IMPACTS OF WATER AND SANITATION ACTIVITIES ON THE ENVIRONMENT IN THE UPPER MARA BASIN

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Abstract
The provision of reliable and safe water supplies is an essential element in improving the quality of life for mankind. However, over time the natural resource base has become severely stressed due to unsustainable use of the resources. This study was undertaken to evaluate the impacts of water, sanitation and hygiene (WASH) activities on the environment in the upper Mara River basin. Sampled water and sanitation projects were identified by observation and Geographic Information System (GIS) was used to map and report on these projects. Impacts of the projects on land and environmental quality were assessed using Land Quality Indicators (LQI); fresh water quality, solid and liquid waste generation and management and soil erosion. Water samples were analyzed for physical, chemical and bacteriological parameters and only 23.4% of sampled water sources were found suitable as domestic water sources. Most open water sources were contaminated with *E. coli* caused by open defecation in the basin which on average was 38%. The study showed that, 21.3% of the sampled water supply projects had evidence of soil erosion around them which was mainly caused by livestock overcrowding at water points. Among the wastewater generating and management activities in upper Mara basin, Bomet municipal stabilization pond posed the greatest pollution threat to the environment since it lacked capacity to treat waste water to standards before it overflowed into the environment. This study recommended that WASH project implementers, users and managers should plan for and implement environmentally sustainable projects. In addition, WASH stakeholders in the basin should make integrated and comprehensive efforts to provide improved water sources and sanitation to all the residents.

Key words: water, sanitation, impact, environment

1.0 Introduction
Access to water and sanitation is a fundamental human right and every individual has a right to a potable source of water. The third target under Millennium Development Goal (MDG) 7 (environmental sustainability) seeks to improve access to sustainable water and improved sanitation. Access to safe drinking water and sanitation is estimated by the percentage of the population using improved drinking water sources and improved sanitation facilities (WHO and UNICEF, 2004). Improved drinking water technologies are those more likely to provide safe drinking water than those characterized as unimproved while improved sanitation facilities are those more likely to ensure privacy and hygienic use, (WHO and UNICEF, 2004).

Water, Sanitation and Hygiene (WASH) is imperative for health, and is also an important part of the livelihood of any household. Health is also affected by environmental management in that, disposal of domestic and other wastes is the cause of many water borne diseases such as diarrhea, (Wetlands International, 2010).

This study evaluated the environmental impacts of WASH activities in the upper Mara catchment, providing appropriate information concerning these activities to show the linkage between contamination of water sources by poorly planned sanitation activities which is not always recognized by WASH practitioners in water supply planning, sanitation provision and waste disposal, (Wetlands International, 2010).

Land Quality Indicators (LQIs) are instruments to help monitor progress towards or away from sustainable land use systems. Impacts on land and environmental quality for the identified projects were assessed using Land Quality Indicators (LQI); water quality, solid and liquid waste generation and management and soil erosion.

1.1 Objective

To analyze the impacts of Water and Sanitation activities on the environment in the upper Mara river basin using land quality indicators: water quality, waste management and soil erosion.

1.2 Study Area

The trans-boundary Mara basin (Figure 1) covers 13,750 km^2 and is located roughly between longitudes 33^{o}47' E and 35^{o}47'E and latitudes 0^{o}38' S and 1^{o}52' S, with the upper 65% area (8,941 km^2) in Kenya, while the remaining lower portion is in Tanzania. The 395 Km long Mara river has for a long time been considered one of the more pristine rivers draining into Lake Victoria, which consequently forms part of the upper catchments of the Nile basin. The main perennial tributaries are the Amala and the Nyangores, which drain from western Mau escarpment. In addition to water, the river provides food, important plants, fertile soils, and critical habitat to people and wildlife. However, the many demands for these resources are sometimes incompatible. The river provides the primary domestic water source for nearby towns and settlements, many of which lack any kind of sewage or water treatment facilities, (LVBC & WWF-ESARPO, 2010).

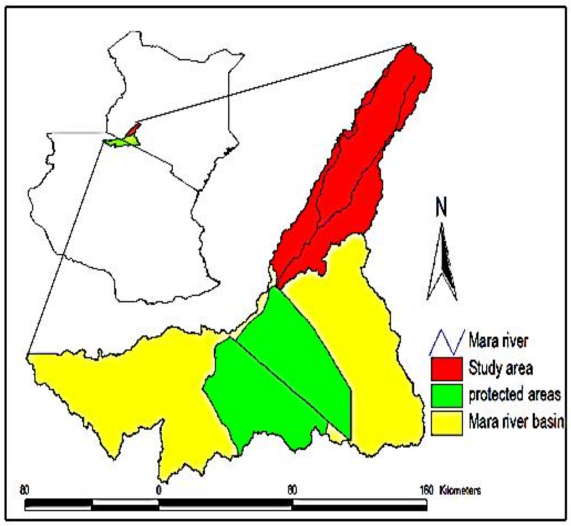

Figure 1: study area

1.3 Impacts of Water and Sanitation Projects on the Environment

Water supply and sanitation systems can impact environment in many ways. Studies have shown that energy and chemicals consumption in production of potable water cause global environmental impact, (Mohapatra *et al,* 2002; Vince *et al,* 2008).

Water supply and sanitation projects may cause increased incidence of infectious water-borne diseases such as cholera, non-infectious disease such as arsenic poisoning, and water-enabled diseases such as malaria, schistosomiasis or bilharzia. Contamination of surface and groundwater supplies with infectious organisms from human excreta is especially serious. Contamination may be caused by poorly designed, operated or maintained sanitation facilities, such as sanitation systems that transfer sewage to receiving waters without treatment, or pit latrines located in areas with high water tables. Infectious diseases may also be spread by improper use of wastewater to grow food crops, (Warner, 2000).

Indiscriminate disposal of organic waste is detrimental to health because it increases breeding habitats of disease carrying agents like rodents and insects. Sewerage disposal poses a major environmental and health threat in African cities. Many African cities either lack sewerage systems or operate inefficient systems serving only a small proportion of the urban population, (Economic Commission for Africa, 1996).

Even where sewers exist they are often blocked with solid waste, and overflow into streets and open spaces, which provide suitable grounds for disease pathogens. The majority of urban residents especially those living in informal settlements use pit latrines, bucket toilets or other sub-standard facilities which increases the chances of untreated human excrement disposal in surface drains and water bodies (Harvey, 2010).

2.0 Materials and Methods

Impacts of the sampled projects on land and environmental quality were assessed using the following indicators as applicable:

(i) Fresh water quality
(ii) Liquid Waste generation and management
(iii) Solid waste generation and management
(iv) Soil erosion

2.1 Measurement of Water Physical-Chemical and Nutrient Parameters

Samples were collected from 47 water points across the upper Mara catchment (Figure 2). The water points included: direct river sources, boreholes, water pans, protected springs, piped water projects and rainwater harvesting projects. They were tested for dissolved oxygen, conductivity, turbidity, pH, temperature nitrates and fluorides in replicates of three using a multi parameter Hach probe and a Hach Calorimeter.

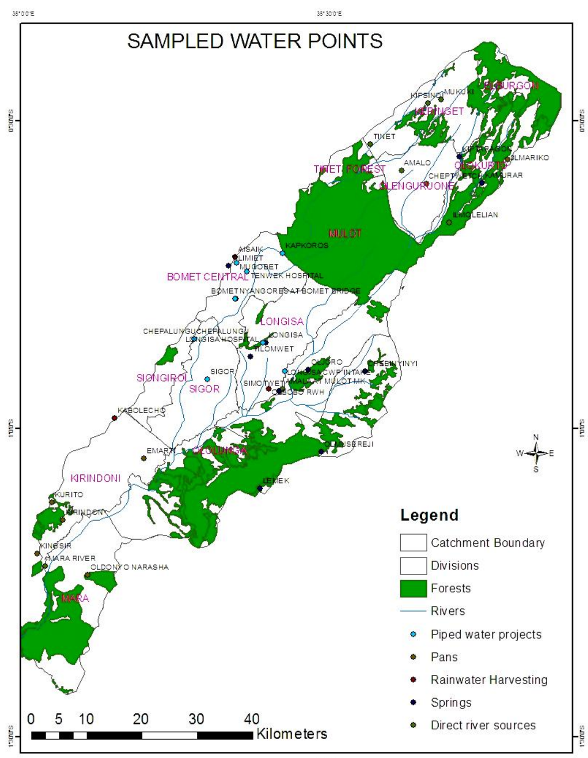

Figure 2: Sampled water sources

2.2 Coliform Testing

Coliform analysis for all the samples was done using Most Probable Number (MPN) procedure at Bomet water laboratory. The technique involved three successive steps; presumptive test, confirmed test and complete test which detect the coliform bacteria as indicator for faecal contamination (APHA, 1998). The quality of the water samples was compared with Kenya water quality regulations of 2006 standards for water sources for domestic use**.**

2.3 Waste Water Quality Analysis

Waste water effluent samples were collected and tested for (Bio-oxygen demand) BOD_5, fluorides, total dissolved solids and total suspended solids. The BOD test was carried out by measuring the dissolved oxygen (DO) of the water sample, sealing the sample to prevent further oxygen dissolving in and incubating it at 20 °C in the dark to prevent photosynthesis for five days, and the dissolved oxygen was measured again. The difference between the final DO and initial DO was taken as the BOD. Fluorides, total dissolved solids and total suspended solids using Hach Calorimeter. The results were compared with Kenya water quality regulations of 2006 standards for effluent discharge into the environment**.**

2.4 Solid Waste Characterization

Estimation of solid waste quantities and compositions was done using the load count analysis and field sampling and analysis. Domestic wastes within the river channel (100 meters stretch) and along the banks (up to 30 meters from the main river channel) was collected and analysed at their points of disposal. The waste characterization also involved the sorting out of the waste components at the Bomet municipal dumpsite. In total 3 samples of 15kg each were taken, the samples was then spread and sorted out into different components

2.5 Soil Erosion Measurements

Direct measurement of changes in soil level using point measurements were done around the sampled WASH projects with observable evidence of soil erosion around them. Secondary data from various public health divisional offices in the Upper Mara and the Kenya Bureau of statistics were analyzed to assess household access to water and sanitation.

3.0 Results

3.1 Access to water Upper Mara Basin

According to WHO and UNICEF (2004) classification of water sources, about 63% of households in the upper Mara basin obtained water from unimproved sources of rivers, ponds and water vendors while 32% households obtained water from springs, wells or boreholes, only 3% have piped water supply and on 1% used rain harvested water as shown in Figure 3.

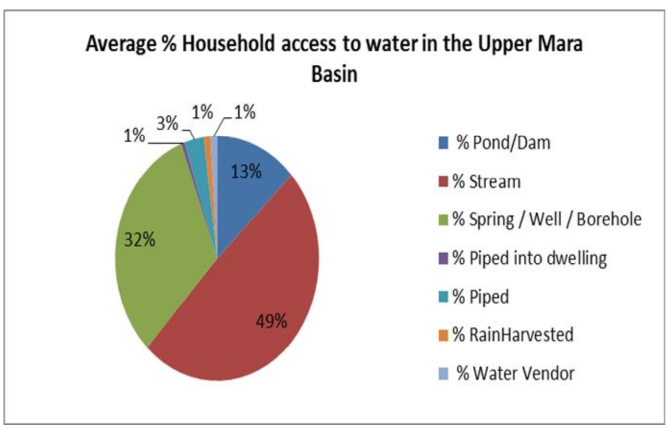

Figure 3: Average domestic water sources in Upper Mara

3.2 Suitability for Domestic Supply

Only 23.4% of the sampled water sources were found suitable sources for domestic water sources according to the Kenya 2006 water quality regulations, 80% of the sampled boreholes had higher fluoride levels than the minimum allowed of 1.5mg/l, 76.8% of the direct river water sources were found to be unsuitable due to high levels of suspended solids and presence of *E. Coli,* most water pans (88.9%) had presence of *E. coli,* high levels of suspended solids and nitrates levels more than the minimum levels allowed of 10mg/l.

3.3 Access to Sanitation Upper Mara Basin

On average 38% of household in the Upper Mara practiced open defecation in the bushes for their human waste disposal while the highest number of households (58%) used pit latrines and averagely 0% were connected to a main sewer, the rest used septic tanks and Ventilated improved pit (VIP) latrines as in Figure 4.

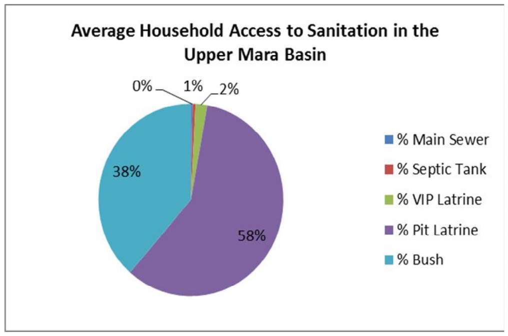

Figure 4: Average human waste disposal methods in Upper Mara

3.4 Domestic Solid Waste Composition

Analysis of the waste to establish its composition revealed that polythene bags were the most dominant (49%) by volume and commonly encountered waste within Mulot and Bomet towns along Amala and Nyangores tributaries. Additional waste included: recyclable office paper (17%), plastic bottles (10%), textile/torn clothing (8%), manila bags/ropes (3%), leather (3%), food waste (6%) among other waste like broken glass, tins/cans, sponge, rotting wooden pieces and ceramic/moulded waste (4%), (Figure 5).

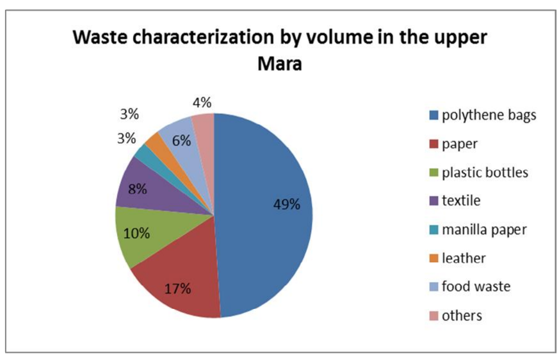

Figure 5: Solid waste characterization along Amala and Nyangores Rivers

3.5 Solid Waste Disposal

Most of the solid waste was disposed by open burning and dumping especially in urban and market centers, some hotels and hospitals used incinerators while others utilized composting Solid waste in Itembe, Silibwet, Tenwek and Longisa Market centers collected weekly and burned openly in the market centers while in the major towns such as Bomet a tractor hitched with an open trailer was used for garbage transport to a dumping site. The municipal council of Bomet (major town center in the catchment) had no license to operate a dumpsite. There was no separation of wastes from the source and the dumping site was open.

3.6 Liquid Waste Management

Wastewater in the upper Mara was generated from tea factories, urban centers (domestic, slaughter houses and car washes), hospitals and hotels in the lower parts of basin. Domestic waste water generated in Bomet town was disposed into septic tanks developed by individual developers since the town lacks a public sewer system. Wastewater exhausted from septic tanks was discharged into a stabilization pond near Nyangores River which lacked capacity to fully treat the waste water and the overflow is discharged into Nyangores River. Waste water from tea factories was treated by screening and stabilization before it is allowed to seep into tree plantations. Table 1 shows wastewater quality from various sources.

Table 1: Wastewater quality analysis from various sources

Sample	pH	BOD_5 mg/l	Fluorides mg/l	TSS mg/l	TDS mg/l
Bomet car wash	7	110	0	1067	575
Kapsimotwa slaughter house	6.86	398	0	897	1842
Tenwek hospital	7.62	28	0.68	14	394
Bomet municipal pond	7.66	644	0	1076	3910
Bomet slaughter house	7.56	1514	0.6	1067	945
Olonana hotel	7.47	23	1.35	30	484
Standard effluent discharged to the environment	**6.5-8.5**	**30**	**1.5**	**30**	**1200**

3.7 Soil Erosion

The study showed that, 21.3% of the sampled water supply projects were observed to have evidence of soil erosion around them as shown by changed levels of soils. It was observed that 40.4% of the sampled water points were shared with livestock due to lack of provision of distributed cattle water troughs in the area or due to lack of alternative sources for livestock supply.

4.0 Discussion

The source of drinking water is an indicator of whether the water is suitable for drinking or not in terms of quality; the improved drinking water technologies are more likely to provide safe drinking water than the unimproved. Therefore 63% of the household in the Upper Mara basin were found vulnerable to using contaminated water from unimproved sources.

The study showed a positive correlation (r=0.38) of the *E. Coli* per 100ml of water sampled from open water sources in various divisions and percentage households open defecating, indicating that open defecation was the most likely source of open water contamination. *E. coli*; one of the coliform groups is always found in faeces and is, therefore, a direct indicator of feacal contamination and the possible presence of enteric pathogens in water.

Poor waste disposal and collection efficiency in the upper Mara gave rise to huge amounts of waste. Domestic wastes add large amounts of organic and inorganic substances into aquatic systems (Bashir and Kawo, 2004), which in turn increases turbidity, suspended and dissolved solids into the river water. Plastic bags and plastic bottles/containers are a threat to public health as they may collect water during rainfall and retain it, creating suitable breeding grounds for disease vectors like mosquitoes, flies and cockroaches as well as rodents like rats which can lead to the spread of diseases (Ngwuluka *et al*, 2009). In addition, polythene bags can be detrimental to animal health and worse still lead to their death if consumed (Singh, 2005). Carelessly disposed waste, emitted unpleasant odor, contributed to blockage of drainages, defaced urban habitations in the upper Mara.

Waste water must be treated before it is either discharged onto water courses or open field in order to reduce its potential environmental hazards. The Kenya water quality regulations of 2006 prohibits the discharge of toxic pollutants in large amounts into water courses or open lands and indicate in section 11 that 'No person shall discharge or apply any poison, toxic, noxious or obstructing matter, radioactive waste or other pollutants or permit any person to dump or discharge such matter into the aquatic environment unless such discharge, poison, toxic, noxious or obstructing matter, radioactive waste or pollutant complies with the standards set out in the Third Schedule of the Regulations' however discharges from Bomet stabilisation pond, carwash and slaughter house as well as discharge from Kapsimotwa slaughter house did not comply with the standards thus polluting the environment. Pollution of surface water bodies mainly results from pollutants transported through surface runoff and uncontrolled discharge of untreated and partially treated sewage (Inanc *et al*. 1998; Martin *et al*. 1998)

Overcrowding of livestock at a water point caused erosion, livestock sharing a water point with humans easily results in contamination of water with livestock feaces and body fluids, and it may also attract disease vectors (particularly flies) which are a source of contamination. A Chi Square test performed to determine if livestock sharing related with erosion at water points indicated that there was a significant relationship, (X^2 (1) = 6.599, P = .010 (at an alpha level of .05) between livestock sharing water point with humans and soil erosion occurring at those sites. Erosion around water points usually reduces the service period of the supply point by undercutting concrete aprons, well covers, and pump footings. It often leads to stagnant water around the supply point.

5.0 Conclusion and Recommendations

5.1 Conclusion

Majority of the population (63%) in the upper Mara had poor access to adequate portable water and are therefore vulnerable to using contaminated water from unimproved sources which most (76.6%) were unsuitable for domestic water supply due to either high levels of fluorides, nitrates, total suspended solids or presence of *E. Coli*. Poor access to sanitation by residents of the upper Mara lead to contamination of most of the open water sources with *E. coli*. The positive correlation (r=0.38) of the *E. Coli* per 100ml of water sampled from open water sources in various divisions and percentage households open defecating, indicated that open defecation is the most likely source *E. coli* that contaminated the open water sources.

Poor waste disposal and collection efficiency in urban and market centres in the upper Mara basin gave rise to huge amounts of waste which were not collected and disposed safely therefore, most solid waste was left lying in dumpsites or burned openly emitting unpleasant odor, blocking storm drainages and defacing the centres. Among the dumped solid wastes, polythene bags were the most dominant (49%) by volume and they posed a threat to public health by creating suitable breeding grounds for disease vectors and to animal health if consumed.

Bomet municipal stabilization pond posed the greatest pollution threat to the environment since it lacked capacity to treat wastewater to standards before it overflowed into the environment, the BOD_5 of the wastewater from this pond was at 1514mg/l before discharge. The *E. coli* count of water in Nyangores River below this pond was 180 /100ml indicating that the wastewater from this pond contaminated the river. Overcrowding livestock at water points lead to erosion since all water points shared between livestock and human had evidence of soil erosion including gullies.

5.2 Recommendations

Combined effective efforts must be made by all Water, Sanitation and Hygiene stakeholders in the basin to provide the residents of the upper Mara basin with improved sources of water and improved sanitation to reduce their vulnerability to contaminated water and to create open defecation free (ODF) villages that will reduce pollution of the environment with feacal matter and contamination of water by *E. Coli*. This will reduce the linkage of waterborne diseases associated with poor WASH services.

WASH project implementers, users and managers should plan, implement and operate environmentally friendly WASH projects and apply effective efforts to:

(i) Avoid overcrowding of livestock at water points by providing water to individual farmers or wide spread water troughs for the pastoral communities to avoid degradation of the sites
(ii) Ensure effective treatment of water before supplying it for domestic water use.
(iii) Ensure effective treatment of effluents before discharging it to the environment.

Solid waste generated in the basin should be collected and disposed efficiently to avoid environmental pollution and to destroy breeding grounds for disease vectors and rodents. Further research should be conducted to evaluate the impacts of the septic tanks in Bomet town to the groundwater.

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