Household greywater treatment for peri-urban areas of Nakuru Municipality, Kenya

Within the EU funded ROSA-project (Resource oriented Sanitation concepts in peri-urban areas in Africa) different greywater treatment pilot systems were implemented and assessed in Nakuru municipality.

Authors: Raude, Mutua, Chemelil, Kraft, Sleytr

Abstract

Within the EU funded project ROSA (Resource oriented Sanitation concepts in peri-urban areas in Africa) a baseline survey was carried out to asses the current greywater disposal situation, the quantity and quality of greywater in the peri urban areas of Nakuru, Kenya. It was found out that most of the produced greywater is not used, not reused and not treated although contaminated with nutrients and bacteria. Therefore there is a big demand for adequate treatment systems which are implemented within the ROSA project and presented in this article.

Introduction

Around the entire world, insufficient access to safe water and basic sanitation has led to more deaths than in military conflicts. According to estimates by UNDP (2006), for every single minute, over 3 children lose their lives due to diseases related to unsafe water and poor sanitation. The World Health Organization (WHO) attributes 13-17% mortality from diarrhoea for children less than 5 years of age. Safe water and basic sanitation must be regarded as a basic human right and should therefore be accessible and affordable to all (MWI, 2007). To achieve the UN Millennium Development Goals (MDGs) and the national strategy in the Economic Recovery Strategy for Wealth and Employment Creation (ERS-WEC), it is important to address sanitation challenges in urban and peri-urban areas. Kenya faces serious challenges with regard to water and sanitation services. Despite the efforts of investments provided in the past years by the government and development partners, existing facilities have continued to deteriorate and have also failed to meet the demand of the equally increasing population (MWI, 2007). These challenges are particularly severe in many rural and rapidly growing settlements of urban poor where over 60% of the urban populations live. With a population growth of about 8% in the low income urban settlements (MWI, 2007), many unplanned structures still continue to be built.

Greywater (wastewater stream from kitchen, laundry, sinks, bath-tubs and showers) produced by the average household is the largest in volume. When freshly released, it contains a relatively lower number of potentially harmful compounds. Consequently, it is often discharged untreated into a watercourse or any available empty space under the assumption that serious damage might not result. These practices however present potential risks of transmission of a large number of water-related diseases. Hence, there is need for proper management of aquatic resources and also of the pollutants. A sensible management strategy involves analysis of the composition of greywater and creating a barrier through quality improvement before reuse or safe disposal. Therefore in this study greywater was characterized in quantity and quality to define, design and build adequate treatment options.

Current situation in Nakuru

Nakuru municipality in Kenya, where centralised sewerage connection is inadequate, faces a serious challenge of sustainable access to safe wastewater disposal in the unplanned settlements. In such areas, safe wastewater disposal can be achieved by in-situ separation of domestic wastewater in various streams (grey, yellow, beige, brown and black water) at the source of generation and handling each stream individually. Beige water is anal cleansing water; yellow water is wastewater stream made up of urine and flush water. Black water is a combination of brown and yellow water which is also referred to as night soil while brown water is wastewater stream composed of faeces and flush water. Source separation allows for adequate treatment of different wastewater flows according to their characteristics.

The generated amount of greywater is influenced by factors such as existing water supply services and infrastructure, number of household members, age distribution, lifestyle characteristics etc. (Morel and Diener, 2006). It greatly varies as a function of these dynamics of the households. Table 1 shows daily produced greywater amounts per household in 4 selected areas in Nakuru. Greywater is disposed of in any open spaces available, plastic paper filled storm water drains (Figure 1) or sometimes re-used with limited pre-treatment.

Table 1: Calculated amount of produced greywater per household (Kraft, 2009)

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

The common practice in the investigated settlements is to dispose greywater in septic tanks and pit-latrines (29 %) as presented in Figure 2. As a result, most pit-latrines emit foul smell and are full of flies. However, though to a limited extend (3 %) greywater is reused for cleaning pit-latrines thus increasing the problem even further.

This common practice has resulted in a major environmental and public health concern to the residents. The choice of technology in these areas for basic wastewater management is a household decision because

Figure 1: Greywater disposal to storm water drain in Nakuru

ownership and acceptance by the household is a key to sustainable greywater treatment. Decentralized wastewater treatment systems range in size from individual on-site systems serving one household to shared facilities serving about 40 households or public facilities for several households sharing one sanitary facility. However, there is need to develop different treatment options to offer technical solutions in order to reduce health and environmental risks as a result of domestic greywater pollution. This work proposed promoting resources-oriented sanitation, where available nutrients in the effluent can be utilized while reducing environmental pollution. This can drastically reduce fertilizer usage whose price is beyond the reach of urban farmers.

Resources-oriented sanitation that also includes greywater and solid waste management offers economically, ecologically sustainable and

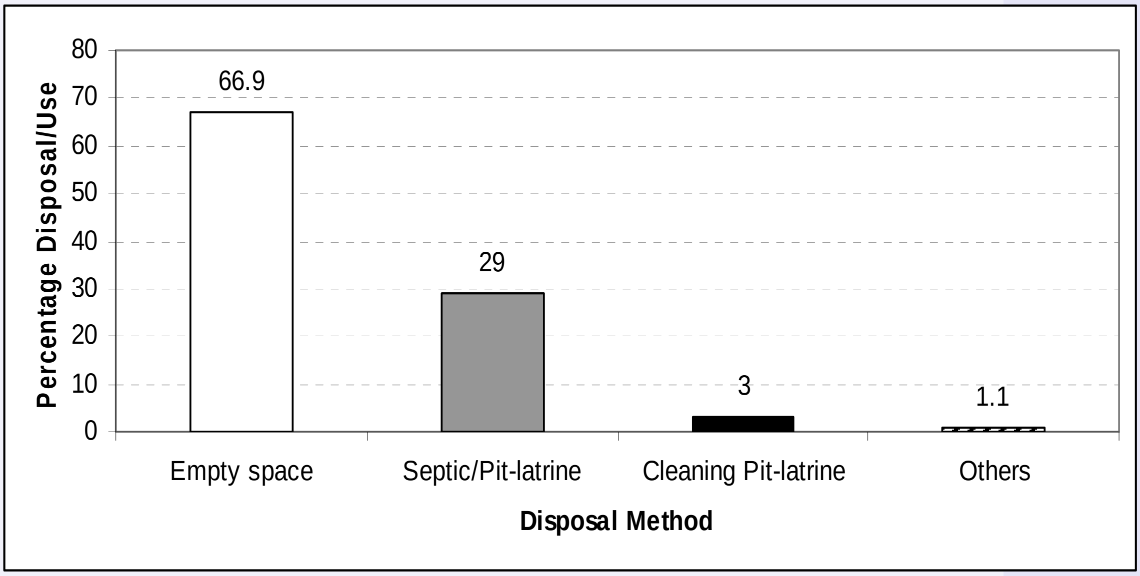

Figure 2: Main greywater disposal practice in the investigated areas of Nakuru

culturally acceptable systems that aim at closing the natural nutrient and water cycle. This can be achieved through best sanitation management practices aimed at improving public health and general environment. Since good hygiene and adequate sanitation are pre-requisites for good health, safe disposal or reuse of greywater can be a solution to achieving good hygiene. Population density however presents itself as a challenge since sanitation related health risks are high in densely populated urban areas. Furthermore, the unplanned settlement structures, like most of the peri urban areas inhibit the integration of sanitation systems. As a result, sewerage connections become technically impossible to construct and sometimes to operate leading to current greywater disposal methods in use that involve emptying in any available open space including roads and foot paths. For safe disposal, greywater can be treated by subjecting it to an on-site treatment system such as the household based constructed wetland at Lake View settlement (Figure 3) and Crater View Secondary School in Nakuru Municipality, Kenya.

Figure 3: Lake View settlement area

To address this problem a horizontal-sub-surface flow constructed wetland (HSSF CW) was established at Lake View and Crater View Secondary School through the support of ROSA project (Langergraber et al, 2008). Within this project a survey to identify and characterise greywater generation and disposal habits in Nakuru provided the basis for designing and implementing resource-oriented greywater treatment systems. In Table 2 the mean values for the following physico-chemical and bacteriological parameters are given: Temperature, pH, Dissolved Oxygen (DO), 5-day Biochemical Oxygen Demand (BOD_5), electrical conductivity (EC), salinity, Total Dissolved Solids (TDS), turbidity, Total Suspended Solids (TSS), organic- and inorganic content, total phosphorus, ortho-phosphohate, ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N)and Faecal Coliforms (FC) of 59 greywater samples (24 samples from kitchen, 25 samples from laundry, 10 samples from combined greywater and additional five source water samples). All methods used for the greywater analyses were according to the Manual for Water Quality Analysis, Egerton University, Kenya (Oduor, 2008)

Table 2: Summary of the greywater and source water characteristics (median values) (Kraft, 2009)

Parameter	Unit	Kitchen	Laundry	Combined	Source
Amount	l/d	5.5	56	65.5	87.5
Temperature	°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_5	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	n. d.
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	n. d.
NO_3-N	mg/l	3.68	2.44	1.97	3.49
NO_2-N	mg/l	2.63	8.61	2.71	n. d.
FC	log cfu/ 100ml	7.05	5.49	7.04	1.19

n.d. ..not detectable

Piloting area- Nakuru Municipality

Nakuru municipality is on the floor of Great Eastern branch of the Rift Valley and the fourth largest city in Kenya. It is also the administrative headquarters of Rift Valley province and a hub of the province's commercial activities. The town lies between latitude 0° 10' and 0° 20' South and longitude 36° 10' East and at 1859 m above sea level (MCN et al., 1999). It covers an area of 290 km² of which Nakuru National park takes 188 km² leaving 102 km² to town functions. The population is estimated at 450,000 people (MCN et al., 1999). This municipality like many other urban centres in Kenya has experienced a rapid population growth

Figure 4: Greywater disposal in Nakuru

Figure 5 Greywater disposal in Nakuru

Figure 6: Greywater sampling

thus exerting pressure on existing water and wastewater management facilities.

Implementation of greywater treatment options

Results from Table 1 and Table 2 were used as a guide in developing site specific greywater quality improvement systems ideal for the high density population, low income peri-urban settlements. Table 3 presents some of the considerations in design and construction of the HSSF CW system at Crater View Secondary School and Lake View residential area. The design of the wetland was based on the rule of thumb such as the Austrian and German design standards (ÖNORM B 2505, 2008, and DIN A-262, 2006, respectively) without considering and quantifying the processes occurring inside such filters in detail. More recently, however, efforts have been made to understand and quantify processes in pilot facilities (Langergraber, 2008). To avoid creating another environmental problem in form of malaria mosquito breeding sites, horizontal subsurface flow (HSSF) constructed wetland (CW) system was chosen and water surface maintained at 15-30 cm below the ground level. To sensitize a wider group from Nakuru Municipality, the pilots were established at one residential area (Lake View) and a secondary school (Crater View).

Development of a greywater treatment system involved consideration of institutional and social issues in addition to technical factors. These issues influenced controlled decision making during the planning and preliminary design stages. Also, it involved using a guide to project development after Reeds et al. (1995) involving characterization of greywater by defining the volume and composition to be treated. Concept feasibility which involves determining if any of the natural systems are compatible with site conditions and requirements for greywater treatment.

Table 3: Design details

No	Name	Description
1	Pre-treatment	Two chamber (0.25 & 0.75 m³) litter trap, coarse organic matter; grease trap of cleaning interval not more than 4 times/yr
2	Surface area	Horizontal sub-surface flow constructed wetland (HSSF CW); length = 2m, width = 1m
3	Inlet	Stone distributor; slotted pipe for greywater distribution, inlet depth = 0.86m
4	Treatment volume	Fine gravel (D60 = 3.5mm, Cu = 1.8); initial porosity = 40%; with an average wetted depth of 0.875m; Hydraulic conductivity was 17m/day
5	Outlet	Outlet depth = 0.9m; variable effluent outlet height
6	Flow	Flow rate is set at 1m3/day; hydraulic loading rate (HLR) is 500mm/day
7	Other design considerations	bottom slope of 1-2%; gravel media; geo membrane liner of 1mm thickness
8	Filter material	Building sand cheap and locally available (3-8mm grain-size)
9	Plants	Vetiver grass (*Vetiveria zizanioides*)
10	Retention time	2 days
11	Cost	Treatment system including hand-wash facility Euros 1, 500

Figure 7: Washing facility- Crater View Secondary School

Figure 8: James and Laura – sampling at the HSSF CWs

Results and discussion

The removal rates of the HSSF CW based on an average percentage pollutant reduction are presented in Table 4: BOD_5 99.7%, TSS 97%, TP 88.%, NH_4-N 97% and FC 18% . Sampling commenced four months later after the plants had established. This greywater treatment system was designed with a retention period of less than 48 hours in the settling tank. However, water flow from a nearby borehole through the washing facility was highly variable. The variability was caused by pumping power fluctuations as a result of blackouts and power rationing affecting the entire country. Low electricity output occasioned by low water levels in the hydro-power stations influenced the systems. Consequently, greywater turned septic due to longer storage periods in the settling tanks. A fence had to be built around the site to avoid possible health risks for students that wanted to investigate the system by digging holes into the filter bed and to protect the plants from being eaten by animals.

The general reaction from the school community was positive though with some disappointments. They had a very high expectation of using the effluent for irrigation in the school kitchen garden but due to its high bacterial contamination the outflow of the pilot system could not be recommended for save use. In consecutive studies it is planned to adapt the greywater treatment systems to improve the effluent quality so it can be used safely.

Conclusion

Based on these results and further piloting, HSSF CWs are a promising technology in urban and peri-urban areas that are not served by the central sewer system. Within Nakuru municipality, many poor households are unable to access wastewater collection, transport and treatment services that could save the lives of children and adults from water related ailments. Unless these services reach the poorest, universal coverage will not be achieved. New sanitation policies and initiatives often pay little attention to the greywater handling systems. Population growth and urbanization are a major challenge and present themselves as the main obstacle in integrating sanitation in these settlements. Meanwhile, urban residents continue to suffer from poor sanitation. High child mortality due to poor hygienic conditions is a harsh illustration of the inequalities in society. Generally, problems of poverty are inextricably linked with those of water; its availability, proximity, quantity and quality. The combination of safe drinking water and hygienic sanitation facilities as presented in this case of household based greywater treatment is a pre-condition for good health and success in the fight against poverty, hunger, child deaths and gender inequality. This is also one way of unlocking the billions of people locked in the cycle of poverty and diseases worldwide. Thus, piloting is a tool that helps mobilize community members towards collective action and empowers them to take further action in the future. The outcomes illustrate what communities can achieve by undertaking further initiatives for their own environmental management.

Table 4: Results from influent – effluent laboratory sample analysis

Parameter	EC	Salinity	DO	TDS	BOD_5	TSS	TP	FC	NH_4^+
Units	µS/cm	g/l	mg/l	mg/l	mg/l	mg/l	mg/l	Log 10 FC/100ml	mg/l
Influent	1929	1.0	3.01	1257	104.0	255	2.43	4.97	3.17
Effluent	1644	0.8	0.08	1084	0.33	9	0.29	4.09	0.09
Reduction [%]	14	20	-	14	99.7	97	88	18	97

Acknowledgements

The work is carried out within the project ROSA (*Resource-Oriented Sanitation concepts for peri-urban areas in Africa*; Contract No. 037025-GOCE; duration: 1.10.2006 – 31.3.2010), a Specific Target REsearch Project (STREP) funded within the EU 6th Framework Programme, Sub-priority "Global Change and Ecosystems". The authors are grateful for the support.

References

DWA-A 262 (2006): Grundsätze für Bemessung, Bau und Betrieb von Pflanzenkläranlagen mit bepflanzten Bodenfiltern zur biologischen Reinigung kommunalen Abwassers. Arbeitsblatt, *DWA - Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V.*, Hennef, Germany [in German].

Kraft, L. (2009): Characterisation of Greywater from peri-urban areas in Nakuru, Kenya. *Master theses;* BOKU University, Vienna, Austria.

Langergraber, G. (2008): Modeling of Processes in subsurface flow constructed wetlands- A review. *Vadoze Zone Journal* 7(2), 830-842.

Langergraber, G., Meinzinger, F., Lechner, M., de Brujne, G., Sugden, S., Niwagaba, C.B., Mashauri, D., Mutua, B.M., Teklemariam, A., Achiro, I., Kiarie, S.C., Laizer, J.T., Ayele, W. (2008): The ROSA project – A new approach to sustainable sanitation in Eastern African cities. *Proceedings of the 6th IWA World Water Congress*, 8-12 September 2008, Vienna, Austria. (CD-ROM, paper 664279)

MCN, (1999): Municipal Council Nakuru Strategic Structure Plan. Action Plan for Sustainable Urban Development of Nakuru town and its Environs, Volume 1. GoK, Nakuru, Kenya.

Morel A. and Diener, S. (2006): *Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods.* Sandec (Swiss Federal Institute of Aquatic Science and Technology (Eawag): Dübendorf, Switzerland.

MWI (2007): Ministry of Water and Irrigation. Awareness Raising and Marketing Strategies. Accelerating Access to Sanitation. *East African Regional Conference*, 27-28 November 2007, Nairobi, Kenya.

Odour, S.O. (2008): *Manual for Water Quality Analysis.* Egerton University, Njoro, Kenya

ÖNORM B 2505 (2005): *Bepflanzte Bodenfilter (Pflanzenkläranlagen) – Anwendung, Bemessung, Bau und Betrieb (Subsurface-flow constructed wetlands – Application, dimensioning, installation and operation).* Österreichisches Normungsinstitut, Vienna, Austria [in German].

Reed, S.C; Crites, R. W; and Middlebrooks, E.J (1995): Natural systems for waste management and treatment. *McGraw-Hill*, New York, USA.

UNDP (2006): United Nations Development Program, Environment and Energy. http://www.undp.org/water (last access: 01.10.2009).

Name: James Raude,
Benedict Mutua,
Mathew Chemelil
Organisation: Department of Agricultural Engineering, Egerton University
Town, Country: Egerton, Kenya
e-mail: ramesso@yahoo.com.
bmmutua@yahoo.com,
mcchemelil@yahoo.com

Name: Laura Kraft,
Kirsten Sleytr
Organisation: University of Natural Resources and Applied Life Sciences, Vienna; Institute for Sanitary Engineering and Water Pollution Control
Town, Country: Vienna, Austria
e-mail: kraft_laura@yahoo.de,
Kirsten.sleytr@boku.ac.at