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Evaluation of TSS, BOD5, and TP in Sewage Effluent Receiving Sambul River

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Abstract

Proper treatment of sewage to remove suspended solids, organic matter and nutrients is necessary before the effluent is discharged into aquatic bodies. The major environmental concern at Sambul river is the potential pollution by effluent received from sewage treatment plant in Moi University. In this study, evaluation of the Sambul river was analysed using key water quality parameters, and comparisons made with those of the National Environmental Management Authority (NEMA). Purposive sampling design was used to select three sampling points; outlet where sewage effluent from STP is discharged into Sambul river, downstream of Sambul river where bio-treated sewage has mixed with river Sambul waters, and upstream (control) of Sambul river where the river water does not mix with STP effluent. A total of 72 water samples were collected for this study. At each sampling point, triplicate water samples for analysis were collected bi-weekly in sterilized plastic bottles from May to August 2015. Total suspended solids (TSS), BOD_5 and total phosphorus (TP) were determined using standard laboratory methods. Results showed that levels of TSS, BOD_5 and TP were within the acceptable standards of NEMA. Upstream parameters showed no significant differences with those of downstream (BOD $F_{4,115}$=38965.46; p=0.9734; TSS $F_{4,115}$=708.50; p=0.9999; total phosphorus $F_{4,115}$=2107.17; p=0.9972), indicating that there is no change in water quality at river Sambul as a result of effluent received from STP.

Keywords: Pollution; Sewage effluents; Sambul river

Introduction

Aquatic ecosystems in developing countries are polluted through indiscriminate release of untreated or improperly treated wastewater. Sources of **wastewater include** surface runoff, domestic or sewage effluents, industrial discharges and agricultural activities. Wastewater must be treated effectively to prevent pollution of the receiving environment and to safeguard public health. Numerous nutrients, solids, and other contaminants exist in raw sewage hence treatment of sewage is thus vital before effluent is released to the ecosystem [1].

In many developing countries poor sanitation condition is widespread. In 2012, only 30% of the population in sub-Saharan Africa had access to improved sanitation [2]. The main improved sanitation systems such as pit latrines and toilets dominated in many countries whereas systems that safeguarded the collection, transportation and proper treatment of wastewater remained very low. In Kenya the available good quality water is presently projected at 650 m^3 per year per capita and could drop to about 350 m^3 per year per capita by the year 2020 due to pollution and drought factors [3]. Water scarcity in Kenya slows development hence the need for water saving and regulation policies. Sewage effluent discharges must meet environmental standards to ensure environmental protection. In Kenya, wastewater discharge permits are issued by the National Environmental Management Authority (NEMA) in accordance to the Environmental Management and Co-ordination [4]. NEMA coordinates and publishes regulations on all matters relating to the environment.

The major environmental concern of Sambul river is the potential pollution from effluent Moi received from Moi University sewage treatment plant. At the treatment plant wastewater undergoes biological treatment in stabilization ponds [5]. The receiving Sambul river could be contaminated through nutrient loading which is likely to lead to eutrophication and algal blooms. Furthermore possible pollution of Sambul river will reduce its water quality to harmful levels for aquatic life and riparian population downstream [6]. The physicochemical and biological characteristics of sewage effluent must be within the set environmental levels for discharge provided by NEMA for the effluent receiving environments and public health protection.

Total suspended solids are solids in water that can be trapped by a filter including decaying plants, silt, animal matter, industrial wastes, and sewage. In general, raw wastewater comprises of solids of different types and sizes. The presence of excess suspended solids is harmful to the health of a water body consequently affecting aquatic life. TSS values are used to monitor and assess efficacy of wastewater treatment plants to guarantee the health of effluent receiving water bodies. Discharge of settleable solids to water a body increases sedimentation rates and often destroy and alter habitats for aquatic organisms. Release of sewage effluents with excess suspended solids to rivers and other aquatic systems can increase levels of pathogens and contaminants including bacteria, protozoa, nitrates and phosphorus, pesticides, mercury, lead and other metals [7]. Pathogens can attach to suspended materials and increase the risk of disease outbreaks. High levels of TSS prevents penetration of light to the submerged plants leading to reduced rates of physiological processes such as photosynthesis and respiration in aquatic organisms. The inability of plants to photosynthesise will eventually lead to death and the decaying process that demands more oxygen use from water.

Biodegradable organic materials such as proteins, carbohydrates and fats can cause pollution if discharged into aquatic environments. Large amounts of biodegradable materials are hazardous to aquatic

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bodies because microorganisms will initiate biochemical reactions by utilising dissolved oxygen in the water to breakdown the wastes. The amount of oxygen organisms need to breakdown wastes in wastewater is referred to as the biochemical oxygen demand (BOD). The BOD test measures the biodegradable fraction of the wastewater by monitoring the assimilation of organic material by aerobic microorganisms and therefore a suitable indicator of treatment efficiency. If effluent with high levels of BOD is discharged into a stream or river, it will accelerate bacterial growth in the river and consume the oxygen levels in the river.

Phosphorus exists in sewage water in forms that include soluble organically-bound phosphate and Inorganic phosphates. The organically-bound phosphate in wastewater is from human excreta and urine. Effluent with excess phosphorus is the main cause of eutrophication in surface water bodies such as lakes and rivers [8]. In wastewater treatment phosphorus remains attached to sediments. Consequently, phosphorus removal in wastewater treatment plants must be enhanced to prevent its release to the environment [9]. In wastewater treatment plants phosphorus in organic materials is finally oxidized to phosphates. This study investigated changes in the quality of effluent received from sewage treatment stabilization ponds in Moi University by direct measurement of TSS, BOD_5 and TN and comparison with NEMA standards. The results of the study are expected to be useful to Sambul community and Moi University by offering information on the effectiveness of sewage treatment plant in removing pollutants from its effluent.

Materials and Methods

Study area

The study was conducted at Sambul river and Moi University, situated in Uasin Gishu County, Kenya (Figure 1). The sewage treatment plant at the University performs biological treatment of sewage through a series of ponds before discharging effluents to Sambul river.

Experimental design and sampling

Moi University sewage treatment plant (STP) (Figure 2) provides biological treatment of wastewater. The waste stabilization ponds constructed are simple to operate and maintain. Routine tasks comprises of cutting the embankment grass, removing scum, and any other floating vegetation from pond surface, keeping the inlet and outlet channels clear and repairing any damage to the embankments.

The STP at Moi University receives and treats domestic wastewater from the entire premises. The mean inflow of influent into the treatment plant is 3,200 m^3/day. STP Inlet (Figure 2) is the point where wastewater is received at the treatment plant. Screening of wastewater occurs at this point. Wastewater flows through a coarse screen (size opening 50 mm), where all the floatable solids are trapped for removal. A fine screen (size opening 25 mm) is also fitted downstream of the coarse screen to trap materials that passes through the coarse screen. If the coarse screen in the channel is blocked due to excessive solids in the wastewater, the level of wastewater rises in the channel and wastewater starts flowing through the emergency bypass channel, which has another coarse screen (size opening 75 mm).

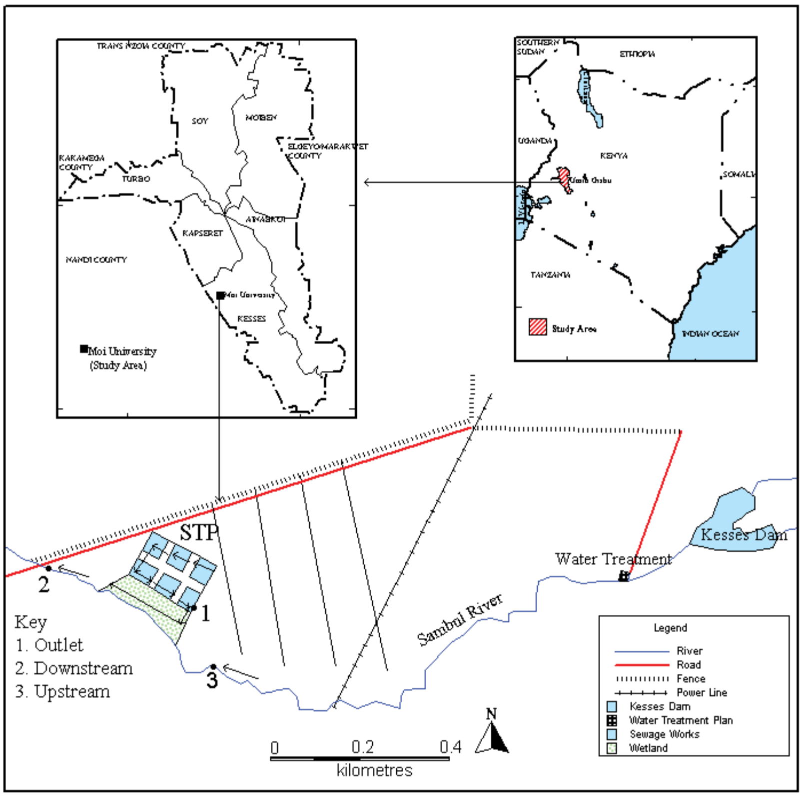

Figure 1: Map showing study sites at river Sambul (by Kanda, Geographic Information Systems Laboratory, MOI University, 2015).

From the inlet channel, wastewater flow into stabilization ponds which are six in number. There are two anaerobic ponds, primary and secondary facultative ponds, and two maturation ponds (Figure 2). An anaerobic pond (width 51 m, length 51 m and depth 3 m) allows for sewage settling, some BOD removal and anaerobic digestion of solids. Anaerobic breakdown occurs when solids settle at the bottom and are eliminated as bacteria decompose organic matter. In addition, organic nitrogen is hydrolysed to ammonia in anaerobic ponds. From the anaerobic pond, wastewater flows into the primary facultative pond (width 80 m, length 220 m, and depth 1.7 m). Phosphorus and nitrogen removal occur in facultative ponds. The primary facultative pond provides some anaerobic digestion in the benthic zone, and aerobic respiration at the water surface. The primary pond discharges wastewater into the secondary facultative pond (width 70 m, length 220 m, and depth 1.7 m) where wastewater is aerobically treated.

Maturation ponds (each width 70 m, length 70 m, and depth 0.5 m) receive effluent from the secondary facultative pond to polish the wastewater. In this ponds pathogens die as the levels of suspended solids is low and pathogens are exposed to ultra violet radiations and perish and remaining BOD is removed by heterotrophic bacteria. Maturation ponds discharge wastewater into the outlet channel where effluent is disinfected by the charcoal and gravel deposits along the channel. From the outlet channel, wastewater effluent is discharged into the wetland. The effluent released into the ecosystem has undergone biological treatment in the stabilization ponds within the sewage treatment plant. At the wetland more nutrients are absorbed by the plants through bio filtration thus reducing the nutrient load. From the wetland wastewater effluent is then discharged to Sambul river. The quality of effluent discharged into river Sambul must be within the standards outlined by environmental agencies such as National Environment Management Authority (NEMA).

Sampling points for this study were selected using a purposive design. This generated water samples that were used to evaluate changes in TSS, BOD_5 and TN at Sambul river. Three sampling points (Figure 1) were selected as follows; sampling point 1 (SP1), which is the outlet where effluent is released from the sewage treatment plant into the Sambul river. At this point, effluent has undergone biological treatment. Sampling point 2 (SP2), which is at downstream of Sambul river where biologically treated effluent is mixed with waters from the Sambul river. The last point was sampling point 3 (SP3), which is upstream of Sambul river a point before the Sambul river water mixes with effluent from the sewage treatment plant. This point served as a control, reflecting the most naturally preserved conditions of river ecosystem without the influence of the sewage effluent. Wastewater samples at each of the three (SP1-SP3) sampling points were collected twice every month from May to August 2015. Wastewater samples were collected in 1 L sterilized plastic bottles. During each sampling period, sample water was used to rinse sample bottles before collection. Triplicate samples were collected from each sampling site. All samples were the labelled, iced and taken to the laboratory for analyses.

Determination of total suspended solids, biochemical oxygen demand (BOD_5) and total phosphorus (TP)

Gravimetric method was used to determine TSS in water samples [10], and the following equation was then used to calculate TSS (mg/L) in a sample.

$$TSS(mg / L) = \frac{W1 - W2}{V}$$

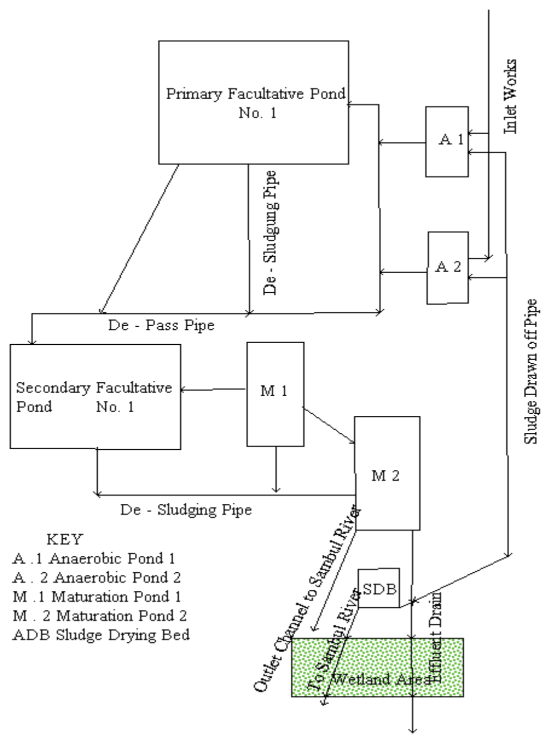

Figure 2: MOI University sewage treatment plan schematic flow diagram (by Kanda, Geographic Information Systems Laboratory, Moi University, 2015).

Where,

W1=mass of dried residue and filter paper in grams.

W2=initial weight of filter paper

V=volume of sample water taken

The BOD_5 (mg/L) of water samples was determined by getting the variation between dissolved oxygen (DO) on day one and day five. Calculation for BOD_5 (mg/L) was then determined by the following formula:

$$BOD(mg/L) = \frac{D1 - D2}{P}$$

Where,

D1=DO (mg/L) value in initial sample

D2=DO (mg/L) value in final sample

P=decimal volumetric fraction of sample used (ml of sample/300 ml).

Wastewater Total Phosphorus (TP) (mg/L) concentrations were determined using potassium per sulphate digestion followed by ascorbic acid procedure [11].

Data analysis

Data from this study was analysed using the Statistical Package for Social Science (SPSS version 22 then one way Analysis of Variance (ANOVA) was used to determine significant differences. Contaminants removal efficiencies from the outlet to downstream sampled points were determined for the tested parameters in percentages.

Results

Samples data for the study period are shown in Tables 1-3 for the outlet, downstream and upstream studied points respectively. Total Suspended Solids (TSS) mean values for the different sampled points ranged from 2.63 ± 0.95 to 22.94 ± 1.98 mg/L (Table 4). The mean TSS for upstream (control) was not significantly different from that of downstream ($F_{4,115}$=708.50; p=0.9999) but was significantly different from that of the outlet ($F_{4,115}$ = 708.50; p=0.5068). There was 79.56% TSS removal at the downstream sampled point (Table 4). The mean value for BOD_5 at upstream (control) was not significantly different from that of downstream ($F_{4,115}$=38965.46; p=0.9734) but was significantly lower than that of outlet ($F_{4,115}$=38965.46; p<0.0001) (Table 4). At downstream, BOD_5 removal efficiency was 87.00%. Total Phosphorus values for the different sampled points ranged from 0.04 ± 0.01 to 2.02 ± 0.04 mg/L (Table 4). Mean total phosphorus level for upstream (control) was significantly lower than that of outlet ($F_{4,115}$=2107.17; p<0.0001) but showed no significant differences from that of downstream ($F_{4,115}$=2107.17; p=0.9972) (Table 4). TP removal efficiency was 95.05% at the downstream sampled point (Table 4).

Discussion

Sewage effluent discharges into aquatic bodies have continued to be a major concern for governments and environmentalist around the world. This is agitated by the physicochemical and microbial content in sewage that are used as indicators of environmental degradation in the effluent receiving environment [6]. Environmental regulations on effluent discharge have emerged currently to ensure that the impact of sewage effluents is greatly reduced. In Kenya the NEMA formulates and issues environmental standards to be adhered to in sewage treatment plants across the country. The findings of this study were within the allowable limits by NEMA, subsequently ensuring environmental health protection [12,13]. There were high levels of BOD_5 at the outlet (17.99 mg/L) was higher than at downstream (2.34 mg/L). The BOD_5 mean values at outlet were within the NEMA allowable standard of 30 mg/L. This implies that the observed concentration of BOD at outlet sampled point would not affect water quality at the effluent receiving Sambul river. Based on the reduced BOD outlet value, the sewage treatment plant at Moi University is relatively efficient in treating

Date/parameter	14/5/15	29/5/15	11/6/2015	25/6/15	9/7/2015	23/7/15	7/8/2015	21/8/15
TSS	22.45	23.98	22.74	22.87	22.67	22.96	22.95	22.89
BOD_5	16.98	17.89	18.02	19.04	17.67	17.88	17.76	17.9
TP	1.98	2.06	2	2.02	2.03	2.01	2.04	2.01

Table 1: Data for outlet sampled point May to August 2015.

Date/parameter	14/5/15	29/5/15	11/6/15	25/6/15	9/7/2015	23/7/15	7/8/2015	21/8/15
TSS	3.89	4.56	4.67	4.78	4.98	4.84	4.65	4.12
BOD_5	2.42	2.35	2.44	2.36	2.56	2.22	2.32	2.46
TP	0.04	0.03	0.02	0.06	0.03	0.05	0.04	0.01

Table 2: Data for downstream sampled point May to August 2015.

Date/parameter	14/5/15	29/5/15	11/6/15	25/6/15	9/7/2015	23/7/15	7/8/2015	21/8/15
TSS	2.56	2.67	2.87	2.42	2.65	2.61	2.66	2.63
BOD_5	1.02	1.06	1.05	1.03	1.04	1.05	1.04	1.05
TP	0.02	0.03	0.01	0.01	0.04	0.05	0.04	0.05

Table 3: Data for upstream sampled point May to August 2015.

Parameter	Outlet (O)	Downstream (D)	Upstream (U)	Removal % increase or decrease (O/D)	NEMA allowable limits
TSS	22.94 ± 1.98a	4.69 ± 0.86b	2.63 ± 0.95b	79.56	30
BOD	17.99 ± 1.02 a	2.34 ± 0.07 b	1.06 ± 0.04 b	87	30
TP	2.02 ± 0.04a	0.05 ± 0.01b	0.04 ± 0.01b	95.05	2 Guideline value
Mean (± SEM) in the same row followed by the same alphabet letter are not significantly different at p=0.05					

Table 4: levels of selected physicochemical parameters and NEMA standards.

sewage. In addition, the removal efficiency of BOD at the downstream point was 87.00% implying that the treatment plant does not increase the pollution of the river. The reduced levels of BOD_5 at outlet also explain the functioning of the sewage stabilization pond [5].

The total suspended solids (TSS) for downstream (4.69 mg/L) was significantly lower than that of inlet (22.94 mg/L). The outlet value was within the NEMA standard of 30 mg/L. The reduced TSS levels at the outlet could be attributed to the sewage treatment plant TSS removal efficiency through the sedimentation of settleable solids. TSS removal of 79.56% was observed in the study implying that the treatment plant is efficient in ensuring that impact of effluents at the receiving Sambul river is reduced and that the riparian community as users of river Sambul is safeguarded [3]. Discharge of effluents with high levels of suspended solids into aquatic bodies lowers water quality and depletes dissolved oxygen available for aquatic life.

The removal of nutrients in sewage effluents is necessary to reduce the effects on the receiving water bodies [14]. The study findings showed Total phosphorus (TP) mean value at the outlet (2.02 mg/L) was higher than that of downstream (0.05 mg/L). The removal efficiency of 95.05% of TP at downstream indicates the relative efficiency of Moi university sewage treatment plant and the study is similar to that by Waiser et al. [15]. The reduced levels of TP at downstream imply that no eutrophication could occur in Sambul river that would significantly deteriorate water quality and hinder aquatic life metabolic and physiological processes.

Conclusion

Treatment of sewage effluents before discharge into aquatic bodies is vital to prevent pollution and protect the entire environment and public health. From this study, it was concluded that effluent discharged to Sambul river from Moi University sewage treatment plant is within the allowable limits of NEMA. Based on the reduced levels of the TSS, BOD_5 and TN at downstream Sambul river, it showed that the sewage treatment plant is relatively efficient in reduction of organic and nutrient loads from the sewage water. This way, effluents with reduced contaminants if released into the ecosystem are incapable of harming aquatic life, declining water quality and causing disease epidemics to the riparian communities downstream.

Author's Contributions

This work was carried out by the author. The author designed the study, wrote the protocol and interpreted the data, anchored the field study, gathered the initial data, performed preliminary data analysis, managed the literature searches and produced the initial draft. The author read and approved the final manuscript.

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