Abstract

Treatment of sewage water remains a big problem in developing countries where many populations are not sewered and sewage water is left to run into water ways without any form of treatment at all. Release of untreated and poorly treated sewage water into the environments is one of the reasons for contamination of surface waters and destruction of aquatic ecosystems. Sewage stabilization ponds (SSPs) are artificially constructed ponds that use biological treatment mechanisms to purify sewage water. They are simple to construct and maintain, have low capital investment and require less skilled personnel. The main objective of this study was to evaluate the numbers of coliforms and the levels of Biochemical Oxygen Demand (BOD\textsubscript{5}) and Dissolved Oxygen (DO) in sewage water treated by SSPs. This study was conducted at the University of Eldoret sewage treatment plant which has 4 SSPs. The determination of the numbers of coliforms and levels of BOD\textsubscript{5} and DO in the sewage water at 5 different points (raw sewage influent, pond 1 effluent, pond 2 effluent, pond 3 effluent and pond 4 effluent) was done for 10 months. Results from this study indicated that the numbers of coliform bacteria and BOD\textsubscript{5} levels reduced significantly (p<0.05) from one station to the next and the least values were recorded for station 5 while DO levels increased.
1. Introduction

Surface water bodies in developing countries are highly polluted as a result of indiscriminate discharge of wastewaters from industrial, agricultural, and domestic/sewage activities [1] [2]. In developing countries, most effluents that are released into the environment are poorly treated and normally still high in BOD5 and bacterial numbers and subsequently low in DO thereby posing a lot of danger to the receiving environments. A stabilization pond is a large shallow excavation that receives sewage from a sewer system, detains the sewage so that biological process can destroy most of the disease-causing organisms, and discharges the effluent as treated sewage [3] [4]. Sewage stabilization pond systems provide reliable, low-cost, and relatively low-maintenance treatment for domestic discharges especially in areas that may be out of reach of Municipal sewage treatment plants such as refugee camps, schools and hospitals in rural areas. The general objective of this study was to evaluate the numbers of coliform bacteria and the levels of BOD5 and DO in sewage water treated by the SSPs at University of Eldoret.

2. Materials and Methods

2.1 Study Area

University of Eldoret has four stabilization ponds that are arranged in series with wide dykes separating them. These ponds were constructed in 1967 but became operational in 1968. They are located in the Southwestern part of the University and drain sewage water and sewage from the students’ hostels, academic area and staff residence (population: about 40,000). Each of the ponds is 150 × 32 × 1.5 m and only one of these receives sewage water influent at a time. The sewage water and sludge are retained in the pond for about two weeks during which algae, bacteria and other organisms act on them by mineralizing the organic matter content. The effluents are conveyed through sewers made of concrete pipes from one pond to the next until the effluent gets to the last pond from where it is channeled into a nearby swamp.

2.2 Experimental Design And Sampling

Water samples were collected from five sites: raw sewage in-flow to the first stabilization pond, the stabilization pond itself, inflow into the second pond and the second pond itself, inflow into the third pond and the third pond itself, inflow into the fourth pond and the effluent from the fourth pond and the effluent receiving stream (Marura swamp) over a 10 month period (February 2013 to October 2013).

![Figure 2.2.1: Illustration of the university of Eldoret sewage stabilization ponds](image-url)
Sampling was done twice every month for the months for the said period. Samples was collected by filling 500 ml sterile brown bottles, iced and processed within 12 hours of collection. Figure 2.2.1 gives an illustration of the study area. The sampling stations and their descriptions are further outlined in table 2.2.1 below:

<table>
<thead>
<tr>
<th>Sampling station</th>
<th>Description of station</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Point of entry of raw sewage into pond 1</td>
</tr>
<tr>
<td>2</td>
<td>Point of entry of pond 1 effluent into pond 2</td>
</tr>
<tr>
<td>3</td>
<td>Point of entry of pond 2 effluent into pond 3</td>
</tr>
<tr>
<td>4</td>
<td>Point of entry of pond 3 effluent into pond 4</td>
</tr>
<tr>
<td>5</td>
<td>Point of exit of pond 4 effluent into Marura swamp.</td>
</tr>
</tbody>
</table>

2.3 Examination Of Water Samples For Coliforms

Examination of sewage samples for Faecal Coliform counts (FC) and Total coliforms (TC) was performed using standard pour plate techniques. Isolation was done on selective bacteriological medium (MacConkey Agar) at 37°C and 44.5°C for TC and FC respectively followed by incubation for 48 hours. The colonies growing on the specific media were enumerated using a Quebec colony counter. Table 2.3.1 illustrates the isolation criteria for the TC and FC.

<table>
<thead>
<tr>
<th>Isolation Medium</th>
<th>Incubation Temperature °C</th>
<th>Incubation Period (Hours)</th>
<th>Bacteria Isolated</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC</td>
<td>37</td>
<td>48</td>
<td>TC</td>
</tr>
<tr>
<td>MAC</td>
<td>44.5</td>
<td>48</td>
<td>FC</td>
</tr>
</tbody>
</table>

MAC- MacConkey Agar

2.4 Determination Of Dissolved Oxygen And Biochemical Oxygen Demand Of Sampled Effluents

The DO in water samples were determined using a multiparameter analyzer (HACH company) using methods described in the Manufacture’s manual. The BOD₅ of water samples was determined by getting the difference between DO of samples on day 1 and day 5.

2.5 Data Analysis

The data from this research was analyzed using spreadsheets such as Ms Excel and SPSS packages. Analysis of variance was done to determine the significance differences in parameters of pond influents and effluents

3. Results

The bacterial load of TC and FC alongside BOD5 were all high at the entrance to the first pond (station 1) and then decreased to significantly lower levels at the point of exit from the last pond (station 5). The results on means of TC and FC in influent and effluent samples of the SSPs system at University of Eldoret are shown in table 3. At the entrance (station 1), the average number of TC and FC per 100 ml was recorded at 28710 and 19860 CFUs/100mls of samples respectively while
at the exit (station 5), these numbers decreased to values of 9100 and 3550 CFUs/100mls of samples respectively portraying an average yield purification of 68.30% and 82.12% respectively.

Table 3.1: Means of total coliforms and faecal coliforms (CFUs per 100 mls) in influent and effluent sewage samples of sewage stabilization pond system at university of Eldoret.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Influent (Station 1)</th>
<th>Final Effluent (Station 5)</th>
<th>% Increase Or Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC</td>
<td>28710</td>
<td>9100</td>
<td>68.30</td>
</tr>
<tr>
<td>FC</td>
<td>19860</td>
<td>3550</td>
<td>82.12</td>
</tr>
</tbody>
</table>

The histogram in figure 3.1 shows the comparison between TC and FC in sewage effluents per station in the University of Eldoret SSPs system. From the results, it was realized that even though both the TC and FC reduced significantly in effluents from one station to the next, the numbers of FC were significantly lower than the numbers of TC per station.

Figure 3.1: Means of total coliforms and faecal coliforms per station in sewage samples from university of Eldoret sewage stabilization ponds

The results on means of BOD$_5$ and DO in influent and effluent samples of the SSPs system at University of Eldoret are provided in table 4. At the entrance (station 1), the average BOD$_5$ and DO were recorded at 4.85 and 2.37 mg/l of samples respectively while at the exit (station 5), the concentration of BOD$_5$ and DO were recorded at 1.16 and 9.79 mg/l respectively.

Figure 3.1: Means of total coliforms and faecal coliforms per station in sewage samples from university of Eldoret sewage stabilization ponds

The results on means of BOD$_5$ and DO in influent and effluent samples of the SSPs system at University of Eldoret are provided in table 4. At the entrance (station 1), the average BOD$_5$ and DO were recorded at 4.85 and 2.37 mg/l of samples respectively while at the exit (station 5), the concentration of BOD$_5$ and DO were recorded at 1.16 and 9.79 mg/l respectively.
Table 4: Means of dissolved oxygen and biochemical oxygen demand (mg/l) in influent and effluent sewage samples of sewage stabilization pond system at University of Eldoret.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Influent (Station 1)</th>
<th>Final Effluent (Station 5)</th>
<th>% Increase Or Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD₅</td>
<td>4.85</td>
<td>1.16</td>
<td>76.08</td>
</tr>
<tr>
<td>DO</td>
<td>2.37</td>
<td>9.79</td>
<td>75.79</td>
</tr>
</tbody>
</table>

These results portrayed that as sewage water purification progressed, the levels of BOD₅ decreased significantly while the levels of DO increased significantly showing that the two parameters were inversely proportional to one another. The average percent increase in DO and percent decrease in BOD₅ in treated effluents were found to be 75.79 and 76.08 respectively. The concentration of BOD₅ per station is provided in figure 3. From the results, it was noted that the BOD₅ showed a maximum value at the entrance to the first pond (station 1), and this then reduced more and more with the direction of flow of water with the least mean BOD₅ being recorded for station 5. The mean BOD₅ was 4.85 mg/l, 3.04 mg/l, 2.21 mg/l, 2.16 mg/l and 1.16 mg/l for stations 1, 2, 3, 4 and 5 respectively.

The reverse of the BOD₅ trend was observed for DO in sewage effluents. From the results on means of DO in sewage effluent samples, it was noted that DO was minimal at the entrance to the first pond (station 1) and decreased more and more with the flow of water to a maximum value at the point of exit of sewage effluents from the last pond (station 5) figure 3.3. The mean DO of effluent samples was found to be 2.37 mg/l, 4.66 mg/l, 6.35 mg/l, 7.31 mg/l and 7.79 mg/l for stations 1, 2, 3, 4 and 5 respectively.
Aloo Becky N, Dr. Josephine Mulei, Dr. Lizzy Mwamburi: Evaluation Of Coliforms, Biochemical Oxygen Demand And Dissolved Oxygen In Sewage Water Treated By Sewage Stabilization Ponds

Figure 3.3: Concentration of dissolve oxygen per sampling station at university of Eldoret sewage stabilization ponds.

Figure 3.4: Comparison of levels of biochemical oxygen demand and dissolved oxygen per station in sewage samples from university of Eldoret sewage stabilization ponds.
4. Discussion

The use of SSPs has been considered as the ideal way of improving effluent quality by means of natural processes [5]. The SSPs are one of the lower cost methods for treating the sewage emanating from small communities and this is achieved at minimum maintenance and operational requirements [6]. In these ponds, the organic matter is broken down by aerobic bacteria into simple inorganic materials such as carbon dioxide and water. Algae utilize these compounds to produce complex organic materials that make up algal cells. During this process algal cells generate oxygen which is utilized by bacteria [7]. In essence all these lead to the efficient mineralization of organic matter, that is, lower biochemical oxygen demand (BOD) and inactivation of pathogenic bacteria, yeasts and viruses [8].

According to the results obtained in this study, the University of Eldoret Sewage SSPs system appeared to be very efficient in sewage treatment. It appeared to generate, in fact, a nearly complete removal of organic matter and a satisfactory reduction of faecal contamination in the sewage effluents studied. In this study, the coliform load showed a maximum mean at the entrance to the first pond (station 1) and decreased with the minimum means being recorded at the point of release of the treated effluents into the receiving water body (Station 5). Most of the work on bacterial removal in SSPs has concentrated on the removal of the bacterial indicator organisms (*E. coli* (FC) and FC). The reduction in numbers of bacteria in the consecutive ponds could be attributed to the damage to the cytoplasmic membranes of bacteria caused by sunlight [9]. The processes that may remove coliforms in SSPs include natural die-off, sedimentation, filtration, ultra-violet light ionization, unfavorable water chemistry, temperature effects, and predation by other organisms and pH [10].

There was a marked increase in levels of DO in sewage effluents leaving the treatment plant (Station 5; 9.79 mg/l) than there was in the effluents coming into the treatment plant (Station 1; 2.37 mg/l). The increase in levels of DO could be attributed to the fact that the more and more organic matter was being degraded in the effluents as they were channeled from one pond to the next thereby decreasing the BOD and allowing for levels of DO to go up. The means of DO across the stations were inversely proportional to the means of BOD. The raw incoming sewage effluents (station 1) had high BOD (4.85 mg/l), while the effluents leaving the treatment plant into the receiving water body had lower BOD (1.16 mg/l). The high BOD in inflows could be contributed by the high levels of organic matter in the raw sewage that required high levels of oxygen to be oxidized. The decrease of BOD in the outflows illustrates the functioning of anaerobic zone of the ponds. Anaerobic bacteria convert organic carbon into methane and in the process, remove up to 60% of the BOD [11] [2] [12]. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%. The general observation made in this study was that as the coliform load and BOD decreased with water flow from one station to the next, the DO tended to increase. The reason for this could be because as the sewage treatment preceded from one pond to the next, the quantities of organic matter were eliminated thereby reducing BOD and allowing most of the dissolved oxygen from algal activities to be retained in the effluents.

5. Conclusions

Efficient sewage treatment before disposal is necessary in order to avoid problems that are related to eutrophication of receiving water bodies and degradation of the environment at large. From this study, it was concluded that SSPs can be efficient and simple methods of treating sewage water before releasing them into the environment. They can become handy in areas where households or
institutions are not connected to municipal sewers and therefore require alternative means of sewage treatment. Sewage stabilization ponds are an efficient mechanism in treatment of sewage water and are capable of reduction of coliform load and BOD$_5$ thereby allowing the DO of treated effluents to increase. The increase in DO in treated effluents leaving the treatment plant showed that the SSPs are quite efficient in reduction of organic content of the sewage water. This way, such effluents that are low in organic load and high in DO if released into the environment are incapable of harming the aquatic life or causing diseases to users of surface waters. This study recommends the construction and use of these ponds in places that are out of reach of the conventional treatment plants so as to protect the environment from untreated discharges.

**Acknowledgements**

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**Literature Cited**


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