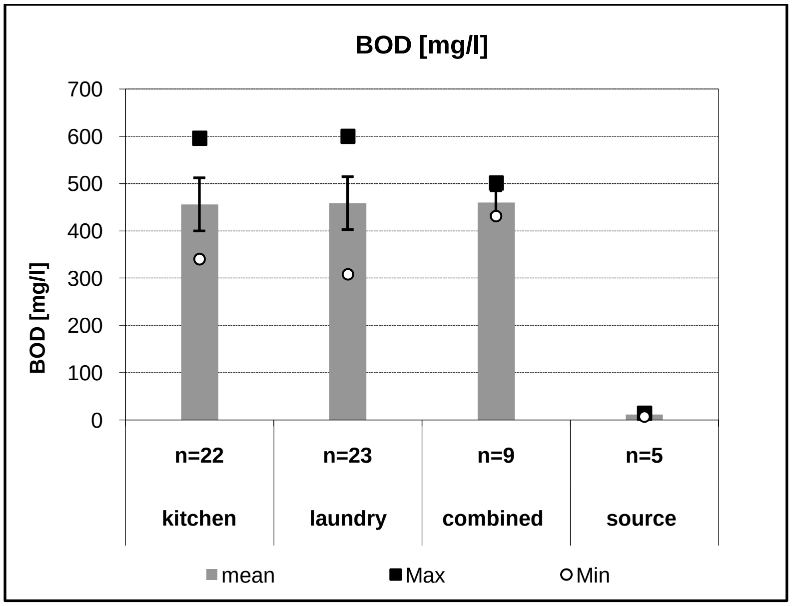

Figure 21: Average values, standard deviation, and minimum and maximum value of BOD for different sources of greywater and source water

It appears that the median concentration for BOD in kitchen, laundry and combined greywater does not differ from each other significantly (445-455 mg/l) as shown in table 11 below.

Compared to the results given in literature, (table 12) the BOD_5 in this study is higher than in the studies conducted in Costa Rica (167 mg/l), Israel (330 mg/l), Nepal (129 mg/l) and Malaysia (129 mg/l), however it is comparable to the results of Palestine (590 mg/l) and Jordan (275 – 2287 mg/l). This might be due to the fact that in Kenya a lot of detergents as well as cooking oil is used and therefore the organic content is high, hence the BOD values are also very high WHO (2006a). The BOD is also highly depending on the amount of water which is used hence if the water consumption is low the BOD results are high (MOREL and DIENER, 2006)

There might be doubts if the BOD results are comparable to the ones from literature because the methods for measuring the BOD cannot easily be compared. As mentioned in chapter material and methods, the BOD_5 was determined without any chemical inhibitor hence it might not be directly comparable to the results mentioned in literature. However it is also strange that the BOD values do not differ significantly from each other as all the other parameters do. This may mean that the method used does not get reliable results, which must be considered if this parameter is used for further studies.

As stated by the CSBE (2003), acceptable BOD_5 values differ from country to country and depend on intended use. In Jordan, for example, a BOD_5 concentration < 150 mg/l is allowed for the irrigation of trees and crops. However according to the WHO (2006b) irrigation water with a BOD_5 of 110 – 400 mg /l will raise the soil fertility and improve microbiological activity as a higher BOD concentration causes a higher anaerobic population in the soil and may clog soil pores.

Table 11: Statistic values for BOD (mg/l) in greywater and source water

	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	22	456	445	56	340	596
Laundry	23	459	449	56	308	600
Combined	9	460	455	25	431	501
Source	5	11	13	3	7	14

Table 12: Domestic greywater characteristics in different countries (MOREL and DIENER. 2006)

	Costa Rica [1]	*Palestine [2]*	*Israel [3]*	*Israel [4]*	*Nepal [5]*	*Malaysia [6]*	*Jordan [7]*
Q (l/p/d)	107	≈ 50	≈ 100	≈ 100	72	≈ 225	≈ 30
pH	–	6.7–8.35	6.5–8.2	6.3–7.0	–	–	6.7– >8.35
EC (µS/cm)	≈ 400	1585	1040–2721	1000–1300	–	–	475–1135
SAR	–	2.3–5.7	–	–	–	–	1.0–6.8
COD (mg/l)	–	1270	822	702–984	411	212	–
BOD (mg/l)	167	590	477	280–688	200	129	275–2287
COD/BOD	–	2.15	1.72	1.80	2.06	1.64	–
TSS (mg/l)	–	1396	330	85–285	98	76	316
TN (mg/l)	–	–	–	25–45	–	37	–
NH_4-N (mg/l)	–	3.8	1.6	0.1–0.5	13.3	13	–
TP (mg/l)	–	–	–	17–27	–	2.4	–
PO_4-P (mg/l)	16	4.4	126	–	3.1	–	–
Na^+ (mg/l)	–	87–248	199	–	–	–	–
MBAS (mg/l)	–	–	37	4.7–15.6	–	–	45–170
Boron (mg/l)	–	–	–	1.4–1.7	–	–	–
Faecal coli (cfu/100ml)	1.5–4.6 × 10^8	3.1 × 10^4	2.5 × 10^6	5 × 10^5	–	–	1.0 × 10^7
O&G (mg/l)	–	–	193	–	–	190	7–230

Note: These figures do not reflect national averages but relate to specific cases with specific settings. Type of water supply and living standards appear to be more decisive than the location.

1: Dallas et al. (2004); 2: Burnat and Mahmoud (2005); 3: Friedler (2004); 4: Gross et al. (2006a); 5: Shrestha et al. (2001); 6: Martin (2005); 7: Al-Jayyousi (2003), Faruqui and Al-Jayyousi (2002); Bino (2004).

4.2.6. Electrical conductivity, salinity and total dissolved solids (TDS)

TDS were not measured from the first sampling as the meter was not available; hence the first results are of sample number 12 for the greywater samples.

For kitchen greywater there are extremely high values for sample 13 (EC: 2308 µS/cm, salinity: 1.3 g/l, TDS: 1640 mg/l) and sample 16 where the EC (2712 µS/cm), salinity (1.6 g/l) and TDS (1994 mg/l) reach their maximum values. However it is interesting to note that there are also two cases (sample 2 and 11) where the values (EC: 320 µS/cm, salinity: not detectable and EC: 366 µS/cm, salinity: not detectable) are very low. The minimum of TDS is in sample 21 with a concentration of 393 mg/l as it was not possible to measure this parameter from sample 1 to 11. The mean is 1023 µS/cm for EC; the median is 974 µS/cm and the standard deviation 591 µS/cm. For salinity the mean is 0.45 g/l, the median 0.45 g/l and the standard deviation 0.41 g/l. The mean for TDS is 872 mg/l, the median 800 mg/l and the standard deviation 468 mg/l.

In laundry greywater samples 15 (EC: 4320 µS/cm, salinity: 2.9 g/l, TDS: 3422 mg/l) and 25 show extremely high EC, salinity and TDS values (EC: 5050 µS/cm, salinity: 2.9 g/l, TDS: 3470 mg/l). The minimum values are represented by sample 5 (EC: 431 µS/cm, salinity: 0.0 g/l) as there was no result for TDS, the minimum for this parameter is 387 mg/l (sample 16). The mean values are 1590 µS/cm for EC, for salinity 0.78 g/l and 1268 mg/l for TDS. The median is 1365 µS/cm for EC, for salinity 0.50 g/l and for TDS 993 mg/l. For EC the standard deviation is 1113 µS/cm, for salinity 0.73 g/l and for TDS 982 mg/l.

For combined greywater there are only six results for TDS. There are two cases where all three parameters are showing very high values, these are samples 7 (EC: 1792 µS/cm, salinity: 1.1 g/l and TDS: 1332 mg/l) and 8 (EC: 2780 µS/cm, salinity: 1.7 g/l and TDS: 2060 mg/l). The minimum values for EC and TDS are 863 µS/cm and 311 mg/l and for salinity it is 0.2 g/l. The mean EC is 1023 µS/cm, for salinity it is 0.69 g/l and for TDS 1083 mg/l. The median is 974 µS/cm for EC, 0.55 g/l for salinity and 981 mg/l for TDS. The standard deviation for EC is 591 µS/cm, for salinity it is 0.44 g/l and for TDS it is 582 mg/l.

All results show an increased concentration compared to the source water ranging from 303 µS/cm to 516 µS/cm for EC, the salinity is 0.20 g/l and the TDS values are between 204 mg/l and 328 mg/l. The mean is 387 µS/cm for EC, 0.20 g/l for salinity and 354 mg/l for the TDS. The median is 323 µS/cm for the EC, 0.20 g/l for salinity and for TDS 223 mg/l. The standard deviation is 103 µS/cm for the EC, for salinity it is zero and for TDS it is 58 mg/l.

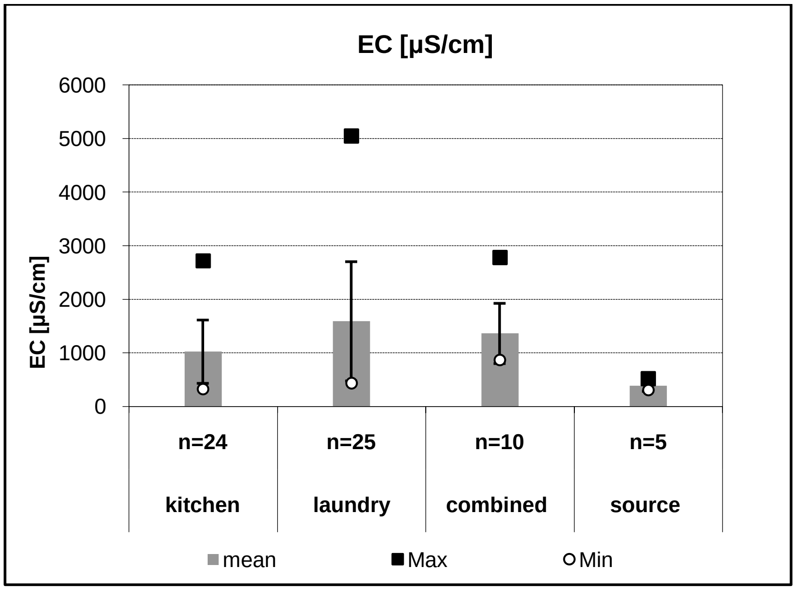

Figure 22: Average values, standard deviation, and minimum and maximum value of EC for different sources of greywater and source water

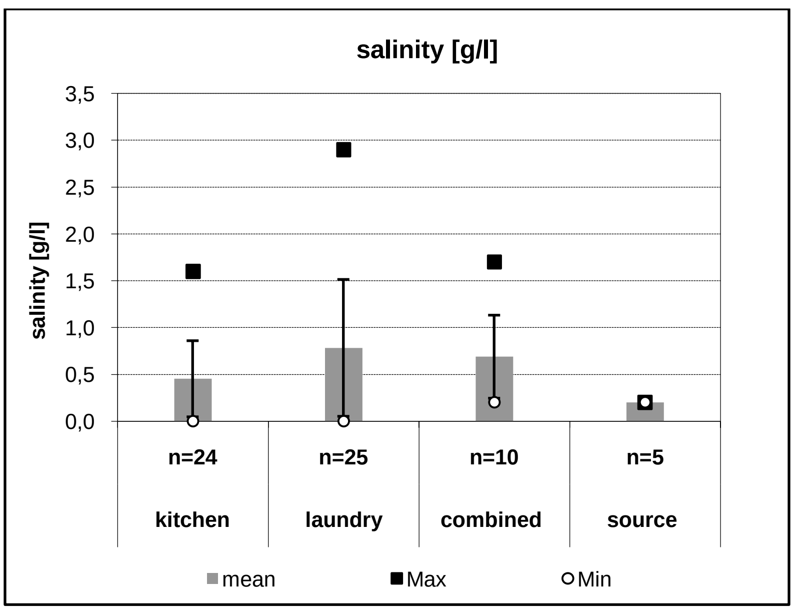

Figure 23: Average values, standard deviation, and minimum and maximum value of salinity for different sources of greywater and source water

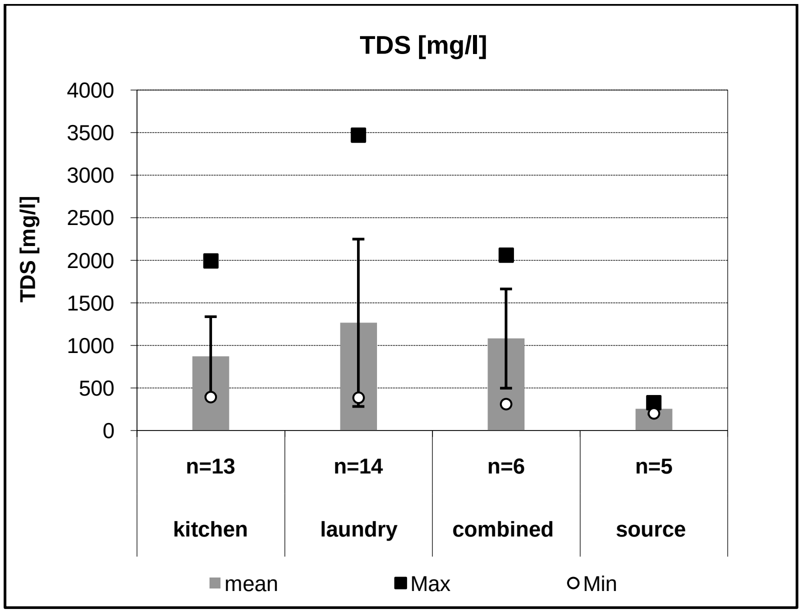

Figure 24: Average values, standard deviation, and minimum and maximum value of TDS for different sources of greywater and source water

Compared to the results from literature (table 12), the results in this study (table 13) are much higher for the extreme values especially in laundry greywater. This might be due to the used washing detergents since sodium based soaps and washing powder are the main source of high EC (MOREL and DIENER, 2006).

As stated by the DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1996), the problem of irrigation with high salinity water is that the salt content increases with the depth. As plants take in the water but leave most of the salts, the salt content is accumulating and leached deeper into the soil.

According to ANDERSON and CUMMINGS (1999) with an EC above 300 µS/cm care should be taken when the water is used for irrigation, especially when overhead sprinklers are used. From 800 – 2500 µS/cm it is necessary to have suitable soils, good drainage and salt tolerant plants. Above 2500 µS/cm it is not recommended to use this water for irrigation. However, water up to 6000 µS/cm can be used on very salt tolerant crops (Appendix: table 26).

Table 13: Statistic values for EC, salinity and TDS in greywater and source water

EC in µS/cm						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	1023	974	591	320	2717
Laundry	25	1590	1365	1113	431	5050
Combined	10	1363	1247	562	863	2780
Source	5	387	323	103	303	516
Salinity in g/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	0.45	0.45	0.41	not detectable	1.60
Laundry	25	0.78	0.50	0.73	not detectable	2.90
Combined	10	0.69	0.55	0.44	0.20	1.70
Source	5	0.20	0.20	0.00	0.20	0.20
TDS in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	13	872	800	468	393	1994
Laundry	14	1268	993	982	387	3470
Combined	6	1083	981	582	311	2060
Source	5	254	223	58	204	328

MOREL and DIENER (2006) determine that greywater irrigation with a typical 300–1.500 µS/cm EC, should not lead to yield loss if moderately sensitive crops are cultivated. Figure 25 shows the loss of crop yield as a function of the electrical conductivity.

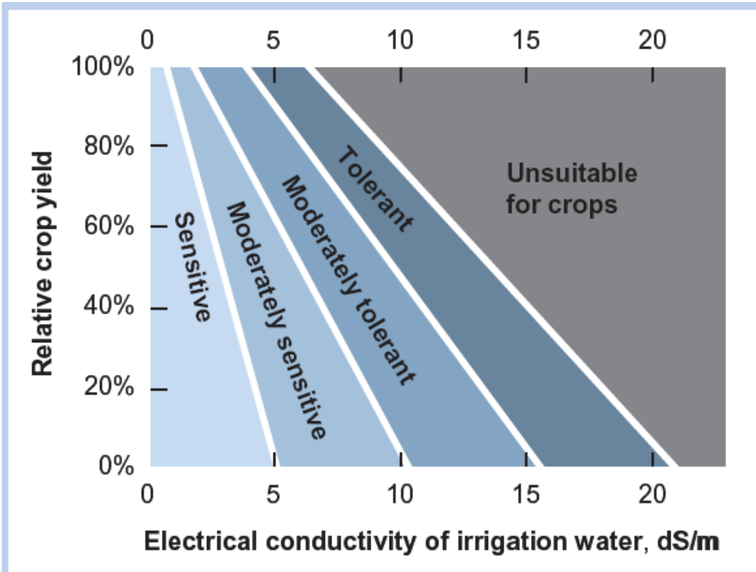

Figure 25: Loss in crop yield as a function of electrical conductivity (MOREL and DIENER 2006)

The WHO guidelines for excreta and greywater use in agriculture (WHO, 2006a) mention, problems with salinity for conductivities of higher than 3 dS/m (= 3000 µS/cm) depending on soil type as well as leaching and drainage conditions.

The restriction on use for EC by WHO guidelines for interpretation of water quality for irrigation (WHO, 2006b) is shown in Appendix table 23.

Another problem appears when salts are leached out from the soils and could reach aquifer or surface water. This will have a negative effect on the river ecosystem and on people using water downstreams (Appendix, table 25: Impact on groundwater and surface water bodies by different compounds). However, MURPHY (2006) argues that it is not worse to irrigate crops with greywater compared to directly discharge the treated wastewater into the rivers. This is because wastewater treatment plants are usually not able to eliminate highly soluble salts such as sodium and chlorides.

On a long term basis, greywater will always raise salinity of soil and groundwater due to the fact that it contains more salt than fresh water (WHO, 2006b). Hence it is necessary to control and mitigate salinisation.

<u>Mitigation:</u>

The negative effects of salinity can be eased in different ways. According to WHO (2006a) salinity is of concern especially in arid and semi-arid countries, where accumulated salts are not washed out from the soil by rain.

Therefore first of all it is important to irrigate plants frequently with enough water to ensure that salts are transported below the root zone (WHO, 2006b). This is called leaching. Secondly it is crucial to choose highly salt tolerant crops such as tomatoes and cabbage (MURPHY, 2006). Relative salt tolerance of various commercial crops at germination is shown in Appendix table 27. Thirdly appropriate soil drainages are very useful to alleviate salinity impacts particularly when water tables are high (U.S. EPA, 2004).

According to WHO (2006b) drainages are especially important in semi-arid areas, where irrigation takes place over a longer time. Drainages prevent water tables from rising and enable water surplus to run off from soil surfaces and root zones. As drainage water may contain environmental harmful matters the quality of the drainage water should be monitored (TANJI and KIELEN, 2002).

Probably the most effective solution to avoid salinisation is source control, such as decreasing salt inputs by environmental friendly soaps and washing powder with less sodium and chlorides. According to MURPHY (2006), 38% of the sodium concentration in domestic wastewater could be cut down at no costs by changing laundry products.

4.2.7. Total suspended solids (TSS), organic and inorganic content

The results for total suspended solids (TSS) as well as organic and inorganic content from the sampled greywater are shown on the following graphs. There are results missing for organic and inorganic content as the furnace used for ashing the filters was not working during that time.

For kitchen greywater the results for TSS, organic and inorganic content resemble each other with a very high concentration for one sample (TSS: 6350 mg/l, organic content: 6040 mg/l, inorganic content: 310 mg/l). In general the organic content is much higher in all greywater samples than the inorganic content which has its maximum for kitchen at 460 mg/l. The minimum is 255 mg/l for TSS, 215 mg/l for organic content and 5 mg/l for inorganic content. Mean values are 1871 mg/l for TSS, 1828 mg/l for organic content and 115 mg/l for inorganic content. The median is for TSS 1255 mg/l, 1200 mg/l for organic content and 80 mg/l for inorganic content. The standard deviation for TSS is 1737 mg/l, 1757 mg/l for organic content and 123 mg/l for inorganic content.

Also for laundry the concentrations for TSS, organic content and inorganic content are similar to each other with high concentrations for sample number 6 (TSS: 4420 mg/l, org.content: 3420 mg/l and inorg. content: 1000mg/l) and number 25 (TSS: 4500 mg/l, org.content: 3060 mg/l and inorg. content: 1440mg/l). For sample number 15 the inorganic content reaches its maximum of 1720 mg/l. The lowest concentrations for TSS and inorganic content are in sample number 16 (TSS: 350 mg/l, inorganic content: 20 mg/l) while for organic content it is sample number 19 with a concentration of 320 mg/l. The mean values for laundry greywater are 1541 mg/l (TSS), 1218 mg/l (organic content) and 422 mg/l (inorganic content). The median is 1090 mg/l for TSS, 870 mg/l for organic content and 260 mg/l for inorganic content. Standard deviation is for TSS 1256 mg/l, 944 mg/l for organic content and 450 mg/l for inorganic content.

In the combined, there are extraordinarily high concentrations of the three parameters for sample 7 (TSS: 2170mg/l, organic content 1450 mg/l and inorganic content 720mg/l). However the TSS reaches its maximum value of 2690 mg/l in sample number 3. Unfortunately there are no results for organic and inorganic content for this sample. The minimum for combined is represented by sample 9 (TSS: 610 mg/l, organic content; 520 mg/l, inorganic content: 90 mg/l). The mean is 1124 mg/l for TSS, for organic content 738 mg/l and for inorganic content 273 mg/l. The median is for TSS 775 mg/l, 545 mg/l for organic content and 220 mg/l for inorganic content. The standard deviation is 719 mg/l for TSS, 342 mg/l for organic content and 227 mg/l for inorganic content.

For the source water the TSS ranges from a minimum of 1.2 mg/l (sample 4) to 4.8 mg/l (sample 1). The organic content is also high for sample 1 whereas the inorganic content reaches its maximum of 0.4 mg/l in samples 3 and 5. Mean concentrations are 2.4 mg/l (TSS), 2.2 mg/l (organic content) and not detectable for inorganic content. The median is 2.0 mg/l for TSS, 1.60 mg/l for organic content and not detectable. The standard deviations are 1.4 mg/l (TSS), 1.5 mg/l (organic content) and not detectable for inorganic content.

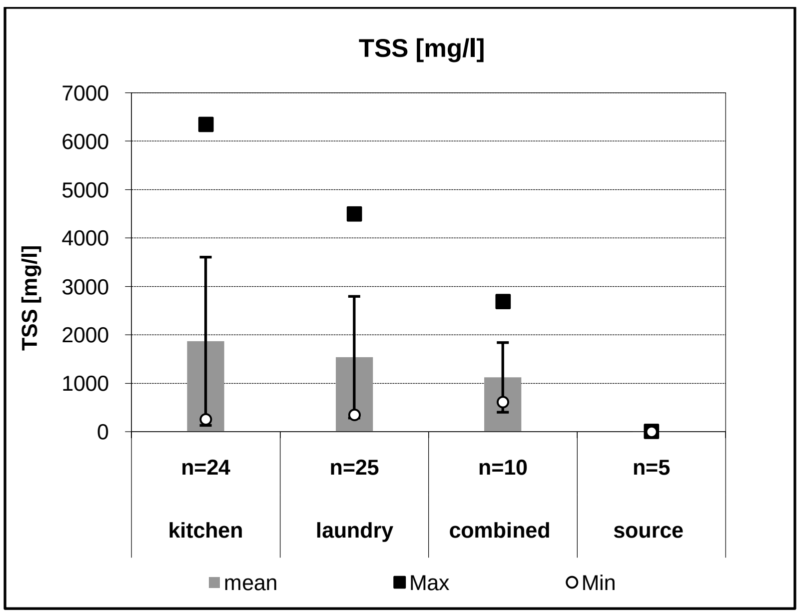

Figure 26: Average values, standard deviation, and minimum and maximum value of TSS for different sources of greywater and source water

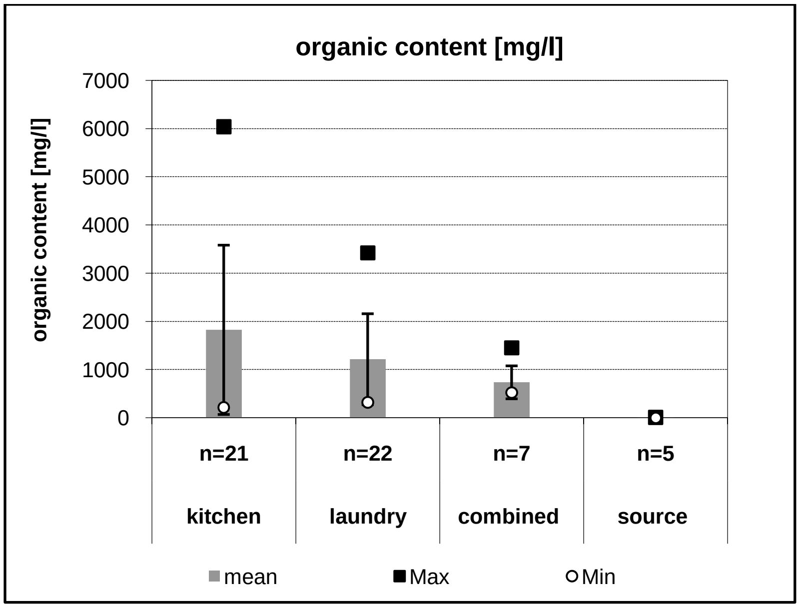

Figure 27: Average values, standard deviation, and minimum and maximum value of organic content for different sources of greywater and source water

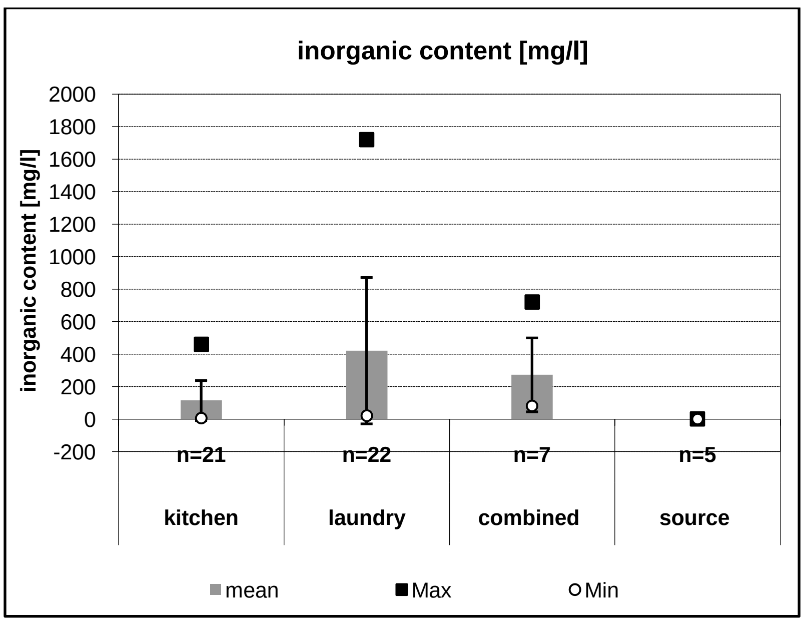

Figure 28: Average values, standard deviation, and minimum and maximum value of inorganic content for different sources of greywater and source water

As stated by WHO (2006b), colloidal and suspended organic matter have a positive effect on moisture and nutrients content as they improve soil structure. Furthermore they bind heavy metals in the soil. Nevertheless as already mentioned in context with the BOD, if the organic content is too high, an anaerobic condition may occur, which, if combined with nitrogen, may cause nitrogen loss due to denitrification.

According to the DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1996), the suspended solids are clogging the treatment system as well as the soil, which may not allow water to infiltrate well enough for seedlings to emerge. An analysis in Oman showed a TSS of 353 mg/l, 505 mg/l and 315mg/l for shower, sink and laundry greywater (PRATHAPAR et al., 2005). According to MOREL and DIENER (2006), suspended solids range from 50-300 mg/l but can be as high as 1500 mg/l, highly dependent on water volumes which are used for washing.

The results of this study are shown in the table 14 below. It is interesting to notice that independently from the source, all greywater samples show a higher amount of organic content compared to the amount of inorganic content. However, the highest amount of TSS and organic content is found in kitchen greywater while the maximum of inorganic content is in laundry greywater. Compared to the results of other publications, the concentrations are very high, which might be due to the lower amount of water used for washing.

Table 14: Statistic values for TSS, organic and inorganic content

TSS in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	1871	1255	1737	255	6350
Laundry	25	1541	1090	1256	350	4500
Combined	10	1124	775	719	610	2690
Source	5	2.4	2.0	1.4	1.2	4.8
Organic content in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	21	1828	1200	1757	215	6040
Laundry	22	1218	870	944	320	3420
Combined	7	738	545	342	520	1450
Source	5	2.2	1.6	1.5	1.2	4.8

Inorganic content in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	21	115	80	123	5	460
Laundry	22	422	260	450	20	1720
Combined	7	273	220	227	80	720
Source	5	not detectable	not detectable	not detectable	not detectable	0.40

4.2.8. Total phosphorus (TP) and soluble reactive phosphorus (SRP)

In kitchen greywater there are especially high results for sample 13 (TP: 23.12 mg/l, SRP: 15.50 mg/l) and sample 16 (TP: 24.92 mg/l, SRP: 18.95 mg/l). However it is also interesting to note that there are cases with very low results like for sample number 4 (TP: 2.00 mg/l, SRP: 0.16 mg/l) and 21 (TP: 0.83 mg/l, SRP: 0.17 mg/l). Mean concentrations are 9.18 mg/l for TP and 4.34 mg/l for SRP. The median is 7.59 mg/l for TP and 3.28 mg/l for SRP. The standard division is 6.46 mg/l for TP and 4.58 mg/l for SRP.

For laundry the results for TP and SRP are similar to each other with high concentrations for sample number 11 (TP: 30.19 mg/l, SRP: 12.40 mg/l) and 13 (TP: 22.74 mg/l, SRP: 10.51mg/l). The minimum for TP is 1.62 mg/l and for SRP it is 0.50 mg/l. Mean value is 9.94 mg/l for TP and 3.79 mg/l for SRP. The median is 9.02 mg/l for TP and 2.77 mg/l for SRP. The standard deviation is 7.92 mg/l for TP and 3.16 mg/l for SRP.

In the combined greywater the TP concentrations range from 2.60 to 25.18 mg/l and for SRP from 0.57 to 16.53 mg/l. For sample 8 especially high results (TP: 25.18 mg/l and SRP: 16.53 mg/l) are shown in the graphs above. The minimum for both parameters is represented by sample number 10 (TP: 2.60 mg/l and SRP: 1.05 mg/l). Mean values are 9.80 mg/l for TP and 5.64 mg/l for SRP, the median is 8.28 mg for TP and 4.96 mg/l in combined greywater. The standard deviation is 6.05 mg/l (TP) and 4.27 mg/l (SRP).

The concentration of source water is lower than in the greywater samples for both parameters with a range from 0.03 to 0.04 mg/l (TP) and 0.05 to 0.07 mg/l (SRP). The mean for TP is 0.038 mg/l and for SRP 0.06 mg/l, the median is 0.04 mg/l for TP and also 0.05 for SRP. The standard deviation is 0.004 mg/l for TP and 0.01 mg/l for SRP.

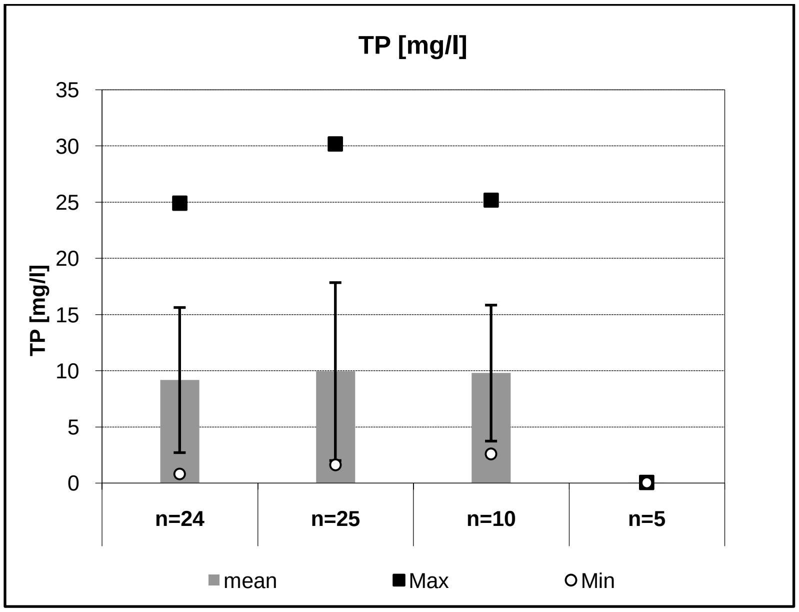

Figure 29: Average values, standard deviation, and minimum and maximum value of TP for different sources of greywater and source water

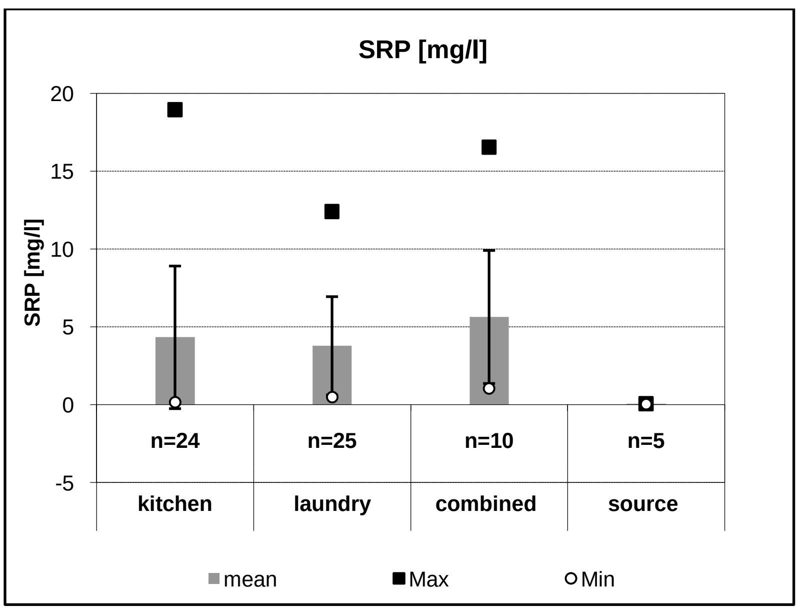

Figure 30: Average values, standard deviation, and minimum and maximum value of SRP for different sources of greywater and source water

As all nutrients analysis were carried out by the Standard Methods for the Examination of Water and Wastewater (APHA, 1995) these results should be mainly comparable to the results from literature. However in general it is difficult to get detailed information in literature about the exact methods used for determining the parameter.

The main sources for phosphorus in greywater are laundry detergents (WHO, 2006c). According to MOREL and DIENER (2006), greywater contains up to two third of the phosphorus load compared to the total loads in domestic wastewater, where phosphate containing detergents are used. As it appears from results in Nakuru Municipality that the median concentrations for total phosphorous is higher for laundry greywater (TP: 9.02 mg/l) than for the other greywater sources. Nevertheless also the median concentrations for combined (TP: 8.28 mg/l and SRP: 4.96 mg/l) and kitchen (TP: 7.59 mg/l. SRP: 3.28 mg/l) greywater show very high results (table 15). The results from different literature show similar high concentrations for TP (table 16).

High phosphorus levels generally are no problem for plants (US.EPA, 2004). However, phosphorus is bound to soil and therefore may accumulate especially near the soil surface where it might be easily washed in aquatic environments due to runoff and soil erosion (WHO, 2006b). In aquatic environment, phosphorus leads to eutrophication, algae growth and oxygen depletion (MURPHY, 2006).

Table 15: Statistic values for TP and SRP in greywater and source water

TP in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	9.18	7.59	6.46	0.83	24.92
Laundry	25	9.94	9.02	7.92	1.62	30.19
Combined	10	9.80	8.28	6.05	2.60	25.18
Source	5	0.038	0.04	0.005	0.03	0.04
SRP in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	4.34	3.28	4.58	0.16	18.95
Laundry	25	3.79	2.77	3.16	0.50	12.40
Combined	10	5.64	4.96	4.27	1.05	16.53
Source	5	0.06	0.05	0.01	0.05	0.07

Table 16: Concentration of TP in greywater from different studies

Reference	Source	TP [mg/l]
Murphy (2006)	Kitchen	0.36 – 13.1
Christova – Boal et. al (1995)	Laundry	0.06 – 42
Jeppersen and Solley (1994)	Combined	0.6 – 27.3

4.2.9. Ammonium-nitrogen (NH_4-N)

In kitchen greywater especially high concentrations for ammonium-nitrogen are shown for sample number 16 (11.98 mg/l) and 18 (12.03 mg/l) and very low results for samples 2 (0.11mg/l) and 4 (0.15 mg/l).The mean concentration is 3.54 mg/l, the median is 2.13 mg/l and the standard deviation is 3.55 mg/l.

The ammonium-nitrogen results for laundry greywater range from 0.31 mg/l to 33.13 mg/l. Remarkably high concentrations are shown in sample number 6 (33.13 mg/l) and very low results are presented for sample 2 (0.31 mg/l), 14 (0.48 mg/l) and 19 (0.41 mg/l). Laundry samples show a mean concentration of 6.75 mg/l a median of 5.29 mg/l and a standard deviation of 7.09 mg/l.

For combined greywater the concentrations are in a range from 0.41 to 36.52 mg/l. Especially high concentrations are shown for sample number 3 (36.52 mg/l) and sample 8 (27.16 mg/l) while very low results are represented by sample 10 (0.41 mg/l). The mean concentration is 11.58 mg/l, the median is 7.32 mg/l and the standard deviation is 11.42 mg/l.

There is almost no ammonium-nitrogen detectable as the maximum concentration of ammonium-nitrogen in the source water sample is 0.01 mg/l. For all other samples the amount is under the detection limit and hence cannot be determined.

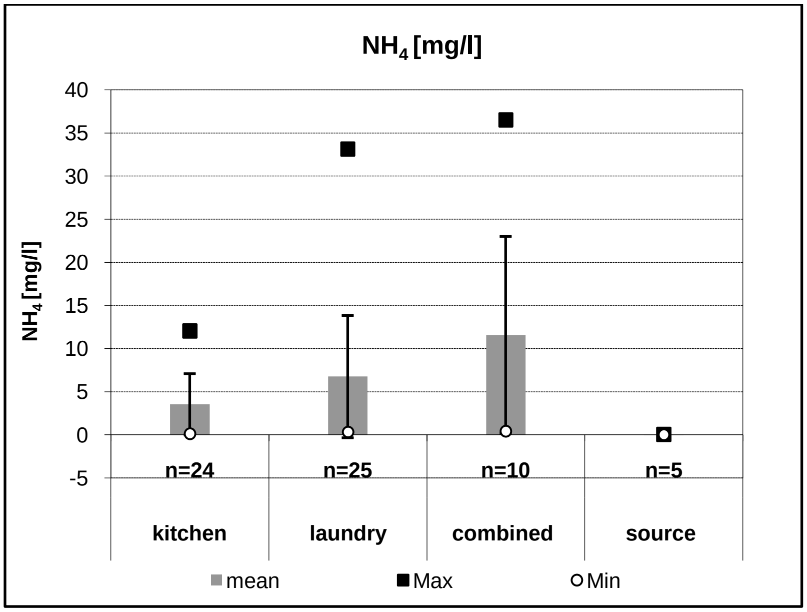

Figure 31: Average values, standard deviation, and minimum and maximum value of NH_4-N for different sources of greywater and source water

4.2.10. Nitrate-nitrogen (NO_3-N)

In the kitchen greywater nitrate-nitrogen is especially high for sample 5 (17.20 mg/l) but there are also extremely low values of 0.48 mg/l (sample 1) and 0.65 mg/l (sample 2). The mean concentration is 5.10 mg/l, the median is 3.68 mg/l and the standard deviation is 4.31 mg/l.

The results for laundry range from 0.14 mg/l to 24.03 mg/l (sample 15). The lowest concentrations are 0.14 mg/l (sample 10), 0.41 mg/l (sample 1) and 0.58 mg/l for sample 5. The mean concentration is 3.96 mg/l, the median is 2.44 mg/l and the standard deviation is 5.05 mg/l.

The combined greywater has a maximum of 16.53 mg/l and a minimum concentration of 0.27 mg/l. Mean concentration is 3.80 mg/l, the median is 1.97 mg/l and the standard deviation is 4.96 mg/l.

It is interesting that even the concentration of the source water range from 2.98 to 4.70 mg/l, with a mean concentration of 3.76 mg/l, a median of 3.49 mg/l and a standard deviation of 0.76 mg/l.

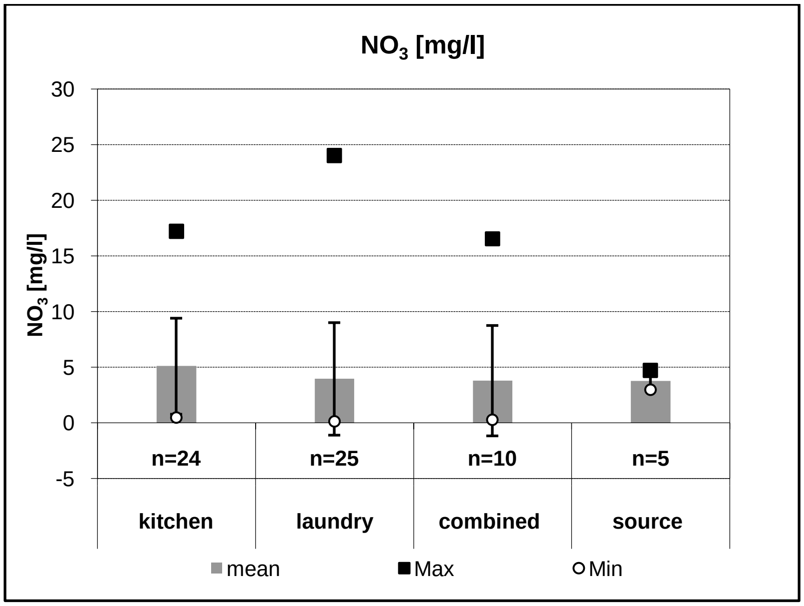

Figure 32: Average values, standard deviation, and minimum and maximum value of NO_3-N for different sources of greywater and source water

4.2.11. Nitrite-nitrogen (NO_2-N)

For sample 5 in kitchen greywater there is one extraordinary high value of 54.88 mg/l for nitrite-nitrogen while all other results range from 0.20 mg/l (sample 1) to 12.93 mg/l (sample 12). The mean concentration is 5.59 mg/l, the median is 2.63 mg/l and the standard deviation is 11 mg/l.

For laundry greywater the nitrite-nitrogen concentration has a minimum of 0.75 mg/l in sample 10 and very high results for samples 23 (34.34 mg/l) and 13 (32.10 mg/l). The mean concentration for the samples is 11.10 mg/l, the median is 8.61 mg/l and the standard deviation is 9.25 mg/l.

In combined water samples there are high values for samples 4 (10.25 mg/l), 5 (14.15 mg/l) and 9 (12.72 mg/l). The minimum is 0.54 mg/l and found in sample 7. The mean concentration is 5.36 mg/l, the median 2.71 mg/l and the standard deviation is 5.09 mg/l.

There is a maximum of 0.01 mg/l nitrite-nitrogen in the source water sample for sample 5, for all other samples the concentration is under the detection limit.

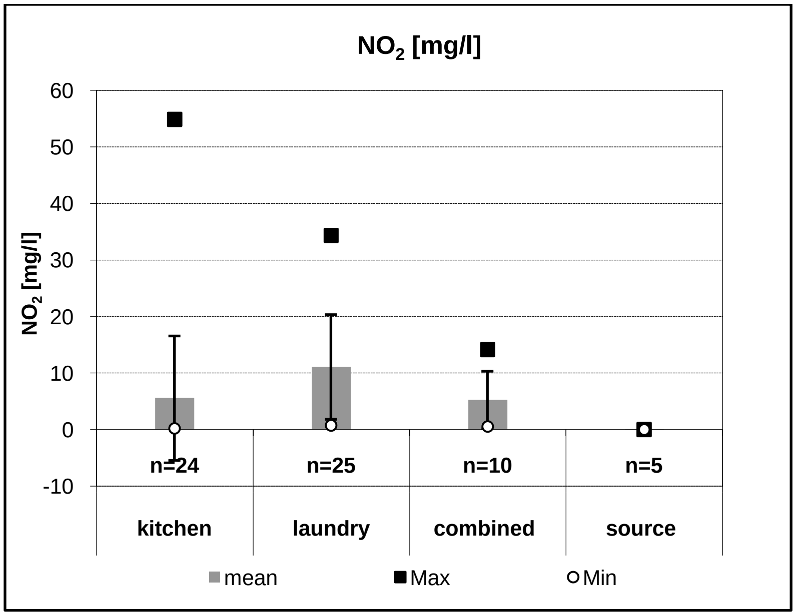

Figure 33: Average values, standard deviation, and minimum and maximum value of NO_2-N for different sources of greywater and source water

If the results for ammonium-nitrogen, nitrate-nitrogen and nitrite-nitrogen from this study are compared with the results from literature it appears that the greywater samples from Nakuru are mainly higher concentrated (table 17).

Comparing the median concentrations for ammonium-nitrogen in kitchen (2.13 mg/l), laundry (5.29 mg/l) and combined greywater they are in the range given in the literature (table 18). Higher values are shown for the median concentration of nitrate-nitrogen and nitrite nitrogen (table 17). Especially for nitrate-nitrogen this is due to high concentrations in source water as the median of source water is already tenfold higher than the maximum given for greywater samples in literature. Furthermore as nitrogen in greywater results from household products and from food proteins (MOREL and DIENER, 2006) this might also be a reason for the increased values compared to results of other publications.

High concentrations of nitrogen may cause negative effects on crop yield and quality as well as on ground- and surface water (Appendix table 25). Furthermore nitrates are stable in groundwater and can build up to concentrations that might contribute to methaemoglobinaemia (blue-baby syndrome) in bottled-fed infants if this water is used to prepare baby food (WHO, 2004). Also phosphorus nitrogen can end up in aquatic environments where it stimulates algae and aquatic plant growth (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996).

Nevertheless according to US.EPA (2004) nitrogen is the most beneficial nutrient for plant growth. If greywater contains high nitrogen concentration like shown in this study, it is possible to dilute it and to use it only for irrigation during the first stage of growth, when crop demands high amounts of nitrogen or for plants with higher nitrogen demand (DEPARTMENT OF WATER AND FORESTRY, 1996).

To prevent leaching and groundwater contamination it is important to use soil drainage and to monitor the drainage water (TANJI and KIELEN, 2002). Further control measures for high nitrogen levels stated by the WHO (2006b) are shown in Appendix table 28.

Table 17: Statistic values for ammonium-nitrogen, nitrate-nitrogen and nitrite-nitrogen

NH_4 in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	3.54	2.13	3.55	0.11	12.03
Laundry	25	6.75	5.29	7.09	0.31	33.13
Combined	10	11.58	7.32	11.42	0.41	36.52
Source	5	not detectable	not detectable	not detectable	not detectable	0.01
NO_3 in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	5.10	3.68	4.31	0.48	17.20
Laundry	25	3.96	2.44	5.05	0.14	24.03
Combined	10	3.80	1.97	4.96	0.27	16.53
Source	5	3.76	3.49	0.76	2.98	4.70
NO_2 in mg/l						
	Number of samples	Mean	Median	Std.Deviation	Minimum	Maximum
Kitchen	24	5.59	2.63	11.00	0.20	54.88
Laundry	25	11.10	8.61	9.25	0.75	34.34
Combined	10	5.26	2.71	5.09	0.54	14.15
Source	5	not detectable	not detectable	not detectable	not detectable	0.01

Table 18: Concentration of ammonium-nitrogen, nitrate-nitrogen and nitrite-nitrogen in greywater from different studies

Reference	source	NH_4-N [mg/l]	NO_3-N [mg/l]	NO_2-N [mg/l]
Murphy (2006)	kitchen	0.3 – 3.0	-	< 0.1- 0.8
Christova – Boal et. al (1995)	laundry	< 0.1 – 1.9	0.10 - 0.31	-
Jeppersen and Solley (1994)	combined	< 0.1 – 25.4	< 0.1 – 0.35	-

4.2.12. Faecal coliforms

For the first four samples there are no results for faecal coliforms of all greywater sources since in the beginning of the sampling period there was no membrane filtration unit available.

The log numbers for faecal coliforms per 100ml kitchen greywater sample are all ranging from 6.08 (sample 24) to 8.18 (sample 19) log number/100ml. The mean concentration is 6.95 log number/100ml, the median 7.05 log number/100ml with a standard deviation of 0.63 log number/100ml.

The concentration for faecal coliforms in laundry greywater samples range from the minimum of 4.54 log number/100ml (sample 12) to the maximum of 7.12 log number/ 100ml (sample 2). The mean concentration is 5.57 log number/100ml, the median is 5.49 log number /100ml and the standard deviation is 0.72 log number/100ml.

In combined greywater the concentration range from 6 to 7.46 log number/100ml, there is a maximum of 8.63 log number/100ml represented by sample 7 and a minimum of 6.25 log number/100ml by sample 5. The mean concentration is 7.03 log number/100ml and the median 7.04 log number/100ml with a standard deviation of 0.72 log number/100ml.

The maximum concentration of the source water sample is 4.41 log number/100ml (sample 5) while the minimum is zero (sample 4). The mean concentration of faecal coliforms in source water is 1.15 log number/100ml, the median 1.19 log number/100ml and the standard deviation 1.03 log number/100ml.

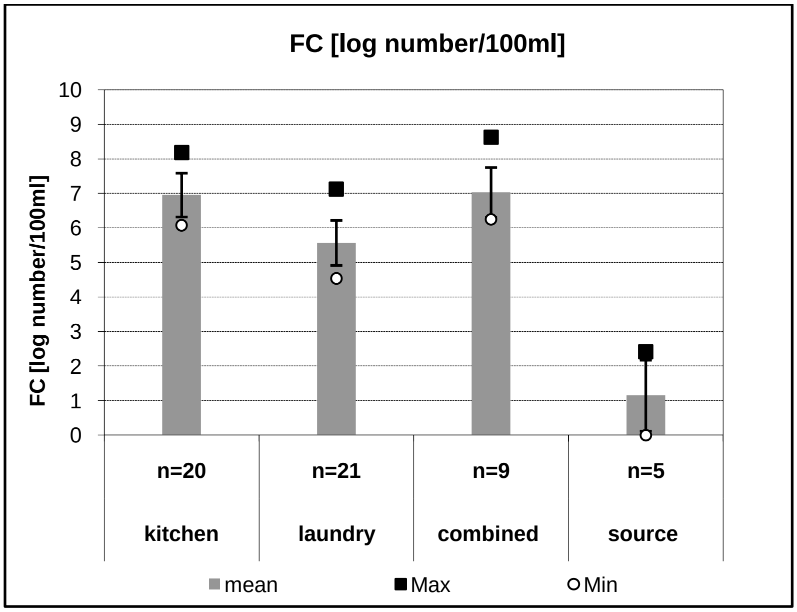

Figure 34: Average values, standard deviation, and minimum and maximum value of FC for different sources of greywater and source water

The risk of getting ill from pathogens is correlated to the concentrations of faecal coliforms in greywater, hence the higher the amount of pathogens in the samples the higher the health risk (DEPARTMENT OF WATER AND FORESTRY, 1996).

The results for faecal coliform concentrations in the greywater samples from Nakuru Municipality are shown in the table 19 below. The median concentration for faecal coliforms in greywater is high for all greywater sources. Combined has the highest concentration of 7.04 log number/100ml followed by kitchen greywater with a concentration of 7.05 log numbers/100ml and laundry greywater with 5.49 log numbers/ 100ml.

It is important to note that there is already a median concentration of 1.19 log number/100ml in the source water sample. Compared to the results from literature (table 20) the results of this study show higher concentrations of faecal coliforms.

The microbiological analysis has been carried out according to the Manual of Parasitological and Bacteriological Techniques (WHO, 1996). Therefore the results should be comparable to the ones published by the WHO (2006a). However there is always a problem as there are no indications about the method used for determining the amount of faecal coliforms. Nevertheless the membrane filtration method might not be the ideal solution for determining FC as it is very sensitive to contaminations during the analysis.

MURPHY (2006) compares concentrations of faecal coliforms in sewage and greywater. His results indicate that kitchen greywater has concentrations of faecal coliforms in the range of raw sewage (5 to 7 log number/100ml) while greywater from other sources has concentrations closer to secondarily treated wastewater (5.3 log number/100ml).

If this is compared with the results from table 19 it becomes clear that the concentrations for FC in all greywater sources are in the range of raw sewage. The results for kitchen and combined greywater are especially high hence these sources may require stricter controls if used in irrigation where human contact is not excluded (MURPHY, 2006).

According to MOREL and DIENER (2006) faecal contaminations are high in households with young children or babies due to contamination through nappies washing and child care. Another possibility of faecal contamination is due to contaminated food via the kitchen sink (OTTOSSON, 2003) and due to showering and anal cleansing (WHO, 2006a).

However, another source might be already contaminated source water. According to this study the mean concentration for faecal coliforms in source water was 1.1 log number/ 100ml with a maximum of 2.41 log number/ 100 ml in a freshwater storage container. In all the sampled households, water access is limited. The source water is stored for a long time which might be the reason for the high FC concentration.

According to OTTOSSON and STENSTROM (2003), the high concentrations of FC result from greywater containing a high amount of easily degradable organic compounds; hence the regrowth rate is very high for E.coli and other coliforms. Therefore these numbers may lead to an overestimation of faecal loads and the corresponding risks.

The WHO (2006a) also suggests that E.coli guideline values for wastewater should be applied carefully for greywater because of the high regrowth rate. However, if applied they will give a level of additional safety. For unrestricted irrigation an E.coli value of $<10^3$ per 100ml is suggested by the WHO (2006a).

Health impacts (DEPARTMENT OF WATER AND FORESTRY, 1996):

When greywater is used for irrigation pathogens may contaminate vegetables or fruit, this is mostly of concern when products are eaten raw. Pathogens may cause different diseases such as cholera (Vibrio cholera), thyphoid fever (Salmonella typhi), salmonollosis (Salmonella sp.) and bacillary dysentery (Shigella sp.). Also viruses can cause health problems as gastroenteroitis, hepatitis, poliomyelitis and respiratory illness. Additionally there is the risk due to intestinal nematodes and protozoan parasites like Giardia sp. which untreated greywater may include.

According the DEPARTMENT OF WATER AND FORESTRY (1996), these health impacts can be mitigated by using greywater only for irrigating crops that are not eaten raw, by an irrigation method where the water has no direct contact to crops and or by maximizing the time between the last irrigation and the harvesting.

As stated by WHO (2006a), deactivation of pathogens is faster in hot or sunny regions. Furthermore it is more rapid on the surface of crops and in the soil than in stored greywater.

Table 19: FC concentration in log number/100ml from different greywater sources and source water

	Number of samples	Mean	Median	Std. Deviation	Minimum	Maximum
Kitchen	20	6.95	7.05	0.63	6.08	8.18
Laundry	21	5.57	5.49	0.65	4.54	7.12
Combined	9	7.03	7.04	0.72	6.25	8.63
Source	5	1.15	1.19	1.03	0.00	2.41

Table 20: Concentrations from different parameters in greywater (WHO, 2006a)

Country/reference	Parameters							
	BOD_5 (mg/l)	COD (mg/l)	Suspended solids (mg/l)	Total N (mg/l)	NH_4 (mg/l)	Kjeldahl N (mg/l)	Total P (mg/l)	Faecal coliforms (log numbers/ 100 ml)
Canada / Brandes (1978)	149	366	162	11.5	1.7	11.3	1.4[a]	6.2
Norway / Kristiansen & Skaarer (1979)	130	341	35	19	11.5		1.3 (0.42[b])	5.1
USA[c] / Siegrist & Boyle (1981)	178	456	45			15.9	4.4	6.2
Sweden norm / Naturvårds-verket (1995)	187		107	6.7			4 (1.0[b])	
Norway[c] / Rasmussen, Jenssen & Westlie (1996)	116		39	42.2	36.1		3.97	
Australia / Department of Health (2002)	160		115		5.3	12	8	5.2
Norway[c] / Jenssen (2001)	88	277	–	8.8	3.8	4.9	1.0[b]	4–6
Sweden proposed norm / Vinnerås et al. (2006)	260[c]	520		13.6			5.2	
Germany / Li et al. (2004)	73–142			8.7–13.1	2.5		6.8–9.2	4–6
Malaysia[d] / Jenssen et al. (2005)	128	212	75	37	12.6	22.2	2.4	5.8

BOD_5, five-day biological oxygen demand

[a] Excluding laundry.

[b] Phosphorus-free detergents.

[c] BOD_7, seven-day biological oxygen demand, for the Swedish proposed norm.

[d] Septic tank effluent.

5. Summary and Conclusion

5.1. Introduction

Kenya as many other African countries is confronted with serious problems in water, sanitation and food security. As stated in the latest United Nations World Water Development Report (2009): “Water in a Changing world”, there are 884 million humans (13%) without sufficient access to drinking water, 340 million people of these in Africa (UNESCO, 2009). Due to high population growth followed by an increased demand of water an urgent need for alternative water sources is created.

Resources-oriented or ecological sanitation applied by the ROSA (Resource Oriented Sanitation for peri-urban areas of Africa) project offers an alternative to conventional sanitation and avoids its disadvantages like high costs and high water consumption. It is different from conventional approaches as the concept is recognizing wastewater as a source for irrigation and fertilizing in agriculture and household gardens. This concept shall be applied in four cities in East Africa, called Arba Minch (Ethiopia), Nakuru (Kenya), Arusha (Tanzania) and Kitgum (Uganda). All pilot cities have common problems like a lack of water and high population growth rates combined with inadequate sanitation and water supply. To assure the most effective treatment and an efficient reuse, the wastewater is separated in different streams (urine, faeces and greywater) which differ in terms of pathogens, nutrient content and benefits to soils and plants (ESREY et al., 2001).

According to WHO (2006a), greywater is water from the kitchen, bath and laundry, which generally does not contain significant concentrations of excreta. Its reuse for irrigation in home gardens and agriculture reduces the demand for freshwater, mitigates the stress on water resources and improves food security as plants can be irrigated during the whole year (WHO, 2006a).

5.2. Greywater quality and quantity

Greywater volume is important to know when using it for irrigation as it will affect those sorts of crops which can be cultivated and the used irrigation method (WHO, 2006b). Furthermore due to the dilution factor the volume of water used for washing, cooking and bathing is important for evaluating the quality of greywater. Thus knowledge of the quantity of fresh water used per capita and per household should be sufficient to obtain a first estimate of the characteristics of greywater in a given region (MURPHY, 2006).

Though greywater is generally less polluted than domestic blackwater or industrial wastewater, it may still contain high levels of pathogenic microorganisms, food residues, suspended solids and substances such as oil, fat, soaps or high concentrations of toxic chemicals from household detergents (MOREL and DIENER, 2006). Hence it is fundamental to assess the quality of greywater before reusing it, as poor quality can have a negative impact on the environment, on crop yields and also on human health (MURPHY, 2006).

5.2.1. Purpose of the thesis

In general there is a lack of data on greywater composition. This is also true for the study site Nakuru in Kenya, a pilot city in the ROSA project. Nakuru is the fourth largest city in Kenya with approximately 500 000 inhabitants and a considerable annual population growth rate of 7% (ROSA NAKURU, 2007). Resulting from this the demand for water, sanitation, housing and food is sharply increasing.

In Nakuru only 13 km² of a 240km² area has a sewer system and this only serves the middle and high income areas. In the low- and middle income areas without a sewer connection greywater is mainly disposed untreated on the road, hence creates serious problems for public health and the environment (figure 16).

Therefore in this study the main objective is to characterize type and content of greywater pollutants from different households and different sources (kitchen, laundry and combined) in the peri-urban areas of Nakuru Municipality.

5.2.2. Greywater sampling

Within the sampling period of three months (November 2008 to January 2009), 27 different households in four estates (Kaptembwo, Kwa Rhonda, Lake View and Mwariki) in the peri-urban areas of Nakuru Municipality have been visited for sampling (figure 6).

An overall of 59 greywater samples were taken: 24 samples from kitchen, 25 samples from laundry, 10 samples from combined greywater and additional five source water samples were taken (figure 7). The sampling time was on Monday between eight and ten o'clock in the morning. The median results of the different parameters according to their source are listed in table 21. Average values, standard deviation as well as minimum and maximum values for all parameters are also presented graphically in figure 17 to 34.

5.3. Results

5.3.1. Greywater quantity

According to CARDEN K. et al. (2007) the amount of greywater produced per day is calculated with the amount of water used per day and multiplied by a factor of 0.75. As estimated from the questionnaire on sanitation survey in Nakuru Municipality (February 2007) the amount of water used per household and day is in a range from 20 l/d to 200 l/d in the different sampling areas (table 2 and 3). According to the questionnaire the activity which needs the biggest amount of water in all four areas is bathing and laundry (85.7%) followed by kitchen (8.6%) and for other purposes 5.7 % of the amount of water is used. The amount of produced greywater shown in table 21 is calculated according to the information above. Most of the people in Kaptembwo (66%), Kwa Rhonda (44%), Mwariki (68%) and Lake View (67%) pour their greywater into any empty space in their compound or on the road. The awareness about the problems connected to the disposal of untreated greywater is mainly very low (table5).

5.3.2. Greywater quality

The quality of greywater is different from household to household and also from greywater source to greywater source. First of all the amount of water which is used in kitchen or for laundry has a great influence on the greywater quality as in less amounts of water proportionally higher concentration are found in the samples (MOREL and DIENER. 2006). Furthermore according to MURPHY (2006), the quality also depends on the chemical properties of the fresh water and how often the greywater is reused in the household before it is finally disposed. For example in low income households without tap water in the vicinity, greywater from laundry is mainly reused to clean the floor or for other household purposes. The quality is even changing daily within the households as it is depending on the activities of the household´s occupants like cooking habits (WHO, 2006c). Additionally it also depends on the kind of people living in one household so if there are children or sick people within the household especially the microbiological quality is influenced (MURPHY 2006). To improve the results in further studies it would be advisable to combine the samplings with a short questionnaire where this additional information is collected.

The results of this study (table 21) often show higher concentration as in literature. This might be due to the factors mentioned above. Furthermore another reason might be that most of the literature data on greywater quality are from “middle-income Western-style households” (MURPHY, 2006 p. Xiii).

Table 21: Summary of the greywater and source water characteristics (median values)

Parameter	Unit	Kitchen	Laundry	Combined	Source
Amount	l/d	5.5	56	65.5	87.5
Temp.	°C	20.7	20.0	18.3	23.4
pH		8.1	9.4	8.4	7.0
DO	mg/l	2.17	3.98	1.16	3.50
BOD	mg/l	445	449	455	13
EC	µS/cm	974	1365	1247	323
Salinity	g/l	0.45	0.50	0.55	0.20
TDS	mg/l	800	993	981	223
TSS	mg/l	1255	1090	775	2.00
Org. content	mg/l	1200	870	545	1.60
Inorg. content	mg/l	80	260	220	not detectable
TP	mg/l	7.59	9.02	8.28	0.04
SRP	mg/l	3.82	2.77	4.96	0.05
NH_4-N	mg/l	2.13	5.29	7.32	not detectable
NO_3-N	mg/l	3.68	2.44	1.97	3.49
NO_2-N	mg/l	2.63	8.61	2.71	not detectable
FC	log numbers/ 100ml	7.05	5.49	7.04	1.19

5.4. Conclusion

As the results clearly show, untreated greywater disposal can cause serious health and environmental problems which are often completely underestimated by the persons concerned. Especially the high values for faecal coliforms, phosphorous and nitrogen are reasons enough to take the problem seriously.

There are often children playing on the streets next to or even in the disposed greywater and it is obvious that there is a high risk of diseases being transmitted (DEPARTMENT OF WATER AND FORESTRY, 1996). The high nutrients concentrations contaminate groundwater and if entering surface water lead to eutrophication, oxygen deficiency and kill aquatic animals as ammonia may turn into ammoniac which is highly toxic to aquatic life (KLEE, 1998).

However most of the problematic chemical substances in greywater are very easily and cheaply mitigated for example by source control or banning of phosphate containing detergents (MOREL and DIENER, 2006). Hence it is very important to determine the availability of environmentally friendly detergents in Kenya, the willingness of the people for using biocompatible detergents and the effect on greywater quality if this kind of detergents and soaps are used. Furthermore there is a strong need for creating awareness within the communities especially regarding the negative effects if greywater is poured without treatment as well as the benefits of reuse.

It is very important not to underrate the greywater problem especially in the peri- urban areas, with high population and no adequate sewer systems like the sampling areas of this study. It is obvious that the greywater quality from these areas in Nakuru is not suitable for unrestricted crop irrigation. Hence it is very important that further research is done especially on the reasons for the high contamination as well as on measures to improve the greywater quality. For this reason there is an urgent need for cheap and user-friendly treatment options, guidelines for greywater irrigation as well as awareness creation so that greywater is turning into a benefiting water source instead of being a threat to environment and health.

6. Zusammenfassung und Schlussfolgerung

6.1. Einleitung

Kenia ist wie viele andere afrikanische Länder mit ernsthaften Problemen in den Bereichen Trinkwasserversorgung, Abwasserentsorgung und Ernährungssicherheit konfrontiert. Wie im aktuellen Weltwasser- Entwicklungsbericht der UN steht, gibt es 884 Millionen Menschen (13%) weltweit ohne ausreichenden Zugang zu Trinkwasser, 340 Millionen Menschen davon leben in Afrika (UNESCO, 2009). Dem steigenden Bedarf an Wasser muss durch eine Suche nach alternativen Wasserressourcen begegnet werden, zum Beispiel durch Bewässerung mit gereinigtem Grauwasser. Nach Angaben der WHO (2006a) ist Grauwasser Abwasser aus der Küche, aus dem Bad und beim Wäschewaschen erzeugtes Abwasser. Es enthält in der Regel keine wesentliche Konzentration an Fäkalien. Die Wiederverwendung zur Bewässerung mildert den Druck auf die Wasserressourcen, verringert den Bedarf an Trinkwasser und verbessert die Ernährungssicherheit, weil die Pflanzen ganzjährig bewässert werden können (WHO 2006a).

Die von ROSA (Resource Oriented Sanitation for peri-urban areas of Africa) angewandte kreislauforientierte Abwasserentsorgung (Abbildung 1) bietet eine Alternative zur herkömmlichen Abwasserentsorgung und vermeidet Nachteile wie hohe Kosten und hohen Wasserverbrauch. Das Konzept unterscheidet sich von den üblichen Ansätzen dadurch, dass es empfiehlt, Abwasser zur Bewässerung und Düngung in der Landwirtschaft und in Gärten zu nutzen. Dieses Konzept wird in vier Städten in Ostafrika, Arba Minch (Äthiopien), Nakuru (Kenia), Arusha (Tansania) und Kitgum (Uganda) durchgeführt. Alle am Projekt beteiligten Städte haben ähnliche Probleme wie hohes Bevölkerungswachstum, Wassermangel und unzureichende Abwasserentsorgung. Um eine effektive Behandlung und Wiederverwendung des Abwassers zu gewährleisten erfolgt eine Trennung in verschiedene Ströme (Urin, Fäkalien und Grauwasser), da sich diese im Bezug auf pathogene Mikroorganismen und Nährstoffmengen und somit auch im Nutzen für Boden und Pflanzen unterscheiden (ESREY et al., 2001).

6.2. Quantität und Qualität des Grauwassers

Die Menge an Grauwasser, die für die Bewässerung zur Verfügung steht, bestimmt unter anderem die Pflanzenart, die angebaut werden kann und die Bewässerungsmethode (WHO, 2006b). Außerdem beeinflusst die Menge durch den Verdünnungsfaktor ebenfalls die Qualität des Grauwassers erheblich. So kann die Kenntnis der Grauwassermenge bzw. des Wasserverbrauchs pro Haushalt ausreichen, um eine erste Schätzung zur Qualität abzugeben (MURPHY, 2006).

Obwohl Grauwasser in der Regel weniger verschmutzt ist als Abwasser, das Fäkalien beinhaltet oder industrielles Abwasser, kann es dennoch ein hohes Maß an pathogenen Mikroorganismen, Lebensmittelrückständen, Schwebstoffen und Substanzen wie Öl, Fett, Seifen oder hohe Konzentrationen von giftigen Chemikalien aus Reinigungsmitteln enthalten (MOREL und DIENER, 2006).

Daher ist es von grundlegender Bedeutung, die Qualität von Grauwasser zu bestimmen, bevor dieses wiederverwendet wird, da schlechte Qualität negative Auswirkungen auf die Umwelt, auf die Ernteerträge und auf die menschliche Gesundheit haben können (MURPHY, 2006).

6.2.1. Zielsetzung der Untersuchung

Es besteht ein Mangel an Daten über die Zusammensetzung von Grauwasser. Dies gilt auch für das Untersuchungsgebiet in Nakuru, Kenia. Nakuru ist die viertgrößte Stadt in Kenia mit rund 500 000 Einwohnern und hat ein jährliches Bevölkerungswachstum von 7% (ROSA NAKURU, 2007). Daraus ergibt sich eine erhöhte Nachfrage nach Trinkwasser, Abwasserentsorgung, Wohnraum und Nahrung.

In Nakuru sind nur 13 km² einer insgesamt 240 km² großen Fläche mit einer Kanalisation versorgt, es sind die Wohngebiete der mittleren und hohen Einkommensschichten. In den übrigen Bereichen wird Grauwasser vor allem unbehandelt auf der Straße entsorgt und schafft somit schwerwiegende Probleme für Gesundheit und Umwelt (Abbildung 16).

Das Ziel dieser Untersuchung ist die Bestimmung von Quantität und Qualität des Grauwassers in den Randgebieten der Stadt Nakuru. Das Grauwasser stammt aus verschiedenen Haushalten und verschiedenen Quellen: Grauwasser aus der Küche, beim Waschen von Kleidung entstandenes Grauwasser und gemischtes Grauwasser.

6.2.2. Probenahme des Grauwassers

Innerhalb von drei Monaten (November 2008 bis Januar 2009), wurden bei 27 Haushalten in vier Stadtteilen (Kaptembwo, Kwa Rhonda, Lake View und Mwariki) in den Randgebieten der Stadt Nakuru Proben entnommen (Abbildung 6). Insgesamt waren es 59 Grauwasserproben, davon 24 Proben aus den Küchen, 25 Proben des beim Wäschewaschen entstandenen Grauwassers, 10 Proben aus kombiniertem Grauwasser und fünf Leitungswasserproben (Abbildung 7). Die Probenahme wurden immer am Montag zwischen acht und zehn Uhr morgens durchgeführt. Die Zusammenfassung der Ergebnisse (Median) der verschiedenen Parameter je nach Quelle wird in der Tabelle 22 gezeigt. Alle Ergebnisse werden grafisch in den Abbildungen 17-32 mit Mittelwert, Standardabweichung, sowie Minimum und Maximum dargestellt.

6.3. Ergebnisse

6.3.1. Menge des Grauwassers

Nach Carden K. et al. (2007) wird die täglich produzierte Menge an Grauwasser mit Hilfe des Wasserverbrauchs pro Tag, multipliziert mit einem Faktor von 0,75, bestimmt. Wie aus den Fragebogen-Untersuchungen zur Abwasserentsorgung in der Stadt Nakuru (Februar 2007) hervorgeht, liegt die Höhe des Wasserverbrauchs pro Haushalt und Tag in einem Bereich von 20 l/d bis 200 l/d in den verschiedenen Stadtteilen (Tabelle 2 und 3). Die größte Wassermenge wird für das Baden und die Wäsche (85,7%) verbraucht, für die Küche sind es 8,6% und für andere Zwecke 5,7% des gesamten Wasserbedarfs pro Haushalt und Tag. Die Menge des produzierten Grauwassers (Tabelle 22) wurde an Hand der oben genannten Informationen berechnet.

Die meisten der Menschen in Kaptembwo (66%), Kwa Rhonda (44%), Mwariki (68%) und Lake View (67%) entsorgen ihr Grauwasser unbehandelt entweder auf der Straße oder innerhalb ihres Grundstückes. Das Bewusstsein für die Problematik dieser Beseitigung des Grauwassers ist meist gering (Tabelle 5).

6.3.2. Qualität des Grauwassers

Die Qualität der Grauwasserproben unterscheidet sich von Haushalt zu Haushalt und von Quelle zu Quelle. Vor allem die Menge des Wassers, die in der Küche oder für das Waschen von Kleidung verwendet wird, hat einen großen Einfluss auf die Qualität, da sich in geringerem Wasservolumen proportional höhere Schadstoffkonzentrationen finden (MOREL und Diener, 2006). Die Konzentration der Schadstoffe hängt außerdem ab von der Qualität des Leitungswassers, von Menge und Art der verwendeten Reinigungsmittel und von der Häufigkeit der Wiederverwendung des Grauwassers, zum Beispiel, wenn Waschwasser zum Putzen verwendet wird (MURPHY, 2006). Die Qualität wechselt außerdem täglich innerhalb der Haushalte, je nach Aktivitäten der Bewohner wie zum Beispiel deren Kochgewohnheiten (WHO, 2006c). Kinder und kranke Menschen in einem Haushalt beeinflussen die mikrobiologische Qualität (MURPHY, 2006). Bei weiteren Studien ist zu empfehlen, die Probenahme mit einem kurzen Fragebogen zu verbinden um diese zusätzlichen Daten zu erheben.

Die Schadstoffkonzentrationen aus dieser Studie (Tabelle 22) sind oft höher als die in der Literatur angegeben Werte, dies ist auf die oben genannten Ursachen zurückzuführen. Außerdem stammen die meisten in der Literatur vorhandenen Ergebnisse aus Gebieten, die dem Standard der westlichen Welt entsprechen (MURPHY, 2006).

Table 22: Zusammenfassung der Grauwasser- und Source-Wasser Merkmale (Median Werte)

Parameter	Unit	Kitchen	Laundry	Combined	Source
Amount	l/d	5.5	56	65.5	87.5
Temp.	°C	20.7	20.0	18.3	23.4
pH		8.1	9.4	8.4	7.0
DO	mg/l	2.17	3.98	1.16	3.50
BOD	mg/l	445	449	455	13
EC	µS/cm	974	1365	1247	323
Salinity	g/l	0.45	0.50	0.55	0.20
TDS	mg/l	800	993	981	223
TSS	mg/l	1255	1090	775	2.00
Org. content	mg/l	1200	870	545	1.60
Inorg. content	mg/l	80	260	220	not detectable
TP	mg/l	7.59	9.02	8.28	0.04
SRP	mg/l	3.28	2.27	4.96	0.05
NH_4-N	mg/l	2.13	5.29	7.32	not detectable
NO_3-N	mg/l	3.68	2.44	1.97	3.49
NO_2-N	mg/l	2.63	8.61	2.71	not detectable
FC	log numbers/ 100ml	7.05	5.49	7.04	1.19

6.4. Schlussfolgerung

Wie die Ergebnisse deutlich zeigen, entstehen durch die Entsorgung des unbehandelten Grauwassers auf die Straße erhebliche Gesundheits- und Umweltrisiken. Die betroffenen Personen unterschätzen die Gefahr meist völlig. Vor allem die hohe Anzahl coliformer Bakterien, die der im rohen Abwasser entspricht, sowie die Konzentrationen von Phosphor und Stickstoff sind ein ernst zu nehmendes Problem.

Häufig spielen Kinder auf der Straße neben oder sogar im Grauwasser und es ist offensichtlich, dass hierbei leicht Krankheiten übertragen werden (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). Die hohen Konzentrationen von Nährstoffen führen zu Grundwasserkontaminierung. Der Eintrag in Oberflächengewässer bewirkt eine Eutrophierung, Sauerstoffmangel und durch Bildung von Ammoniak den Tod von Wasserorganismen (KLEE, 1998).

Viele der Schadstoffe im Grauwasser sind sehr einfach und kostengünstig durch Kontrolle der Ursachen wie zum Beispiel durch das Verbot von Phosphaten in Waschmitteln zu verringern (MOREL und DIENER, 2006). Daher ist es sehr wichtig, dass in Kenia phosphatfreie Waschmittel gesetzlich verordnet werden und die Verwendung von biokompatiblen Wasch- und Reinigungsmittel gefördert wird. Die Bevölkerung muss aufgeklärt werden über die Gefahren der Entsorgung des unbehandelten Grauwassers und die Vorteile der Wiederverwendung von Grauwasser.

Es ist offensichtlich, dass die Qualität des Grauwassers aus den untersuchten Gebieten in Nakuru nicht für die uneingeschränkte Bewässerung geeignet ist. Weitere Untersuchungen vor allem über die Gründe der hohen Kontamination sowie zu den Maßnahmen zur Reinigung des Grauwassers sind nötig. Es besteht ein dringender Bedarf an preiswerten, technisch einfachen und benutzerfreundlichen Behandlungsmöglichkeiten des Grauwassers. Außerdem fehlen Leitlinien für die Verwendung von Grauwasser zur Bewässerung.

Neue Wege müssen beschritten werden, damit sich Grauwasser von einem Umwelt- und Gesundheitsrisiko zu einer wertvollen Wasserressource wandelt.

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8. Appendix

Table 23: Guidelines for interpretation of water quality for irrigation (WHO, 2006b)

Parameter		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity EC_w[a]		dS/m	<0.7	0.7–3.0	>3.0
TDS		mg/l	<450	450–2000	>2000
TSS		mg/l	<50	50–100	>100
SAR[b]	0–3	meq/l	>0.7 EC_w	0.7–0.2 EC_w	<0.2 EC_w
SAR	3–6	meq/l	>1.2 EC_w	1.2–0.3 EC_w	<0.3 EC_w
SAR	6–12	meq/l	>1.9 EC_w	1.9–0.5 EC_w	<0.5 EC_w
SAR	12–20	meq/l	>2.9 EC_w	2.9–1.3 EC_w	<1.3 EC_w
SAR	20–40	meq/l	>5.0 EC_w	5.0–2.9 EC_w	<2.9 EC_w
Sodium (Na^+)	Sprinkler irrigation	meq/l	<3	>3	
Sodium (Na^+)	Surface irrigation	meq/l	<3	3–9	>9
Chloride (Cl^-)	Sprinkler irrigation	meq/l	<3	>3	
Chloride (Cl^-)	Surface irrigation	meq/l	<4	4–10	>10
Chlorine (Cl_2)	Total residual	mg/l	<1	1–5	>5
Bicarbonate (HCO_3^-)		mg/l	<90	90–500	>500
Boron (B)		mg/l	<0.7	0.7–3.0	>3.0
Hydrogen sulfide (H_2S)		mg/l	<0.5	0.5–2.0	> 2.0
Iron (Fe)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Manganese (Mn)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Total nitrogen (TN)		mg/l	<5	5–30	>30
pH				Normal range 6.5–8	
Trace elements (see Table A1.2)					

TDS, total dissolved solids; TSS, total suspended solids

Sources: Ayers & Westcot (1985); Pescod (1992); Asano & Levine (1998).

[a] EC_w means electrical conductivity in deciSiemens per metre at 25 °C.

[b] SAR means sodium adsorption ratio ($[meq/l]^{1/2}$); see section A1.5.

Table 24: Effects on soil, crops and livestock by type of compound (WHO, 2006b)

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Nitrogen	Municipal wastewater with 20–85 mg TN/l	Acidification problems provoked by synthetic fertilizers are not observed	Increases productivity in quantity and quality Depending on soil's content and type of crops, problems can arise above 30 mg $N\text{-}NO_3$/l	No problems reported
	Wastewater with >30 mg/l	No reported effects	Can increase succulence beyond desirable levels, causing lodging in grain crops and reducing sugar content in beets and cane Beyond seasonal needs, may induce more vegetative than fruit growth and also delay ripening	Forage, being the main food for cattle, can cause grass tetany, a disease related to an imbalance of nitrogen, potassium and magnesium in pasture grasses
Phosphorus	Municipal wastewater with 6–20 mg/l	No reported effects	Increases productivity	
	Municipal wastewater with >20 mg/l	No reported effects	Reduce copper, iron and zinc availability in alkaline soils	
Potassium	Normal content in municipal wastewater[a]	No reported effects	Increases productivity	
	Content above normal municipal wastewater values[a]	No reported effects	Increases productivity	

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Organic matter	Municipal wastewater with 110–400 mg BOD/l	Improves microbial activity and soil fertility Colloidal and suspended organic matter increase moisture and nutritious content, improving structure Diminishes salinity effects due to a higher water content Retains and binds heavy metals Depending on its composition and soil consumption, can release salts, nitrogen and metals	Increases productivity	No problems reported
	Content in wastewater greater than content in normal sewage[a]	Continuous irrigation and high organic matter contents may clog soil pores and favour an anaerobic population in the root zone Organic matter combined with nitrogen and continuous irrigation can cause important nitrogen losses by denitrification		
Salinity (variable, depending on the water supply content and type of discharges)	Wastewater with: TDS 250–850 mg/l Conductivity <3 dS/m SAR 5–9 Sodium <100 mg/l	No short-term effects observed Long-term salinization occurs at a rate that depends upon the frequency of soil washing and land drainage properties	Problems in sensitive crops with TDS of 450–2000 mg/l and conductivities of 0.7–3 dS/m Conductivities between 5 and 8 dS/m and non-sensitive crops do not display problems If soil is saline, crops absorb more salts, causing the crops' value to diminish in some countries and for some crops, such as vineyards	

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Salinity *(continued)*	Wastewater with: TDS >2000 mg/l Conductivity >3 dS/m SAR >8 Sodium >100 mg/l	Loss of soil structure and capacity for water and air transport, and thus to sustain plants Effects depend on conductivity and SAR values, frequency of soil washing and land drainage conditions	Impacts in almost all types of crops Sodium diminishes yields in sensitive crops up to 100 mg/l SAR >3 affects some crops, depending on the water conductivity Productivity diminishes or even stops if salinization is very high	
Boron (very variable in wastewaters, depending on the water supply content and discharges)	Municipal wastewater with 0.7–3 mg/l Municipal wastewater with >3 mg/l	No reported effects	Affects very sensitive (0.5–0.75 mg/l), sensitive (0.75–1 mg/l) and moderately sensitive (2–4 mg/l) crops Affects moderately sensitive (2–4 mg/l), tolerant (4–6 mg/l) and very tolerant (6–15 mg/l) crops	
Chlorides	Wastewater with 30–100 mg/l Wastewater with >140 mg/l	Can cause salinization, depending on other parameters as well as frequency of soil washing and land drainage conditions	Below 140 mg/l, no effects are observed >140 mg/l, crops are affected, with very visible effects at concentrations >350 mg/l Leaves of sensitive plants (crops and woody plants) are burnt when sprinklers are used for irrigation	
Alkalinity (carbonates and bicarbonates)	Wastewater with 50–200 mg $CaCO_3$/l	No reported effects		No problems reported
	Wastewater with >500 mg $CaCO_3$/l	Concentrations above equilibrium conditions in soils precipitate calcium, affecting soil structure	In warm climates, bicarbonates burn leaves	
Metals	Municipal wastewater or industrial effluents without high metal concentrations	Concentration in soil is increased with time in the first soil layers; depending on pH, organic matter content and irrigation time, metals are either bound to the soil particles or mobile	No effects are observed with normal metal contents of sewage	

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Metals *(continued)*	Municipal wastewater or industrial discharges with high metals content	See Annex 2	See Annex 2	See Annex 2
	Aluminium and iron	Reduce phosphorus mobility	Can cause phosphorus deficiencies	
	Cadmium		Is toxic, and uptake can increase with time, depending on soil concentrations	May be harmful to animals in doses much lower than visibly affect plants
				Absorbed cadmium is stored in kidney and liver; remaining meat and milk products unaffected
	Copper			May be harmful to animals at concentrations too low to visibly affect plants
				Is not a health hazard to monogastric animals, but can be toxic to ruminants (cows and sheep)
				Tolerance to copper increases as available molybdenum increases
	Zinc and nickel		Cause visible adverse effects in plants before plant concentrations are high enough to be of concern in animals or humans	

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Metals *(continued)*	Molybdenum			May be harmful to animals at concentrations that are too low to visibly affect plants Causes adverse effects in animals consuming forage with 10–20 mg/kg and low copper content Consumption of crops with more than 5 mg/kg is toxic to ruminants Molybdenum toxicity is related to the ingestion of copper and sulfate
Toxic organic compounds		Long term: some may biodegrade in soils Some compounds, such as pesticides, might contain metals and contribute to their accumulation in soils	In general, their large sizes and high molecular mass do not allow them to be absorbed through plants Can contaminate plant products through water contact during irrigation; sewage normally contains concentrations too low to cause problems	
Suspended solids	Municipal wastewater with 100–350 mg/l	Clog soils, depending on concentration, composition and soil porosity; >100 mg/l of mineral solids can cause problems If soil is clogged, water infiltration rate diminishes and irrigation becomes less effective		
pH	Municipal wastewater with pH 7–7.4	No reported effects		

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
pH *(continued)*	Wastewater with pH out of the 6.5–8.5 range	If soil alkalinity is not sufficient to maintain pH above 6.5, metal solubilization can occur; when pH is maintained below 8.5, aluminium can be solubilized and soil deflocculated, and nitrogen can be lost by volatilization	Effects depend on the solubilized metal (see Annex 2)	

dS/m, deciSiemens per metre; SAR, soil adsorption ratio; TDS, total dissolved solids; TN, total nitrogen

Sources: NAS & NAE (1972); Seabrook (1975); Sidle, Hook & Kardos (1976); Benham-Blair & Affiliates, Inc. & Engineering Enterprises, Inc. (1979); Marten, Larson & Clapp (1980); Bouwer (1991); Metcalf & Eddy, Inc. (1991); Oron et al. (1992); Pescod (1992); National Research Council (1996); Siebe & Fischer (1996); Shahalam, Abuzahra & Jaradat (1998); Siebe (1998); ACTG (1999); Downs et al. (2000); Friedel et al. (2000); Simmons & Pongsakul (2002); AATSE (2004); Jiménez (2004); Jiménez, Siebe & Cifuentes (2004); Lee et al. (2004).

[a] Municipal wastewater content according to Metcalf & Eddy, Inc. (2003).

Table 25: Impact on groundwater and surface water (WHO,2006b)

Compound	Impact	Relative impact on groundwater or surface water	
		Groundwater	Surface water
Nitrogen	May contaminate underground and surface water bodies by infiltration and irrigation runoff. The amount of nitrogen leached depends on crop demand, hydraulic load due to rain and irrigation water, soil permeability and nitrogen content in soils.	High	Medium
Phosphorus	Agricultural runoff containing phosphorus can cause the growth of aquatic plants as a result of eutrophication in surface water bodies (reservoirs and lakes), which can lead to the obstruction of irrigation infrastructure (filters, weirs, pipes and spillways) and clog filters in water treatment plants.	Not significant	Medium
Biodegradable organic matter	If runoff contains high levels of organic matter, the organic matter can consume dissolved oxygen in lakes and rivers.	Not significant	Medium
Salinity	Saline soil leachates contaminate surface and underground water bodies; up to a certain level, it can limit water use. TDS > 500 mg/l causes flavour but not health problems in water supplies. Very high concentrations have laxative effects on consumers and corrode water distribution equipment.	Medium	Low
Boron	Boron from wastewater is not removed by treatment, almost not retained in soils and not absorbed by plants. Although it is an essential element, it easily becomes toxic above the required levels. By leaching, it enters groundwater and, through runoff or from polluted aquifers, surface water bodies. Accumulation in water bodies limits their use, mainly for irrigation. Some crops are sensitive to boron (see Annex 1).	Medium	Low
Heavy metals	By leaching from acid soils, they can reach aquifers and enter surface waters through runoff.	Low	Low
Toxic organic compounds	Mostly removed by soils.	Not significant	Not significant

TDS, total dissolved solids

Table 26: Water quality guidelines for EC (ANDERSON and CUMMINGS 1999)

EC range (µS/cm)	Usefulness of water
0 - 800	• Good drinking water for humans (provided there is no organic pollution and not too much suspended clay material) • Generally good for irrigation, though above 300 µS/cm, some care must be taken, particularly with overhead sprinklers which may cause leaf scorch on some salt sensitive plants. • Suitable for all livestock
800 - 2,500	• Can be consumed by humans although most would prefer water in the lower half of this range if available. • When used for irrigation, requires special management including suitable soils, good drainage and consideration of salt tolerance of plants. • Suitable for all livestock.
2,500 - 10,000	• Not recommended for human consumption, although water up to 3000 µS/cm could be drunk if nothing else was available. • Not normally suitable for irrigation, though water up to 6000 µS/cm can be used on very salt tolerant crops with special management techniques. Over 6000 µS/cm, occasional emergency irrigation may be possible with care, or if sufficient low salinity water is available, this could be mixed with the high salinity water to obtain an acceptable supply. • When used for drinking water by poultry and pigs, the salinity should be limited to about 6000 µS/cm. Most other stock can use water up to 10,000 µS/cm. • Water over 4000 µS/cm can cause shell cracking in laying hens. • High magnesium levels can cause stock health problems in this range. Analysis recommended.
Over 10,000	• Not suitable for human consumption or irrigation • Not suitable for pigs, poultry or any lactating animals. Beef cattle can use water up to 17,000 µS/cm and adult dry sheep can tolerate 23,000 µS/cm. However it is possible that waters below these EC levels could contain unacceptable concentrations of particular ions. Detailed chemical analysis should therefore be considered before using high salinity water for stock. • Water up to 50,000 µS/cm (the salinity of the sea), can be used to flush toilets provided corrosion in the cistern can be controlled.

Table 27: Relative Salt Tolerance of Various Commercial Crops at Germination (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996)

Crop	Fifty Percent Emergence Reduction (EC (mS/m) of Saturated Soil Extract
Barley	1 600 - 2 400
Cotton	1 550
Sugarbeet	500 - 1 250
Sorghum	1 300
Safflower	1 230
Wheat	1 400 - 1 600
Beet, red	1 380
Lucerne	820 - 1 340
Tomato	760
Rice	1 800
Cabbage	1 300
Muskmelon	1 040
Maize	2 100 - 2 400
Lettuce	1 140
Onion	560 - 750
Bean	800

Table 28: Control measures by polluting agent (WHO, 2006b)

Compound	Control measure
Nitrogen in excess	Dilute wastewater with fresh water when possible
	Limit the quantity of wastewater applied
	Remove excess nitrogen from wastewater
Organic matter	Do not continuously apply wastewater, to allow soil to biodegrade it
	Enhance removal of organic matter from wastewater
Salinity	Avoid the use of water with 500–2000 mg TDS/l or 0.8–2.3 dS/m electrical conductivity, depending on the type of soil and land drainage
	Reduce upstream salt use and discharge into wastewater
Chlorides	With sprinklers, only use water with <100 mg/l
	In irrigation by flooding, use water with <350 mg/l
	Irrigate by night to prevent leaf burn
Toxic organic compounds in soil and crops	Pretreat or segregate industrial discharges from sewage
	Promote cleaner production in industries, to avoid using toxic compounds
	Educate society to use less toxic compounds and, when used, dispose of them safely
Metals	Pretreat or segregate industrial discharges from sewage
	Use wastewater only in soils having a pH >6.5
Suspended solids	Use water without solids >2–5 mm
	Remove suspended solids by pretreatment of wastewater
	Plough soils when clogged

TDS, total dissolved solids

Sources: Seabrook (1975); Bole & Bell (1978); Reed, Thomas & Kowal (1980); USEPA (1981); Ayers & Wescot (1985); Phene & Ruskin (1989); Bouwer (1991); Oron et al. (1991, 1992); Pescod (1992); Farid et al. (1993); Chang et al. (1995); National Research Council (1996); Jiménez & Chávez (1997); Strauss (2000); Cornish & Lawrence (2001); AATSE (2004); Ensink, Simmons & van der Hoek (2004); Ensink et al. (2004); Foster et al. (2004).

Table 29: Raw data kitchen greywater

sample	Date	household	category	area	temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]	BOD [mg/l]
1	27.10.08	1	KITCHEN	Kaptembwo	33.5	6.23	597	0.0	1.63	-	-
2	27.10.08	2	KITCHEN	Kaptembwo	23.2	8.26	320	0.0	7.50	-	-
3	03.11.08	3	KITCHEN	Kaptembwo	21.5	6.97	1350	0.5	1.84	-	511.43
4	03.11.08	4	KITCHEN	Kaptembwo	19.2	7.18	426	0.0	1.03	-	498.30
5	10.11.08	5	KITCHEN	Kaptembwo	26.8	6.22	1329	0.5	2.20	-	482.23
6	10.11.08	6	KITCHEN	Kaptembwo	27.3	9.85	1260	0.4	6.78	-	509.50
7	17.11.08	7	KITCHEN	Kaptembwo	17.2	9.02	1417	0.5	3.06	-	340.37
8	17.11.08	8	KITCHEN	Kaptembwo	20.7	9.35	393	0.0	3.86	-	457.53
9	23.11.08	9	KITCHEN	Kaptembwo	21.0	6.24	761	0.1	0.41	-	392.59
10	01.12.08	11	KITCHEN	Kaptembwo	21.3	9.63	416	0.0	4.28	-	502.39
11	01.12.08	12	KITCHEN	Kaptembwo	19.2	8.42	366	0.0	2.76	-	425.21
12	15.12.08	13	KITCHEN	Kaptembwo	20.2	9.56	637	0.3	3.63	456	405.28
13	15.12.08	14	KITCHEN	Kaptembwo	20.6	6.61	2308	1.3	2.20	1640	443.39
14	22.12.08	16	KITCHEN	Kwa Rhonda	15.5	4.40	1220	0.8	0.39	970	463.59
15	22.12.08	17	KITCHEN	Kwa Rhonda	20.2	9.45	655	0.4	3.30	467	476.72
16	05.01.09	18	KITCHEN	Kwa Rhonda	18.0	6.75	2717	1.6	1.07	1994	409.41
17	05.01.09	19	KITCHEN	Kwa Rhonda	25.2	8.89	813	0.4	2.14	523	441.37
18	12.01.09	20	KITCHEN	Kwa Rhonda	20.0	5.07	1203	0.7	0.07	860	543.39
19	12.01.09	21	KITCHEN	Kwa Rhonda	24.8	9.50	1353	0.7	2.22	880	595.90
20	19.01.09	22	KITCHEN	Lake View	19.1	4.98	1314	0.7	0.23	959	425.00
21	19.01.09	23	KITCHEN	Lake View	26.3	8.03	623	0.3	2.62	393	446.42
22	26.01.09	24	KITCHEN	Lake View	20.7	9.56	1137	0.6	0.07	800	420.08
23	26.01.09	25	KITCHEN	Lake View	19.0	6.61	858	0.5	0.64	630	426.22
24	02.02.09	26	KITCHEN	Mwariki	21.4	9.41	1089	0.6	1.55	759	419.68

Table 29: Raw data kitchen greywater

TSS [mg/l]	organic content [mg/l]	inorganic content [mg/l]	TP [mg/l]	SRP [mg/l]	NH_4 [mg/l]	NO_3 [mg/l]	NO_2 [mg/l]	FC [log numbers/100ml]
1240	1215	25	4.77	1.38	0.87	0.48	0.20	-
255	215	40	13.54	1.42	0.11	0.65	0.42	-
4860	4820	40	8.87	4.12	0.90	9.97	2.54	-
840	835	5	2.00	0.16	0.15	0.65	1.07	-
495	415	80	7.58	0.85	6.52	17.20	54.88	7.04
5900	5440	460	13.38	7.65	1.70	2.93	4.21	7.01
1990	-	-	6.67	3.95	3.90	8.22	3.90	6.88
640	-	-	3.01	1.16	1.14	1.75	2.72	7.07
1470	-	-	7.10	5.86	2.27	12.00	0.33	7.16
1340	1280	60	3.54	1.12	1.10	4.80	0.97	6.12
1880	1830	50	21.55	6.03	5.97	2.38	0.78	6.25
1090	1010	80	6.25	4.13	2.03	2.60	12.93	6.15
1800	1680	120	23.12	15.50	8.29	10.81	4.49	6.60
1940	1800	140	11.02	7.85	7.78	3.84	1.72	7.15
820	740	80	3.13	0.57	0.55	2.48	6.63	7.54
6350	6040	310	24.92	18.95	11.98	5.22	4.69	7.62
910	750	160	4.12	1.25	1.47	3.96	4.43	7.73
2720	2340	380	10.41	3.11	12.03	11.90	1.91	7.59
470	440	30	8.01	3.21	0.93	4.14	3.47	8.18
1030	900	130	12.69	5.60	4.52	1.90	0.78	7.29
313	300	13	0.83	0.17	0.16	4.64	2.09	7.32
4400	4270	130	7.60	3.36	3.76	3.36	0.43	6.09
870	860	10	6.03	3.04	4.58	3.04	8.28	6.23
1270	1200	70	10.27	3.64	2.23	3.53	10.20	6.08

Table 30: Raw data laundry greywater

sample	date	household	category	area	temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]	BOD [mg/l]
1	27.10.08		LAUNDRY	Kaptembwo	29.5	7.44	676	0.1	2.10	-	-
2	27.10.08	2	LAUNDRY	Kaptembwo	25.3	9.58	1026	0.3	5.60	-	-
3	03.11.08	3	LAUNDRY	Kaptembwo	18.1	9.31	1433	0.5	5.84	-	492.24
4	03.11.08	4	LAUNDRY	Kaptembwo	20.3	9.13	1466	0.5	6.98	-	481.13
5	10.11.08	5	LAUNDRY	Kaptembwo	36.7	9.68	431	0.0	8.20	-	477.18
6	10.11.08	6	LAUNDRY	Kaptembwo	26.7	9.45	2860	1.4	3.97	-	508.49
7	17.11.08	7	LAUNDRY	Kaptembwo	17.7	9.75	1876	0.8	6.60	-	456.52
8	17.11.08	8	LAUNDRY	Kaptembwo	18.2	9.34	1602	0.6	4.51	-	441.37
9	23.11.08	10	LAUNDRY	Kaptembwo	17.9	9.71	949	0.2	5.85	-	308.05
10	01.12.08	11	LAUNDRY	Kaptembwo	20.4	7.55	687	0.1	3.26	-	448.44
11	01.12.08	12	LAUNDRY	Kaptembwo	19.0	9.65	2270	1.0	5.38	-	407.03
12	15.12.08	13	LAUNDRY	Kaptembwo	20.0	9.51	1040	0.5	3.28	977	449.45
13	15.12.08	14	LAUNDRY	Kaptembwo	21.8	9.50	2217	1.2	3.10	1530	450.46
14	22.12.08	15	LAUNDRY	Kwa Rhonda	12.5	7.66	1129	0.6	0.12	733	416.52
15	22.12.08	16	LAUNDRY	Kwa Rhonda	15.6	8.60	4320	2.9	0.07	3422	473.69
16	05.01.09	18	LAUNDRY	Kwa Rhonda	15.2	9.29	488	0.3	3.25	387	430.26
17	05.01.09	19	LAUNDRY	Kwa Rhonda	24.3	9.02	938	0.5	2.69	617	429.25
18	12.01.09	20	LAUNDRY	Kwa Rhonda	18.3	10.08	941	0.5	5.32	699	599.94
19	12.01.09	21	LAUNDRY	Kwa Rhonda	20.0	9.38	720	0.4	3.65	518	548.43
20	19.01.09	22	LAUNDRY	Lake View	18.7	9.30	1365	0.8	4.18	1009	441.37
21	19.01.09	23	LAUNDRY	Lake View	22.3	7.28	1639	0.9	3.36	1121	431.27
22	26.01.09	24	LAUNDRY	Lake View	22.8	9.51	1697	0.9	4.03	1146	426.22
23	26.01.09	25	LAUNDRY	Lake View	18.7	9.50	1995	1.2	4.48	1473	428.24
24	02.02.09	26	LAUNDRY	Mwariki	22.1	8.87	946	0.5	3.22	651	500.96
25	02.02.09	27	LAUNDRY	Mwariki	22.1	10.01	5050	2.9	3.98	3470	503.99

TSS [mg/l]	organic content [mg/l]	inorganic content [mg/l]	TP [mg/l]	NO_3 [mg/l]	NO_2 [mg/l]	FC [log numbers/100ml]
610	475	135	1.99	0.41	1.11	-
555	485	70	2.70	1.59	3.86	-
1080	900	180	11.48	2.26	9.41	-
1660	1390	270	11.00	2.22	5.21	-
460	370	90	4.49	0.58	5.09	6.78
4420	3420	1000	22.94	2.44	11.96	7.12
480	-	-	12.78	3.53	2.16	5.49
750	-	-	21.82	2.11	6.32	4.86
1240	-	-	5.09	1.89	26.56	4.90
640	560	80	4.11	0.14	0.75	5.93
3060	2530	530	30.19	14.64	6.74	5.26
1160	1020	140	4.13	2.81	8.38	4.60
1840	1420	420	22.74	2.91	32.10	5.88
1700	1360	340	5.64	1.50	8.61	5.41
3960	2240	1720	20.94	24.03	2.35	5.69
350	330	20	1.72	2.12	3.95	5.47
760	510	250	9.02	1.65	7.47	5.20
1260	400	860	4.54	2.87	12.04	6.21
450	320	130	1.62	1.75	12.18	6.15
770	600	170	6.25	4.53	11.09	5.71
950	600	350	11.02	2.63	20.35	5.67
1850	1540	310	9.07	3.59	13.15	4.54
2940	2420	520	9.29	5.18	34.34	5.25
1090	840	250	2.99	4.93	9.91	5.75
4500	3060	1440	10.92	6.79	22.51	5.10

Table 31: Raw data combined greywater

sample	date	household	category	area	temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]	BOD [mg/l]
1	27.10.08	1	ALL	Kaptembwo	31.0	8.32	883	0.2	2.73	-	-
2	17.11.08	8	ALL	Kaptembwo	17.1	7.89	1356	0.5	2.20	-	457.53
3	23.11.08	9	ALL	Kaptembwo	20.4	5.59	1255	0.4	0.08	-	483.79
4	23.11.08	10	ALL	Kaptembwo	17.8	7.00	1100	0.3	0.13	-	487.83
5	15.12.08	13	ALL	Kaptembwo	16.5	8.71	1262	0.8	0.60	982	454.50
6	15.12.08	14	ALL	Kaptembwo	16.0	8.41	1238	0.8	1.71	980	447.43
7	19.01.09	22	ALL	Lake View	19.0	4.48	1792	1.1	0.18	1332	441.37
8	26.01.09	24	ALL	Lake View	18.8	8.71	2780	1.7	0.08	2060	431.27
9	26.01.09	25	ALL	Lake View	17.0	8.41	1105	0.6	2.50	833	435.31
10	02.02.09	27	ALL	Mwariki	20.1	8.70	863	0.5	3.11	311	500.96

TSS [mg/l]	organic content [mg/l]	inorganic content [mg/l]	TP [mg/l]	SRP [mg/l]	NH_4 [mg/l]	NO_3 [mg/l]	NO_2 [mg/l]	FC [log numbers/100ml]
750	670	80	7.38	1.86	2.95	0.60	2.09	-
760	-	-	10.72	5.11	5.05	0.31	4.14	6.80
2690	-	-	11.85	7.92	36.52	6.72	3.18	7.46
1050	-	-	9.17	5.46	9.71	2.32	10.25	7.08
1120	900	220	6.70	4.40	6.51	0.94	14.15	6.25
680	540	140	7.34	4.85	12.82	0.27	1.26	6.58
2170	1450	720	10.87	5.07	8.05	1.63	0.54	8.63
790	540	250	25.18	16.53	27.16	16.53	2.23	7.04
610	520	90	6.21	4.18	6.60	4.18	12.72	7.13
619	545	410	2.60	1.05	0.41	4.53	2.04	6.28

Table 32: Raw data source water

sample	date	household	source	Area	temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]	BOD [mg/l]
1	07.02.09	22	Tap	Lake View	26.2	6.87	482	0.2	3.50	305	13.54
2	07.02.09	26	Tap	Mwariki	26.4	7.03	516	0.2	3.50	328	9.90
3	07.02.09	16	Tap	Kwa Rhonda	22.2	7.28	310	0.2	4.87	212	13.04
4	07.02.09	14	Tap	Kaptembwo	23.4	7.03	303	0.2	3.47	204	13.87
5	07.02.09	1	jerry can	Kaptembwo	21.9	7.34	323	0.2	4.02	223	7.06

TSS [mg/l]	organic content [mg/l]	inorganic content [mg/l]	TP [mg/l]	SRP [mg/l]	NH_4 [mg/l]	NO_3 [mg/l]	NO_2 [mg/l]	FC [log numbers/100ml]
4.8	4.8	0	0.04	0.05	0.00	4.70	0.00	1.87
2	2	0	0.04	0.07	0.00	4.43	0.00	0.26
2	1.6	0.4	0.04	0.07	0.01	2.98	0.00	1.19
1.2	1.2	0	0.04	0.05	0.01	3.20	0.00	0.00
2	1.6	0.4	0.03	0.05	0.00	3.49	0.01	2.41

Table 33: Raw data physical and chemical parameters

Sampling 27.10.2008 Kaptembwo

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]
1	HH1 KITCHEN	33.5	6.23	597	0.0	1.63
2	HH1LAUNDRY	29.5	7.44	676	0.1	2.10
3	HH1 ALL	31.0	8.32	883	0.2	2.73
4	HH2 KITCHEN	23.2	8.26	320	0.0	7.50
5	HH2 LAUNDRY	25.3	9.58	1026	0.3	5.6

TSS

sample	Wf [g]	Wc [g]	AFDW [g]	V [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0826	0.1074	0.0831	20	1240	1215	25
2	0.0830	0.0952	0.0857	20	610	475	135
3	0.0833	0.0908	0.0841	10	750	670	80
4	0.0820	0.0871	0.0828	20	255	215	40
5	0.0789	0.0900	0.0803	20	555	485	70

Sampling 3.11.2008 Kaptembwo

sample		temp. [°C]	pH 25°C	EC [µS/cm]	salinity [g/l]	DO [mg/l]
1	HH1 KITCHEN	21.5	6.97	1350	0.5	1.84
2	HH1LAUNDRY	18.1	9.31	1433	0.5	5.84
4	HH2 KITCHEN	19.2	7.18	426	0.0	1.03
5	HH2 LAUNDRY	20.3	9.13	1466	0.5	6.98

TSS

sample	Wf [g]	Wc [g]	AFDW [g]	V [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0820	0.1063	0.0822	5	4860	4820	40
2	0.0897	0.1005	0.0915	10	1080	900	180
3	0.0894	0.1062	0.0895	20	840	835	5
4	0.0900	0.1066	0.0927	10	1660	1390	270

BOD dilution 1:100

Sample	v [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand	BOD [mg/l]
Blank	0	6.80	6.43	0.37	
1	10	5.50	0.07	5.43	511.43
2	10	5.44	0.20	5.24	492.24
3	10	5.38	0.08	5.30	498.30
4	10	5.34	0.21	5.13	481.13

Sampling 10.11.2008 Kaptembwo

sample		temp. [°C]	pH 25°C	EC [µS/cm]	salinity [g/l]	DO [mg/l]
1	HH1 KITCHEN	26.8	6.22	1319	0.50	2.20
2	HH1LAUNDRY	36.7	9.68	431	0.00	8.20
3	HH2 KITCHEN	27.3	9.85	1260	0.40	6.78
4	HH2 LAUNDRY	26.7	9.45	2860	1.40	3.97

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0925	0.1024	0.0941	20	495	415	80
2	0.0876	0.0922	0.0885	10	460	370	90
3	0.0892	0.1187	0.0915	5	5900	5440	460
4	0.0882	0.1103	0.0932	5	4420	3420	1000

BOD dilution 1:100

sample	v [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand	BOD [mg/l]
Blank	0	6.91	6.45	0.46	
1	10	5.40	0.17	5.23	482.23
2	10	5.38	0.20	5.18	477.18
3	10	5.60	0.10	5.50	509.50
4	10	5.65	0.16	5.49	508.49

Sampling: 17.11.2008 Kaptembwo

sample		temp. [°C]	pH 25°C	EC [µS/cm]	salinity [g/l]	DO [mg/l]
1	HH1 KITCHEN	17.2	9.02	1417	0.5	3.06
2	HH1LAUNDRY	17.7	9.75	1876	0.8	6.60
3	HH2 KITCHEN	20.7	9.35	393	0.0	3.86
4	HH2 LAUNDRY	18.2	9.34	1602	0.6	4.51
5	HH2 ALL	17.1	7.89	1356	0.5	2.20

TSS

Sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0890	0.1089	not measured	10	1990	not measured	not measured
2	0.0893	0.0941	not measured	10	480	not measured	not measured
3	0.0890	0.0954	not measured	10	640	not measured	not measured
4	0.0900	0.0975	not measured	10	750	not measured	not measured
5	0.0875	0.0951	not measured	10	760	not measured	not measured

BOD dilution 1:100

Sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	4.43	3.88	0.55	
1	10	4.20	0.83	3.37	340.37
2	10	4.55	0.03	4.52	456.52
3	10	4.58	0.05	4.53	457.53
4	10	4.45	0.08	4.37	441.37
5	10	4.58	0.05	4.53	457.53

Sampling 23.11.2008 Kaptembwo

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]
1	HH1 KITCHEN	21.0	6.24	761	0.1	0.41
2	HH1 ALL	20.4	5.59	1255	0.4	0.08
3	HH2 LAUNDRY	17.9	9.71	949	0.2	5.85
4	HH2 ALL	17.8	7.00	1100	0.3	0.13

TSS

	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0885	0.1032	not measured	10	1470	not measured	not measured
2	0.0876	0.1145	not measured	10	2690	not measured	not measured
3	0.0849	0.0973	not measured	10	1240	not measured	not measured
4	0.0885	0.0990	not measured	10	1050	not measured	not measured

BOD dilution 1:100

	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	5.92	5.33	0.59	
1	10	5.64	1.13	4.51	392.59
2	10	5.43	0.64	4.79	424.51
3	10	5.53	2.48	3.05	250.79
4	10	5.31	0.48	4.83	427.05

Sampling 1.12.2008 Kaptembwo

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]
1	HH1 KITCHEN	21.3	9.63	416	0.0	4.28
2	HH1 LAUNDRY	20.4	7.55	687	0.1	3.26
3	HH2 KITCHEN	19.2	8.42	366	0.0	2.76
4	HH2 LAUNDRY	19.0	9.65	2270	1.0	5.38

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0859	0.0993	0.0865	10	1340	1280	60
2	0.0876	0.0940	0.0884	10	640	560	80
3	0.0886	0.1074	0.0891	10	1880	1830	50
4	0.0897	0.1203	0.0950	10	3060	2530	530

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	5.74	5.35	0.39	
1	10	5.53	0.12	5.41	502.39
2	10	5.62	1.18	4.44	410.41
3	10	5.49	1.28	4.21	386.44
4	10	5.25	1.22	4.03	368.21

Sampling 15.12.2008 Kaptembwo

Time: 8:30 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	sample
1	HH1 KITCHEN	20.2	9.56	637	0.3	1
2	HH1 LAUNDRY	20.0	9.51	1040	0.5	2
3	HH1 ALL	16.5	8.71	1262	0.8	3
4	HH2 KITCHEN	20.6	6.61	2308	1.3	4
5	HH2 LAUNDRY	21.8	9.50	2217	1.2	5
6	HH2 ALL	16.0	8.41	1238	0.8	6

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	TSS sample
1	0.0906	0.1015	0.0914	10	1090	1
2	0.0911	0.0969	0.0918	5	1160	2
3	0.0919	0.0975	0.0930	5	1120	3
4	0.0892	0.0982	0.0898	5	1800	4
5	0.0900	0.0992	0.0921	5	1840	5
6	0.0911	0.0945	0.0918	5	680	6

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]	sample
Blank	0	4.60	4.32	0.28		Blank
1	10	4.40	0.07	4.33	405.28	1
2	10	4.50	0.05	4.45	421.33	2
3	10	4.55	0.05	4.50	426.45	3
4	10	4.43	0.04	4.39	415.50	4
5	10	4.51	0.05	4.46	422.39	5
6	10	4.54	0.11	4.43	419.46	6

Sampling 22.12.2008 Kwa Rhonda

Time: 8:40 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH1 LAUNDRY	12.5	7.66	1129	0.6	0.12	733
2	HH2 KITCHEN	15.5	4.40	1220	0.8	0.39	970
3	HH2 LAUNDRY	15.6	8.60	4320	2.9	0.07	3422
4	HH3 KITCHEN	20.2	9.45	655	0.4	3.30	467

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0895	0.0980	0.0912	5	1700	1360	340
2	0.0889	0.0986	0.0896	5	1940	1800	140
3	0.0886	0.1084	0.0972	5	3960	2240	1720
4	0.0891	0.0932	0.0895	5	820	740	80

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	4.84	4.32	0.52	
1	10	4.75	0.07	4.68	416.52
2	10	4.64	0.05	4.59	411.68
3	10	4.74	0.05	4.69	421.59
4	10	4.76	0.04	4.72	424.69

Sampling 5.01.2009 Kwa Rhonda

Time: 9:10 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH1 KITCHEN	18.0	6.75	2717	1.6	1.07	1994
2	HH1 LAUNDRY	15.2	9.29	488	0.3	3.25	387
3	HH2 KITCHEN	25.2	8.89	813	0.4	2.14	523
4	HH2 LAUNDRY	24.3	9.02	938	0.5	2.69	617

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0886	0.1521	0.0917	10	6350	6040	310
2	0.0897	0.0932	0.0899	10	350	330	20
3	0.0879	0.0970	0.0895	10	910	750	160
4	0.0844	0.0920	0.0869	10	760	510	250

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	4.73	4.32	0.41	
1	10	4.57	0.07	4.50	409.41
2	10	4.31	0.05	4.26	389.50
3	10	4.42	0.05	4.37	400.26
4	10	4.29	0.04	4.25	388.37

Sampling 12.01.2009 Kwa Rhonda

Time: 9:22 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH1 KITCHEN	20.0	5.07	1203	0.7	0.07	860
2	HH1 LAUNDRY	18.3	10.08	941	0.5	5.32	699
3	HH2 KITCHEN	24.8	9.50	1353	0.7	2.22	880
4	HH2 LAUNDRY	20	9.38	720	0.4	3.65	518

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0911	0.1047	0.0930	5	2720	2340	380
2	0.0908	0.1034	0.0994	10	1260	400	860
3	0.0907	0.0954	0.0910	10	470	440	30
4	0.0908	0.0953	0.0921	10	450	320	130

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	5.97	5.58	0.39	
1	10	5.92	0.10	5.82	543.39
2	10	5.98	0.04	5.94	560.82
3	10	5.97	0.07	5.90	556.94
4	10	5.57	0.14	5.43	509.90

Sampling 19.01.2009 LakeView

Time: 9:45 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH1 KITCHEN	19.1	4.98	1314	0.7	0.23	959
2	HH1 LAUNDRY	18.7	9.30	1365	0.8	4.18	1009
3	HH1 ALL	19.0	4.48	1792	1.1	0.18	1332
4	HH2 KITCHEN	26.3	8.03	623	0.3	2.62	393
5	HH2 LAUNDRY	22.3	7.28	1639	0.9	3.36	1121

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0910	0.1013	0.0923	10	1030	900	130
2	0.0925	0.1002	0.0942	10	770	600	170
3	0.0898	0.1115	0.0970	10	2170	1450	720
4	0.0924	0.0971	0.0926	15	313	300	13
5	0.0914	0.1009	0.0949	10	950	600	350

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	4.41	4.32		
1	10	4.41	0.16	4.25	425.00
2	10	4.46	0.09	4.37	441.25
3	10	4.43	0.06	4.37	441.37
4	10	4.47	0.05	4.42	446.37
5	10	4.35	0.08	4.27	431.42

Sampling : 19.01.2009 LakeView

Time: 9:45 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH1 KITCHEN	20.7	9.56	1137	0.6	0.07	800
2	HH1 LAUNDRY	22.8	9.51	1697	0.9	4.03	1146
3	HH1 ALL	18.8	8.71	2780	1.7	0.08	2060
4	HH2 KITCHEN	19.0	6.61	858	0.5	0.64	630
5	HH2 LAUNDRY	18.7	9.50	1995	1.2	4.48	1473
6	HH2 ALL	17.0	8.41	1105	0.6	2.50	833

TSS

Sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0920	0.1360	0.0933	10	4400	4270	130
2	0.0914	0.1099	0.0945	10	1850	1540	310
3	0.0901	0.0980	0.0926	10	790	540	250
4	0.0923	0.1010	0.0924	10	870	860	10
5	0.0915	0.1062	0.0941	5	2940	2420	520
6	0.0901	0.0962	0.0910	10	610	520	90

BOD dilution 1:100

Sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	4.42	4.34	0.08	
1	10	4.34	0.06	4.28	420.08
2	10	4.34	0.12	4.22	418.28
3	10	4.33	0.06	4.27	423.22
4	10	4.30	0.08	4.22	418.27
5	10	4.32	0.08	4.24	420.22
6	10	4.38	0.07	4.31	427.24

Sampling 2.02.2009 Mwariki

Time: 9:45 am

sample		temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH1 KITCHEN	21.4	9.41	1089	0.6	1.55	759
2	HH1 LAUNDRY	22.1	8.87	946	0.5	3.22	651
3	HH2 LAUNDRY	22.1	10.01	5050	2.9	3.98	3470
4	HH2 ALL	20.1	8.70	863	0.5	3.11	619

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0908	0.1035	0.0915	10	1270	1200	70
2	0.0905	0.1014	0.0930	10	1090	840	250
3	0.0913	0.1138	0.0985	5	4500	3060	1440
4	0.0913	0.1104	0.0995	20	955	545	410

BOD dilution 1:100

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	5.20	4.52	0.68	
1	10	5.08	0.21	4.87	419.68
2	10	5.12	0.16	4.96	432.87
3	10	5.03	0.04	4.99	435.96
4	10	5.06	0.10	4.96	432.99

Sampling 7.02.2009 all areas (source water)

Time: from 8:30 am to 10:00am

sample	household	source	area	temp. [°C]	pH	EC [µS/cm]	salinity [g/l]	DO [mg/l]	TDS [mg/l]
1	HH 22	tap	Lake View	26.2	6.87	482	0.2	3.50	305
2	HH 26	tap	Mbugua	26.4	7.03	516	0.2	3.50	328
3	HH 16	tap	Kwa Rhoda	22.2	7.28	310	0.2	4.87	212
4	HH 14	tap	Kaptembwo	23.4	7.03	303	0.2	3.47	204
5	HH 1	storage container	Kaptembwo	21.9	7.34	323	0.2	4.02	223

TSS

sample	empty[g]	dry[g]	AFDW[g]	volume [ml]	TSS [mg/l]	organic content [mg/l]	inorganic [mg/l]
1	0.0920	0.0932	0.0920	250	4.8	4.8	0.0
2	0.0919	0.0924	0.0919	250	2	2.0	0.0
3	0.0913	0.0918	0.0914	250	2	1.6	0.4
4	0.0910	0.0913	0.0910	250	1.2	1.2	0.0
5	0.0910	0.0915	0.0911	250	2	1.6	0.4

BOD dilution 1:1.5

sample	V [ml]	O_2 day1 [mg/l]	O_2 day5 [mg/l]	O_2 demand [mg/l]	BOD [mg/l]
Blank	0	4.02	3.78	0.24	
1	200	5.47	2.57	2.9	13.54
2	200	5.22	3.58	1.64	9.90
3	200	6.48	3.96	2.52	13.04
4	200	5.42	2.91	2.51	13.87
5	200	5.56	4.41	1.15	7.06

Table 34: Standard calibration curves for nutrients

standard calibration curve nitrate-nitrogen (NO_3-N)				
	extinction (420nm)			
concentration in mg/l	1	2.000	3	mean
0.00	0.001	0.002	0.002	0.002
0.25	0.083	0.084	0.084	0.084
0.50	0.194	0.193	0.193	0.193
1.00	0.368	0.369	0.369	0.369
2.50	0.885	0.886	0.887	0.886
5.00	1.804	1.802	1.803	1.803

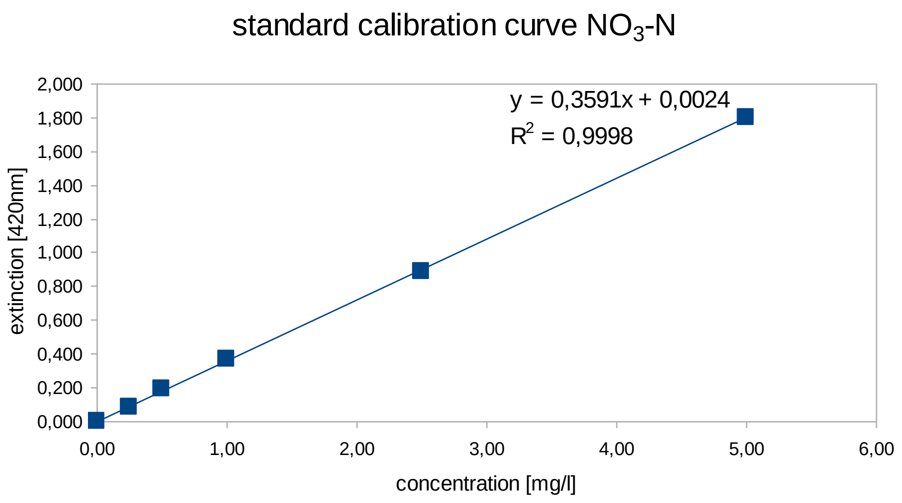

Figure 35: Standard calibration curve nitrate-nitrogen

standard calibration curve nitrite-nitrogen (NO_2-N)				
	extinction (543nm)			
concentration in mg/l	1	2.000	3	mean
0.00	0.002	0.002	0.002	0.002
0.02	0.010	0.010	0.011	0.010
0.05	0.024	0.024	0.023	0.024
0.10	0.043	0.043	0.044	0.043
0.20	0.083	0.083	0.082	0.083
0.50	0.205	0.206	0.206	0.206

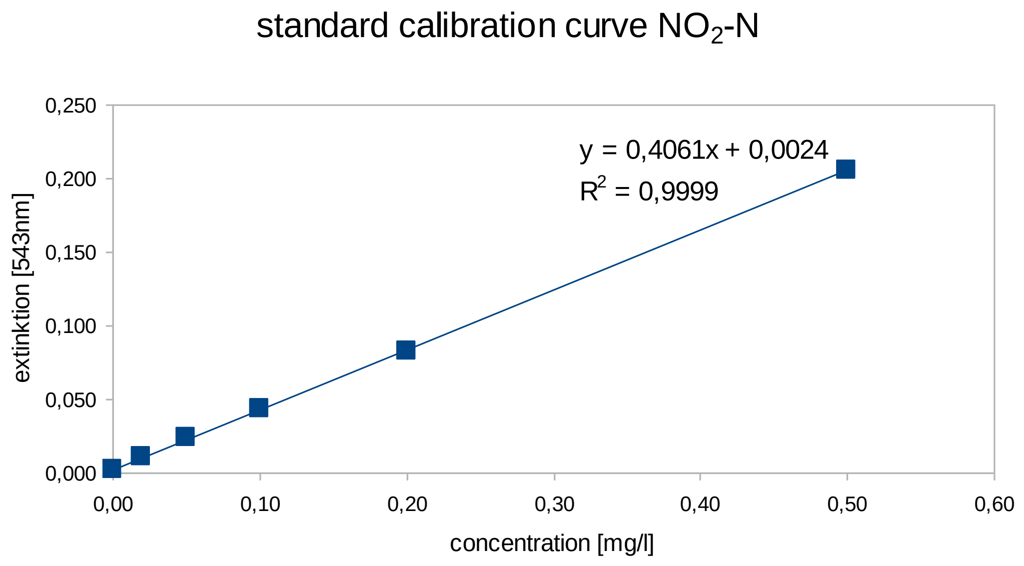

Figure 36: Standard calibration curve nitrite-nitrogen

standard calibration curve ammonium-nitrogen (NH_4-N)				
	extinction (655nm)			
concentration in mg/l	1	2	3	mean
0.00	0.015	0.015	0.016	0.015
0.01	0.025	0.025	0.025	0.025
0.02	0.037	0.037	0.036	0.037
0.05	0.064	0.064	0.064	0.064
0.10	0.115	0.115	0.112	0.114
0.25	0.268	0.268	0.267	0.268

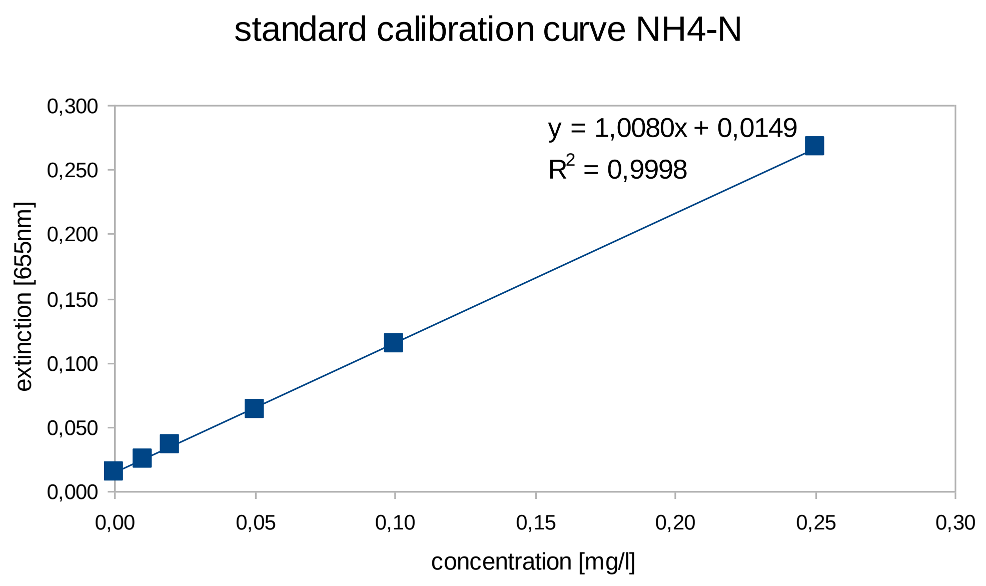

Figure 37: Standard calibration curve ammonium-nitrogen

standard calibration curve soluble reactive phosphorus (SRP)				
	extinction (885nm)			
concentration in mg/l	1	2	3	mean
0.00	0.001	0.001	0.002	0.001
0.01	0.006	0.006	0.006	0.006
0.02	0.013	0.013	0.014	0.013
0.05	0.034	0.035	0.036	0.035
0.10	0.066	0.067	0.067	0.067
0.20	0.129	0.130	0.130	0.130
0.40	0.253	0.253	0.254	0.253
0.50	0.322	0.322	0.321	0.322

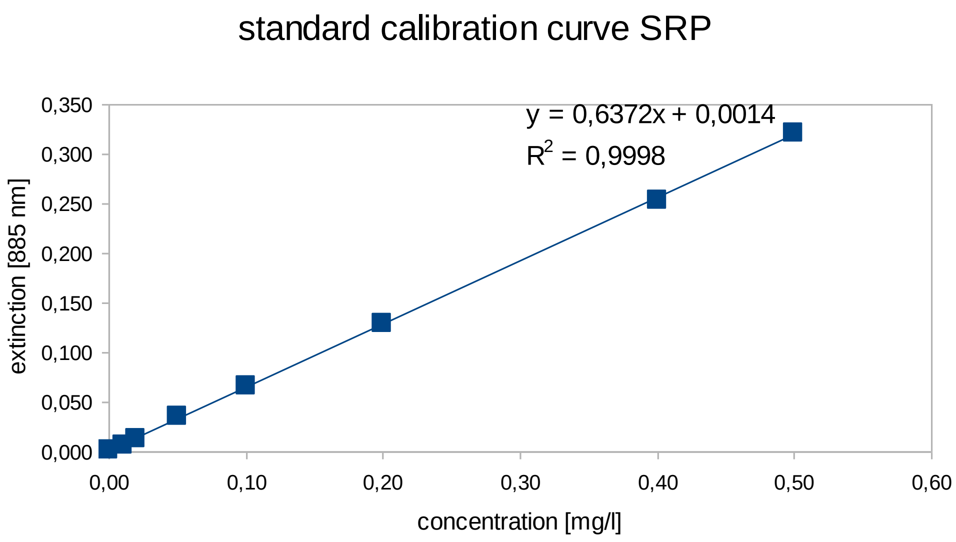

Figure 38: Standard calibration curve SRP

standard calibration curve total phosphorus (TP)				
	extinction (885nm)			
concentration in mg/l	1	2	3	mean
0.00	0.001	0.001	0.002	0.001
0.01	0.006	0.006	0.007	0.006
0.02	0.013	0.013	0.014	0.013
0.05	0.034	0.034	0.035	0.034
0.10	0.064	0.065	0.065	0.065
0.20	0.129	0.129	0.130	0.129
0.40	0.252	0.252	0.253	0.252
0.50	0.312	0.313	0.313	0.313

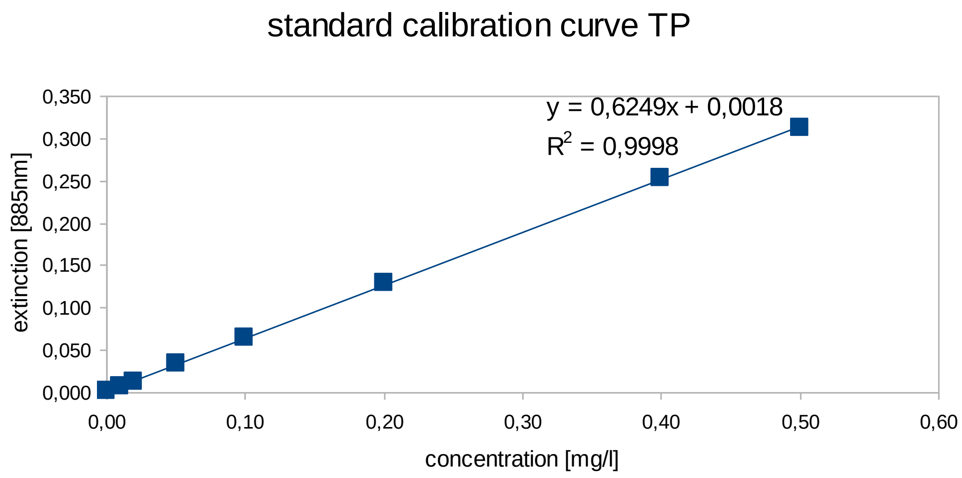

Figure 39: Standard calibration curve TP

Table 35: Calculation of nutrients' concentrations

Sampling: 27.10.2008 Kaptembwo

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018

R^2= 0.9998   x=(y-0.0018)/ 0.6249

samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.604	0.590	0.597	5	2.983	4.77
2	0.255	0.243	0.249	5	1.243	1.99
3	0.911	0.935	0.923	5	4.613	7.38
4	0.898	0.882	0.890	5	4.448	7.11
5	1.679	1.705	1.692	5	8.458	13.53
Std. [conc. 0.50mg/l]	0.324	0.339	0.332	1	0.331	0.53

Soluble reactive phosphorus (SRP)

samples	extinction (885nm)			concentration [mg/l]
	1	2	mean	
Blank	0.001	0.002	0.002	0.00
1	0.894	0.872	0.883	1.38
2	0.384	0.387	0.386	0.60
3	1.182	1.196	1.189	1.86
4	0.529	0.540	0.535	0.83
5	0.921	0.892	0.907	1.42
Std [conc. 0.50mg/l]	0.346	0.341	0.344	0.53

f(x) = 0.6372x + 0.0014

R^2= 0.9998

x=(y-0.0014)/ 0.6372

Ammonium-nitrogen (NH_4-N)

samples	extinction (655nm)			concentration [mg/l]
	1	2	mean	
Blank	0.013	0.013	0.013	0.00
1	0.912	0.907	0.910	0.87
2	2.583	2.553	2.568	2.52
3	3.000	3.000	3.000	2.95
4	0.135	0.134	0.135	0.11
5	0.340	0.338	0.339	0.31
Std [conc. 0.25mg/l]	0.255	0.256	0.256	0.23

$f(x) = 1.0080x + 0.0149$

$R^2= 0.9998$

x=(y-0.0149))/ 1.0080

Nitrate-nitrogen (NO_3-N)

samples	extinction (420nm)			concentration [mg/l]
	1	2	mean	
Blank	0.002	0.002	0.002	0.00
1	0.193	0.157	0.175	0.48
2	0.150	0.154	0.152	0.41
3	0.214	0.227	0.221	0.60
4	0.240	0.239	0.240	0.65
5	0.570	0.580	0.575	1.59
Std [conc. 5mg/l]	1.808	1.787	1.798	4.99

$f(x) = 0.3591x + 0.0024$

$R^2 = 0.9998$

$x= (y-0.0024)/0.3591$

Nitrite-nitrogen (NO_2-N)

samples	extinction (543nm)			concentration [mg/l]
	1	2	mean	
Blank	0.002	0.003	0.003	0.00
1	0.083	0.086	0.085	0.20
2	0.456	0.452	0.454	1.11
3	0.844	0.855	0.850	2.09
4	0.174	0.171	0.173	0.42
5	1.541	1.596	1.569	3.86
Std [conc. 0.50 mg/l]	0.223	0.220	0.222	0.54

$f(x) = 0.4061x + 0.0024$

$R^2 = 0.9999$

$x=(y-0.0024)/0.4061$

Sampling: 03.11.2008 Kaptembwo

Total phosphorus (TP)

$f(x) = 0.6249x + 0.0018$ $x=(y-0.0018)/ 0.6249$

$R^2= 0.9998$

samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.003	0.002	0.003	1	0.003	0.00
1	1.098	1.124	1.111	5	5.543	8.87
2	1.542	1.334	1.438	5	7.178	11.48
3	0.245	0.260	0.253	5	1.250	2.00
4	1.075	1.680	1.378	5	6.875	11.00
Std. [conc. 0.50mg/l]	0.327	0.327	0.327	1	0.325	0.52

Soluble reactive phosphorus (SRP)

$f(x) = 0.6372x + 0.0014$ $x=(y-0.0014)/ 0.6372$

$R^2= 0.9998$

samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.002	0.002	1	0.002	0.00
1	0.520	0.534	0.527	5	2.625	4.12
2	0.549	0.584	0.567	5	2.823	4.43
3	0.108	0.109	0.109	1	0.107	0.16
4	0.855	0.901	0.878	5	4.380	6.87
Std. [conc. 0.50mg/l]	0.314	0.341	0.328	1	0.326	0.51

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.015	0.011	0.013	1	0.013	0.00
1	0.198	0.197	0.198	5	0.923	0.90
2	0.777	0.780	0.779	10	7.655	7.58
3	0.046	0.046	0.046	5	0.165	0.15
4	1.755	1.733	1.744	10	17.310	17.16
Std. [conc. 0.25mg/l]	0.265	0.266	0.266	1	0.253	0.24

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.003	0.002	0.003	1	0.003	0.00
1	0.720	0.718	0.719	5	3.583	9.97
2	0.167	0.164	0.166	5	0.815	2.26
3	0.049	0.050	0.050	5	0.235	0.65
4	0.165	0.160	0.163	5	0.800	2.22
Std [conc. 5 mg/l]	1.798	1.802	1.800	1	1.798	5.00

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2= 0.9999$

samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.003	0.003	1	0.003	0.00
1	1.036	1.037	1.037	1	1.034	2.54
2	0.764	0.771	0.768	5	3.825	9.41
3	0.436	0.440	0.438	1	0.436	1.07
4	0.432	0.420	0.426	5	2.118	5.21
Std [conc. 0.5mg/l]	0.210	0.213	0.212	1	0.209	0.51

Sampling: 10.11.2008
Kaptembwo

Total phosphorus (TP)

$f(x) = 0.6249x + 0.0018$ $x=(y-0.0018)/ 0.6249$

$R^2= 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.002	0.001	0.002	1	0.002	0.00
1	0.932	0.966	0.949	5	4.738	7.58
2	0.278	0.287	0.283	10	2.810	4.49
3	0.841	0.834	0.838	10	8.360	13.38
4	1.413	1.458	1.436	10	14.340	22.94
Std. [conc. 0.50mg/l]	0.296	0.306	0.301	1	0.300	0.48

Soluble reactive phosphorus (SRP)

$f(x) = 0.6372x + 0.0014$ $x=(y-0.0014)/ 0.6372$

$R^2= 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	0.545	0.549	0.547	1	0.546	0.85
2	0.132	0.132	0.132	5	0.653	1.02
3	1.472	0.482	0.977	5	4.878	7.65
4	0.474	0.478	0.476	10	4.745	7.44
Std. [conc. 0.50mg/l]	0.325	0.330	0.328	1	0.326	0.51

Ammonium-nitrogen (NH_4-N)

(x) = 1.0080x + 0.0149

x=(y-0.0149))/ 1.0080

R^2= 0.9998

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.012	0.011	0.012	1	0.012	0.00
1	0.675	0.665	0.670	10	6.585	6.52
2	0.445	0.442	0.444	10	4.320	4.27
3	0.184	0.184	0.184	10	1.725	1.70
4	1.348	1.348	1.348	25	33.413	33.13
Std. [conc. 0.25mg/l]	0.252	0.250	0.251	1	0.240	0.22

Nitrate-nitrogen (NO_3-N)

f(x) = 0.3591x + 0.0024

x= (y-0.0024)/0.3591

R^2 = 0.9998

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	1.121	0.118	0.620	10	6.180	17.20
2	0.022	0.023	0.023	10	0.210	0.58
3	0.107	0.107	0.107	10	1.055	2.93
4	0.090	0.089	0.090	10	0.880	2.44
Std [conc.5 mg/l]	1.788	1.795	1.792	1	1.790	4.98

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$

$x=(y-0.0024)/0.4061$

$R^2= 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.887	0.897	0.892	25	22.288	54.88
2	0.421	0.408	0.415	5	2.070	5.09
3	0.345	0.341	0.343	5	1.713	4.21
4	0.478	0.495	0.487	10	4.860	11.96
Std [conc. 0.50 mg/l]	0.200	0.201	0.201	1	0.200	0.49

Sampling: 17.11.2008 Kaptembwo

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018   x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.000	0.000	0.000	1	0.000	0.00
1	0.830	0.838	0.834	5	4.170	6.67
2	0.797	0.800	0.799	10	7.985	12.78
3	0.372	0.380	0.376	5	1.880	3.01
4	1.380	1.348	1.364	10	13.640	21.82
5	1.330	1.351	1.341	5	6.703	10.72
Std. [conc. 0.50mg/l]	0.296	0.306	0.301	1	0.301	0.48

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014   x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.498	0.511	0.505	5	2.518	3.95
2	0.263	0.260	0.262	10	2.605	4.09
3	0.148	0.150	0.149	5	0.740	1.16
4	0.353	0.355	0.354	10	3.530	5.54
5	0.651	0.653	0.652	5	3.255	5.11
Std. [conc. 0.50mg/l]	0.291	0.308	0.310	1	0.309	0.48

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.015	0.014	0.015	1	0.015	0.00
1	0.568	0.583	0.576	10	5.610	5.55
2	0.483	0.493	0.488	10	4.735	4.68
3	0.103	0.100	0.102	10	0.870	0.85
4	0.820	0.821	0.821	10	8.060	7.98
5	0.888	0.903	0.896	50	44.050	43.69
Std. [conc. 0.25mg/l]	0.252	0.250	0.251	1	0.237	0.22

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.302	0.291	0.297	10	2.955	8.22
2	0.128	0.128	0.128	10	1.270	3.53
3	0.060	0.068	0.064	10	0.630	1.75
4	0.077	0.077	0.077	10	0.760	2.11
5	0.012	0.013	0.013	10	0.115	0.31
Std [conc.5 mg/l]	1.714	1.785	1.790	1	1.789	4.98

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2= 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.000	0.001	1	0.001	0.00
1	0.158	0.160	0.159	10	1.585	3.90
2	0.090	0.087	0.089	10	0.880	2.16
3	0.112	0.110	0.111	10	1.105	2.72
4	0.255	0.260	0.258	10	2.570	6.32
5	0.168	0.170	0.169	10	1.685	4.14
Std [conc. 0.50 mg/l]	0.223	0.220	0.222	1	0.221	0.54

Sampling: 23.11.2008
Kaptembwo

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018 x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.002	0.001	1	0.001	0.00
1	0.450	0.440	0.445	10	4.440	7.10
2	0.741	0.742	0.742	10	7.405	11.85
3	0.308	0.330	0.319	10	3.180	5.09
4	0.579	0.570	0.575	10	5.735	9.17
Std. [conc. 0.50mg/l]	0.301	0.319	0.310	1	0.309	0.49

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014 x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.000	0.000	1	0.000	0.00
1	0.375	0.372	0.374	10	3.735	5.86
2	0.495	0.515	0.505	10	5.050	7.92
3	0.159	0.147	0.153	10	1.530	2.40
4	0.346	0.350	0.348	10	3.480	5.46
Std. [conc. 0.50mg/l]	0.311	0.311	0.311	1	0.311	0.49

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.013	0.012	0.013	1	0.013	0.00
1	0.241	0.244	0.243	10	2.300	2.27
2	0.722	0.776	0.749	50	36.825	36.52
3	0.190	0.196	0.193	10	1.805	1.78
4	1.020	0.965	0.993	10	9.800	9.71
Std. [conc. 0.25mg/l]	0.250	0.280	0.265	1	0.253	0.24

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.003	0.004	0.004	1	0.004	0.00
1	0.433	0.436	0.435	10	4.310	12.00
2	0.275	0.215	0.245	10	2.415	6.72
3	0.075	0.068	0.072	10	0.680	1.89
4	0.088	0.086	0.087	10	0.835	2.32
Std [conc.5 mg/l]	1.801	1.805	1.803	1	1.800	5.00

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2 = 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.014	0.014	0.014	10	0.135	0.33
2	0.130	0.130	0.130	10	1.295	3.18
3	1.066	1.093	1.080	10	10.790	26.56
4	0.423	0.411	0.417	10	4.165	10.25
Std [conc. 0.50 mg/l]	0.210	0.208	0.209	1	0.209	0.51

Sampling: 1.12.2008
Kaptembwo

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018   x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.000	0.000	1	0.000	0.00
1	0.219	0.224	0.222	10	2.215	3.54
2	0.253	0.261	0.257	10	2.570	4.11
3	1.330	1.364	1.347	10	13.470	21.55
4	1.883	1.891	1.887	10	18.870	30.19
Std. [conc. 0.50mg/l]	0.298	0.305	0.302	1	0.302	0.48

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014   x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.142	0.146	0.144	5	0.715	1.12
2	0.084	0.089	0.087	10	0.855	1.34
3	0.381	0.390	0.386	10	3.845	6.03
4	0.781	0.802	0.792	10	7.905	12.40
Std. [conc. 0.50mg/l]	0.308	0.309	0.309	1	0.308	0.48

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.015	0.019	0.017	1	0.017	0.00
1	0.084	0.084	0.084	10	0.670	0.65
2	0.286	0.279	0.283	10	2.655	2.62
3	0.336	0.340	0.338	10	3.210	3.17
4	0.923	0.932	0.928	50	45.525	45.15
Std. [conc. 0.25mg/l]	0.270	0.275	0.273	1	0.256	0.24

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.003	0.002	1	0.002	0.00
1	1.725	1.730	1.728	1	1.726	4.80
2	0.054	0.056	0.055	1	0.053	0.14
3	0.865	0.856	0.861	1	0.859	2.38
4	0.521	0.535	0.528	10	5.260	14.64
Std [conc.5 mg/l]	1.801	1.798	1.800	1	1.798	5.00

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2 = 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.039	0.041	0.040	10	0.395	0.97
2	0.031	0.031	0.031	10	0.305	0.75
3	0.033	0.032	0.033	10	0.320	0.78
4	0.270	0.279	0.275	10	2.740	6.74
Std [conc. 0.50 mg/l]	0.205	0.198	0.202	1	0.201	0.49

Sampling: 15.12.2008 Kaptembwo

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018 x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.002	0.001	1	0.001	0.00
1	0.390	0.394	0.392	10	3.910	6.25
2	0.263	0.255	0.259	10	2.580	4.13
3	0.423	0.417	0.420	10	4.190	6.70
4	0.578	0.580	0.579	25	14.450	23.12
5	0.572	0.567	0.570	25	14.213	22.74
6	0.458	0.462	0.460	10	4.590	7.34
Std. [conc. 0.50mg/l]	0.305	0.298	0.302	1	0.301	0.48

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014 x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.260	0.268	0.264	10	2.635	4.13
2	0.155	0.161	0.158	10	1.575	2.47
3	0.284	0.278	0.281	10	2.805	4.40
4	0.397	0.394	0.396	25	9.875	15.50
5	0.265	0.272	0.269	25	6.700	10.51
6	0.306	0.314	0.310	10	3.095	4.85
Std. [conc. 0.50mg/l]	0.306	0.301	0.304	1	0.303	0.47

Ammonium-nitrogen (NH4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.015	0.013	0.014	1	0.014	0.00
1	0.222	0.218	0.220	10	2.060	2.03
2	1.011	1.018	1.015	10	10.005	9.91
3	0.671	0.673	0.672	10	6.580	6.51
4	0.180	0.183	0.182	50	8.375	8.29
5	0.262	0.264	0.263	50	12.450	12.34
6	1.306	1.310	1.308	10	12.940	12.82
Std. [conc. 0.25mg/l]	0.268	0.270	0.269	1	0.255	0.24

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.003	0.003	1	0.003	0.00
1	0.936	0.940	0.938	1	0.936	2.60
2	1.042	0.989	1.016	1	1.013	2.81
3	0.343	0.340	0.342	1	0.339	0.94
4	0.392	0.390	0.391	10	3.885	10.81
5	1.051	1.048	1.050	1	1.047	2.91
6	0.103	0.102	0.103	1	0.100	0.27
Std [conc.5 mg/l]	1.815	1.810	1.813	1	1.810	5.03

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2 = 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.000	0.001	0.001	1	0.001	0.00
1	1.052	1.050	1.051	5	5.253	12.93
2	0.342	0.340	0.341	10	3.405	8.38
3	0.115	0.116	0.116	50	5.750	14.15
4	0.184	0.182	0.183	10	1.825	4.49
5	1.316	1.293	1.305	10	13.040	32.10
6	0.104	0.102	0.103	5	0.513	1.26
Std [conc. 0.50 mg/l]	0.207	0.203	0.205	1	0.205	0.50

Sampling: 22.12.2008 Kwa Rhonda

Time: 8:40 am

Total phosphorus (TP)

$f(x) = 0.6249x + 0.0018$ $x=(y-0.0018)/ 0.6249$

$R^2 = 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.002	0.001	0.002	1	0.002	0.00
1	0.348	0.360	0.354	10	3.525	5.64
2	0.688	0.693	0.691	10	6.890	11.02
3	0.529	0.521	0.525	25	13.088	20.94
4	0.199	0.195	0.197	10	1.955	3.13
Std. [conc. 0.50mg/l]	0.316	0.317	0.317	1	0.315	0.50

Soluble reactive phosphorus (SRP)

$f(x) = 0.6372x + 0.0014$ $x=(y-0.0014)/ 0.6372$

$R^2 = 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.002	0.001	0.002	1	0.002	0.00
1	0.035	0.032	0.034	10	0.320	0.50
2	0.501	0.503	0.502	10	5.005	7.85
3	0.112	0.118	0.115	25	2.838	4.45
4	0.038	0.038	0.038	10	0.365	0.57
Std. [conc. 0.50mg/l]	0.306	0.311	0.309	1	0.307	0.48

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.013	0.010	0.012	1	0.012	0.00
1	0.847	0.850	0.849	10	8.370	8.29
2	0.931	0.934	0.933	10	9.210	9.12
3	1.882	1.885	1.884	50	93.600	92.84
4	0.301	0.298	0.300	10	2.880	2.84
Std. [conc. 0.25mg/l]	0.308	0.298	0.303	1	0.292	0.27

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.005	0.003	0.004	1	0.004	0.00
1	0.060	0.056	0.058	10	0.540	1.50
2	0.154	0.130	0.142	10	1.380	3.84
3	0.433	0.438	0.436	20	8.630	24.03
4	0.893	0.901	0.897	1	0.893	2.48
Std [conc.5 mg/l]	1.815	1.816	1.816	1	1.812	5.04

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2 = 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.706	0.696	0.701	5	3.500	8.61
2	0.143	0.140	0.142	5	0.703	1.72
3	0.193	0.192	0.193	5	0.958	2.35
4	0.542	0.538	0.540	5	2.695	6.63
Std [conc. 0.50 mg/l]	0.210	0.215	0.213	1	0.212	0.51

Sampling: 05.01.2009 Kwa Rhonda

Time: 9:10 am

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018 x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.625	0.623	0.624	25	15.575	24.92
2	1.083	1.071	1.077	1	1.076	1.72
3	0.515	0.517	0.516	5	2.575	4.12
4	1.128	1.130	1.129	5	5.640	9.02
Std. [conc. 0.50mg/l]	0.307	0.303	0.305	1	0.304	0.48

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014 x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.483	0.484	0.484	25	12.075	18.95
2	0.501	0.504	0.503	1	0.502	0.79
3	0.158	0.161	0.160	5	0.795	1.25
4	0.470	0.474	0.472	5	2.358	3.70
Std. [conc. 0.50mg/l]	0.305	0.310	0.308	1	0.307	0.48

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.019	0.011	0.015	1	0.015	0.00
1	0.494	0.503	0.499	25	12.088	11.98
2	0.302	0.303	0.303	5	1.438	1.41
3	0.162	0.167	0.165	10	1.495	1.47
4	0.641	0.638	0.640	10	6.245	6.18
Std. [conc. 0.25mg/l]	0.298	0.300	0.299	1	0.284	0.27

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.003	0.002	0.003	1	0.003	0.00
1	1.881	1.878	1.880	1	1.877	5.22
2	0.768	0.762	0.765	1	0.763	2.12
3	1.424	1.427	1.426	1	1.423	3.96
4	0.155	0.147	0.151	4	0.594	1.65
Std [conc.5 mg/l]	1.808	1.805	1.807	1	1.804	5.02

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2 = 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.382	0.383	0.383	5	1.908	4.69
2	0.320	0.324	0.322	5	1.605	3.95
3	0.363	0.360	0.362	5	1.803	4.43
4	0.606	0.610	0.608	5	3.035	7.47
Std [conc. 0.50 mg/l]	0.213	0.210	0.212	1	0.211	0.51

Sampling: 12.01.2009 Kwa Rhonda

Time: 9:22 am

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018 x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	1.303	1.302	1.303	5	6.510	10.41
2	0.575	0.561	0.568	5	2.838	4.54
3	1.009	0.995	1.002	5	5.008	8.01
4	0.206	0.201	0.204	5	1.015	1.62
Std. [conc. 0.50mg/l]	0.310	0.308	0.309	1	0.309	0.49

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014 x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.005	0.003	0.004	1	0.004	0.00
1	0.398	0.403	0.401	5	1.983	3.11
2	0.298	0.282	0.290	5	1.430	2.24
3	0.413	0.414	0.414	5	2.048	3.21
4	0.087	0.084	0.086	5	0.408	0.64
Std. [conc. 0.50mg/l]	0.319	0.320	0.320	1	0.316	0.49

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.018	0.012	0.015	1	0.015	0.00
1	1.228	1.230	1.229	10	12.140	12.03
2	0.261	0.262	0.262	10	2.465	2.43
3	0.111	0.110	0.111	10	0.955	0.93
4	0.058	0.057	0.058	10	0.425	0.41
Std. [conc. 0.25mg/l]	0.285	0.289	0.287	1	0.272	0.26

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.004	0.003	0.004	1	0.004	0.00
1	1.078	1.067	1.073	4	4.276	11.90
2	0.263	0.260	0.262	4	1.032	2.87
3	0.379	0.373	0.376	4	1.490	4.14
4	0.164	0.159	0.162	4	0.632	1.75
Std [conc.5 mg/l]	1.788	1.790	1.789	1	1.786	4.97

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$

$R^2 = 0.9999$

$x=(y-0.0024)/0.4061$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.154	0.159	0.157	5	0.780	1.91
2	0.981	0.977	0.979	5	4.893	12.04
3	0.283	0.282	0.283	5	1.410	3.47
4	0.988	0.993	0.991	5	4.950	12.18
Std [conc. 0.50 mg/l]	0.197	0.195	0.196	1	0.196	0.48

Sampling: 19.01.2009 Lake View

Time: 9:45 am

Total phosphorus (TP)

$f(x) = 0.6249x + 0.0018$ $x=(y-0.0018)/ 0.6249$

$R^2= 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	0.791	0.798	0.795	10	7.930	12.69
2	0.389	0.396	0.393	10	3.910	6.25
3	0.680	0.682	0.681	10	6.795	10.87
4	0.107	0.103	0.105	5	0.518	0.83
5	0.690	0.691	0.691	10	6.890	11.02
Std. [conc. 0.50mg/l]	0.308	0.311	0.310	1	0.308	0.49

Soluble reactive phosphorus (SRP)

$f(x) = 0.6372x + 0.0014$ $x=(y-0.0014)/ 0.6372$

$R^2= 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	0.357	0.360	0.359	10	3.570	5.60
2	0.176	0.180	0.178	10	1.765	2.77
3	0.325	0.325	0.325	10	3.235	5.07
4	0.024	0.023	0.024	5	0.110	0.17
5	0.476	0.475	0.476	10	4.740	7.44
Std. [conc. 0.50mg/l]	0.306	0.307	0.307	1	0.305	0.48

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.014	0.015	0.015	1	0.015	0.00
1	0.473	0.470	0.472	10	4.570	4.52
2	0.551	0.548	0.550	10	5.350	5.29
3	0.824	0.830	0.827	10	8.125	8.05
4	0.048	0.053	0.051	5	0.180	0.16
5	1.033	1.038	1.036	10	10.210	10.11
Std. [conc. 0.25mg/l]	0.295	0.287	0.291	1	0.277	0.26

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.002	0.002	1	0.002	0.00
1	0.172	0.175	0.174	4	0.686	1.90
2	0.408	0.411	0.410	4	1.630	4.53
3	0.147	0.150	0.149	4	0.586	1.63
4	0.420	0.418	0.419	4	1.668	4.64
5	0.268	0.210	0.239	4	0.948	2.63
Std [conc. 5 mg/l]	1.805	1.802	1.804	1	1.802	5.01

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2= 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	0.064	0.067	0.066	5	0.320	0.78
2	0.899	0.906	0.903	5	4.505	11.09
3	0.047	0.045	0.046	5	0.223	0.54
4	0.171	0.172	0.172	5	0.850	2.09
5	1.360	1.399	1.380	6	8.268	20.35
Std [conc. 0.50 mg/l]	0.201	0.198	0.200	1	0.198	0.48

Data 26.01.2009 LakeView

Time: 8:45 am

Total phosphorus (TP)

$f(x) = 0.6249x + 0.0018$ $x=(y-0.0018)/ 0.6249$

$R^2= 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	0.478	0.475	0.477	10	4.750	7.60
2	0.567	0.570	0.569	10	5.670	9.07
3	0.632	0.630	0.631	25	15.738	25.18
4	0.753	0.758	0.756	5	3.770	6.03
5	0.582	0.583	0.583	10	5.810	9.29
6	0.389	0.390	0.390	10	3.880	6.21
Std. [conc. 0.50mg/l]	0.309	0.306	0.308	1	0.306	0.49

Soluble reactive phosphorus (SRP)

$f(x) = 0.6372x + 0.0014$ x=(y-0.0014)/ 0.6372

$R^2 = 0.9998$

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0..003	0.001	1	0.001	0.00
1	0.214	0.216	0.215	10	2.140	3.36
2	0.230	0.230	0.230	10	2.290	3.59
3	0.420	0.425	0.423	25	10.538	16.53
4	0.388	0.390	0.389	5	1.940	3.04
5	0.331	0.331	0.331	10	3.300	5.18
6	0.268	0.267	0.268	10	2.665	4.18
Std. [conc. 0.50mg/l]	0.312	0.314	0.313	1	0.312	0.49

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ x=(y-0.0149))/ 1.0080

$R^2 = 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.018	0.015	0.017	1	0.017	0.00
1	0.398	0.395	0.397	10	3.800	3.76
2	0.859	0.864	0.862	10	8.450	8.37
3	2.753	2.759	2.756	10	27.395	27.16
4	0.482	0.478	0.480	10	4.635	4.58
5	1.038	1.045	1.042	10	10.250	10.15
6	0.681	0.685	0.683	10	6.665	6.60
Std. [conc. 0.25mg/l]	0.280	0.278	0.279	1	0.263	0.25

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.003	0.003	0.003	1	0.003	0.00
1	0.206	0.198	0.202	4	0.796	2.21
2	0.518	0.517	0.518	4	2.058	5.72
3	0.108	0.103	0.106	4	0.410	1.14
4	0.919	0.922	0.921	4	3.670	10.21
5	0.297	0.389	0.343	4	1.360	3.78
6	0.199	0.203	0.201	4	0.792	2.20
Std [conc.5 mg/l]	1.809	1.796	1.803	1	1.800	5.00

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2= 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.002	0.002	1	0.002	0.00
1	0.036	0.038	0.037	5	0.175	0.43
2	1.069	1.072	1.071	5	5.343	13.15
3	0.186	0.182	0.184	5	0.910	2.23
4	0.673	0.677	0.675	5	3.365	8.28
5	2.790	2.793	2.792	5	13.948	34.34
6	1.032	1.040	1.036	5	5.170	12.72
Std [conc. 0.50 mg/l]	0.207	0.203	0.205	1	0.203	0.49

Sampling 2.02.2009 Mwariki

Time: 9:45 am

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018   x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.001	0.001	1	0.001	0.00
1	0.643	0.642	0.643	10	6.420	10.27
2	0.374	0.375	0.375	5	1.870	2.99
3	0.139	0.135	0.137	50	6.825	10.92
4	0.328	0.323	0.326	5	1.625	2.60
Std. [conc. 0.50mg/l]	0.320	0.321	0.321	1	0.320	0.51

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014   x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.231	0.235	0.233	10	2.320	3.64
2	0.109	0.108	0.109	5	0.538	0.84
3	0.028	0.030	0.029	50	1.400	2.19
4	0.134	0.135	0.135	5	0.668	1.05
Std. [conc. 0.50mg/l]	0.319	0.320	0.320	1	0.319	0.50

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ $x=(y-0.0149))/ 1.0080$

$R^2= 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.020	0.021	0.021	1	0.021	0.01
1	0.244	0.250	0.247	10	2.265	2.23
2	0.735	0.738	0.737	10	7.160	7.09
3	0.056	0.057	0.057	10	0.360	0.34
4	0.064	0.063	0.064	10	0.430	0.41
Std. [conc. 0.25mg/l]	0.275	0.278	0.277	1	0.256	0.24

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ $x= (y-0.0024)/0.3591$

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.001	0.002	1	0.002	0.00
1	0.320	0.318	0.319	4	1.270	3.53
2	0.443	0.446	0.445	4	1.772	4.93
3	0.613	0.610	0.612	4	2.440	6.79
4	0.412	0.405	0.409	4	1.628	4.53
Std [conc.5 mg/l]	1.794	1.785	1.790	1	1.788	4.97

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$ $x=(y-0.0024)/0.4061$

$R^2= 0.9999$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.000	0.002	0.001	1	0.001	0.00
1	0.828	0.832	0.830	5	4.145	10.20
2	0.803	0.810	0.807	5	4.028	9.91
3	1.825	1.835	1.830	5	9.145	22.51
4	0.170	0.165	0.168	5	0.833	2.04
Std [conc. 0.50 mg/l]	0.201	0.210	0.206	1	0.205	0.50

Sampling: 7.02.2009 source water all areas

Time: 8:30 am – 10:00 am

Total phosphorus (TP)

f(x) = 0.6249x + 0.0018 x=(y-0.0018)/ 0.6249

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	0.028	0.029	0.029	1	0.028	0.04
2	0.031	0.030	0.031	1	0.030	0.04
3	0.027	0.025	0.026	1	0.025	0.04
4	0.026	0.026	0.026	1	0.025	0.04
5	0.024	0.024	0.024	1	0.023	0.03
Std. [conc. 0.50mg/l]	0.321	0.322	0.322	1	0.321	0.51

Soluble reactive phosphorus (SRP)

f(x) = 0.6372x + 0.0014 x=(y-0.0014)/ 0.6372

R^2= 0.9998

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	0.031	0.033	0.032	1	0.031	0.05
2	0.045	0.044	0.045	1	0.043	0.07
3	0.045	0.045	0.045	1	0.044	0.07
4	0.038	0.032	0.035	1	0.034	0.05
5	0.035	0.032	0.034	1	0.032	0.05
Std. [conc. 0.50mg/l]	0.311	0.315	0.313	1	0.312	0.49

Ammonium-nitrogen (NH_4-N)

$f(x) = 1.0080x + 0.0149$ x=(y-0.0149))/ 1.0080

$R^2 = 0.9998$

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.027	0.028	0.028	1	0.028	0.01
1	0.039	0.036	0.038	1	0.010	0.00
2	0.039	0.041	0.040	1	0.013	0.00
3	0.050	0.047	0.049	1	0.021	0.01
4	0.051	0.052	0.052	1	0.024	0.01
5	0.037	0.038	0.038	1	0.010	0.00
Std. [conc. 0.25mg/l]	0.290	0.289	0.290	1	0.262	0.25

Nitrate-nitrogen (NO_3-N)

$f(x) = 0.3591x + 0.0024$ x= (y-0.0024)/0.3591

$R^2 = 0.9998$

Samples	extinction (420nm)			dilution	extinction (420nm)	concentration [mg/l]
	1	2	mean		y	X
Blank	0.002	0.001	0.002	1	0.002	0.00
1	1.690	1.693	1.692	1	1.690	4.70
2	1.596	1.594	1.595	1	1.594	4.43
3	1.070	1.078	1.074	1	1.073	2.98
4	1.158	1.148	1.153	1	1.152	3.20
5	1.256	1.260	1.258	1	1.257	3.49
Std [conc. 5 mg/l]	1.794	1.790	1.792	1	1.791	4.98

Nitrite-nitrogen (NO_2-N)

$f(x) = 0.4061x + 0.0024$

$R^2 = 0.9999$

$x=(y-0.0024)/0.4061$

Samples	extinction (543nm)			dilution	extinction (543nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.000	0.001	1	0.001	0.00
1	0.002	0.002	0.002	1	0.002	0.00
2	0.002	0.001	0.002	1	0.001	0.00
3	0.004	0.003	0.004	1	0.003	0.00
4	0.003	0.003	0.003	1	0.003	0.00
5	0.007	0.007	0.007	1	0.007	0.01
Std [conc. 0.50 mg/l]	0.210	0.208	0.209	1	0.209	0.51

Table 36: Determination of faecal coliforms

Sampling 10.11.2008 Kaptembwo

faecal coliforms

sample	number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1	524	78	0.0055	10945455	7.04
2	300	28	0.0055	5963636	6.78
3	492	65	0.0055	10127273	7.01
4	644	85	0.0055	13254545	7.12

Sampling 17.11.2008 Kaptembwo

faecal coliforms

sample	number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1	392	29	0.0055	7654545	6.88
2	16	1	0.0055	309091	5.49
3	540	101	0.0055	11654545	7.07
4	4	0	0.0055	72727	4.86
5	304	42	0.0055	6290909	6.80

Sampling 23.11.2008 Kaptembwo

faecal coliforms

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		704	89	0.0055	14418182	7.16
	dilution	1:10000	1:100000			
2		140	18	0.0006	28727273	7.46
	dilution	1:10	1:100			
3		392	48	0.55	80000	4.90
	dilution	1:10000	1:100000			
4		58	8	0.0006	12000000	7.08

Sampling 1.12.2008 Kaptembwo

faecal coliforms

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		65	8	0.0055	1327273	6.12
	dilution	1:100	1:1000			
2		430	35	0.055	845455	5.93
	dilution	1:1000	1:10000			
3		89	8	0.0055	1763636	6.25
	dilution	1:100	1:1000			
4		92	7	0.055	180000	5.26

Sampling 15.12.2008 Kaptembwo

faecal coliforms

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		71	6	0.0055	1400000	6.15
	dilution	1:100	1:1000			
2		20	2	0.055	40000	4.60
	dilution	1:1000	1:10000			
3		89	8	0.0055	1763636	6.25
	dilution	1:1000	1:10000			
4		0	220	0.0055	4000000	6.60
	dilution	1:100	1:1000			
5		385	36	0.055	765455	5.88
	dilution	1:1000	1:10000			
6		180	20	0.0055	3636364	6.56

Sampling 22.12.2008 Kwa Rhonda

faecal coliforms

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:100	1:1000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		128	15	0.055	260000	5.41
	dilution	1:10000	1:100000			
2		0	77	0.001	14000000	7.15
	dilution	1:100	1:1000			
3		247	25	0.055	494545	5.69
	dilution	1:10000	1:100000			
4		160	29	0.001	34363636	7.54

Sampling 5.01.2009 Kwa Rhonda

Time: 9:10 am

faecal coliforms

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:10000	1:100000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		213	18	0.001	42000000	7.62
	dilution	1:100	1:1000			
2		153	10	0.055	296364	5.47
	dilution	1:10000	1:100000			
3		258	35	0.001	53272727	7.73
	dilution	1:100	1:1000			
4		78	10	0.055	160000	5.20

Sampling 12.01.2009 Kwa Rhonda

Time: 9:22 am

faecal coliforms

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:10000	1:100000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		198	18	0.001	39272727	7.59
	dilution	1:100	1:1000			
2		812	90	0.055	1640000	6.21
	dilution	1:10000	1:100000			
3		792	45	0.001	152181818	8.18
	dilution	1:100	1:1000			
4		700	85	0.055	1427273	6.15

19.01.2009 LakeView
Time: 9:45 am

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:10000	1:100000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		98	9	0.001	19454545	7.29
	dilution	1:100	1:1000			
2		248	32	0.055	509091	5.71
	dilution	1:100000	1:1000000			
3		216	19	0.0001	427272727	8.63
	dilution	1:10000	1:100000			
4		105	11	0.001	21090909	7.32
	dilution	1:100	1:1000			
5		232	28	0.055	472727	5.67

26.01.2009 LakeView

Time: 8:45 am

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		62	6	0.0055	1236364	6.09
	dilution	1:100	1:1000			
2		16	3	0.055	34545	4.54
	dilution	1:1000	1:10000			
3		545	52	0.0055	10854545	7.04
	dilution	1:1000	1:10000			
4		88	6	0.0055	1709091	6.23
	dilution	1:100	1:1000			
5		92	5	0.055	176364	5.25
	dilution	1:1000	1:10000			
6		675	65	0.0055	13454545	7.13

2.02.2009 Mwariki

Time: 9:45 am

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	dilution	1:1000	1:10000	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		58	8	0.0055	1200000	6.08
	dilution	1:100	1:1000			
2		287	22	0.055	561818	5.75
	dilution	1:100	1:1000			
3		63	7	0.055	127273	5.10
	dilution	1:1000	1:10000			
4		97	8	0.0055	1909091	6.28

7.02.2009 all areas source water

Time: 8:30 am – 10:00 am

sample		number of yellow colonies		original sample volume	faecal coliforms	faecal coliforms
	volume	10ml	100ml	A in [ml]	Cs in [cfu/100ml]	log numbers/100ml
1		6	75	110	74	1.87
	volume	10ml	100ml			
2		0	2	110	2	0.26
	volume	10ml	100ml			
3		2	15	110	15	1.19
	volume	10ml	100ml			
4		0	0	110	0	0.00
	volume	10ml	100ml			
5		22	262	110	258	2.41

Table 37: GPS data of sampled households

date	household	zone	accuracy	x	y	altitude
27.10.08	1	37	+/- 15	170811	9967558	1815
	2	37	+/- 8	170848	9967524	1815
03.11.08	3	37	+/- 12	170817	9967582	1817
	4	37	+/- 16	170878	9967504	1817
10.11.08	5	37	+/- 10	171477	9967476	1826
	6	37	+/- 11	171484	9967446	1826
17.11.08	7	37	+/- 15	171492	9967442	1821
	8	37	+/- 14	171611	9967408	1831
23.11.08	9	37	+/- 10	171193	9967522	1831
	10	37	+/- 10	171125	9967538	1834
01.12.08	11	37	+/- 10	171375	9967310	1831
	12	37	+/- 11	171358	9967100	1826
15.12.08	13	37	+/- 12	171706	9967314	1829
	14	37	+/- 16	171671	9967306	1828
22.12.08	15	37	+/- 13	172010	9966902	1824
	16	37	+/- 10	172029	9966860	1824
	17	37	+/- 8	172088	9966818	1824
05.01.09	18	37	+/- 10	172186	9966702	1814
	19	37	+/- 9	172246	9966692	1813
12.01.09	20	37	+/- 10	172944	9966812	1812
	21	37	+/- 8	172878	9966810	1811
19.01.09	22	37	+/- 8	174865	9966230	1808
	23	37	+/- 8	174843	9966208	1808
26.01.09	24	37	+/- 10	174383	9966206	1811
	25	37	+/- 8	174365	9966206	1812
02.02.09	26	37	+/- 11	173534	9965878	1801
	27	37	+/- 13	173674	9965972	1807

Erklärung

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