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River pollution monitoring: a case study of the Ruaraka River in Kenya

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ABSTRACT

The Tusker Brewery at Ruaraka (located about 6 km from Nairobi City Centre) is the largest brewery plant in Kenya, producing about 2.25 million litres of beer per day. The effluent from the plant is discharged directly into the Ruaraka River without any form of pretreatment.

The impact of the discharge from the brewery plant on the water quality profile of the river was monitored and discussed. Based on the results of a treatability study, the expected impact of the waste on the river if some form of pretreatment of the wastewater in an anaerobic pond is provided prior to discharge was simulated.

INTRODUCTION

One of the most pertinent issues in Water Resources Management of a nation is the control of pollution levels in both the major and minor water bodies threatened by discharges from industrial and institutional establishments. For a country like Kenya which is not blessed with abundance of inland surface water resources, the need to focus attention on monitoring the status of the few available rivers that are potential water sources and are also carriers of waste discharges is of particular importance. The Water Pollution Control Division of the Ministry of Water Development has set up a water quality monitoring network for the main rivers [1] in the country. However, very often, efforts are only intensified when a particular river is identified for a specific water supply or hydroelectric power supply projects.

The fundamental principle governing effluent disposal is to make treatment plants do part of the work and let nature complete it. Serious pollutional problems often arise when nature is called upon to do far more than its share of the work. This was the case with respect to the disposal of untreated effluent from the Tusker Brewery plant into the Ruaraka River.

The Tusker Brewery at Ruaraka

The Tusker Brewery is the largest brewery plant in Kenya, producing about 2.25 million litres of beer per day. The plant is situated at Ruaraka, about 6 km from the Nairobi City Centre, off the Nairobi-Thika road. The raw materials used in the plant include malt, barley syrup, sugar cane, hops, water and yeast.

The malting plant is situated separately at the Nairobi's industrial area where finished malt is produced, and stored to cure, prior to transferring to the Ruaraka Plant. At the brewery plant, the malt is crushed and mixed with hot water at a controlled temperature. The mash is allowed to settle for about one hour to facilitate the extraction of fermentable sugars. After straining to remove the spent grains, the liquid is passed on to a brew kettle, where sugar, barley syrup and hops are added. The mixture, called wort, is then boiled for one hour before pumping to a sedimentation tank. Hops and malt solids are drained out from the bottom of the sedimentation tank and the wort is passed to the fermentation tanks where it is cooled, and oxygenated with air. The fermentation which is aided by yeast, takes place at a controlled temperature of 16^{o}C for 5 days. Some of the recovered yeast is recycled back to the fermentation tanks, while the rest is either sold as fish feed or discarded after dehydration. The carbon dioxide produced during fermentation is liquefied and used for carbonation. The fermented beer is passed to cold storage for a minimum of 10 days at -1^{o}C and a pressure of 1 bar for maturation. The beer is then filtered through a diatomaceous earth filter prior to bottling.

The Tusker Brewery plant operates 5 days a week, except on peak months of November and December, when a seven working day a week is adopted to meet increased demand. The plant consumes about 6.0 million litres of water in a normal 24-hour operation comprising of 3 shifts (6 a.m. to 2. p.m, 2 p.m. to 10 p.m, and 10 p.m. to 6.a.m.). The major wastewater generation activities at the Ruaraka plant are brewing, fermentation, bottling and washing.

The large volumes of strong effluents emanating from brewery plants are reported in literature to be readily biodegradable. Isaac and Mcfiggerns [2] reported BOD/COD ratios greater than 0.5 for brewery effluents and

concluded that brewery wastes are not very different from domestic sewage and could therefore be treated by the normal methods of biological treatment.

EXPERIMENTAL INVESTIGATIONS

The various investigations that were carried out concurrently include: routine monitoring of the river water quality at two sampling points located upstream and immediately downstream of the point of wastewater discharge; monitoring the characteristics of the brewery wastewater; and treatment studies of the wastewater in a laboratory model anaerobic pond.

Brewery wastewater sampling and analysis

During the first phase of the study, wastewater samples were collected from the plant twice a week, with the sampling time varied from week to week to accommodate daily fluctuations in waste-water characteristics. The samples were analysed the same day of collection for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), Dissolved Solids (DS), pH, alkalinity, nitrite and nitrate nitrogen, albuminoid ammonia, and chloride contents in accordance with Standard Methods [3] for the examination of water and wastewater.

Treatment Studies

A laboratory model anaerobic pond (dimensions 0.2 m x 0.4 m x 0.6m deep) was set up in one of the treatment site Laboratories of the Nairobi City Commission and used for the treatment of the brewery wastewater. During start-up the pond was initially half filled with raw sewage from Kariobangi sewage treatment works and topped up with the brewery waste. The pond was then completely covered with black polythene sheets and left for about two weeks before continuous feeding with the brewery waste commenced.

The pond was continuously fed using peristaltic pumps at the rate of about 10 l/d. The content of the influent reservoir was replenished each day with fresh wastewater sample, taken care to store only the quantity of feed required for each day. Sampling of the influent of the pond commenced a week after continuous feeding began. The samples were analysed for BOD, COD, SS, pH and alkalinity in accordance with the Standard Methods [3] for the examination of water and wastewater.

River water quality monitoring

Two sampling points; one immediately upstream and the other immediately downstream of the point of the brewery wastewater discharge; were located. Water samples were collected at these points twice a week and analysed for BOD, COD, and SS, again in accordance with Standard Methods [3].

RESULTS AND DISCUSSION

The discussion in this paper centres mainly on the pollution profiles of the river. Detailed discussion on the results of the investigation covering the characteristics and treatability of the brewery waste has been presented in earlier publications [4]. Therefore, only a summary is presented here as a background to the discussion on water quality profile.

Characteristics and treatability of the wastewater

Figure 1 shows the variations in BOD and COD of the brewery wastewater, while Table 1 shows the summary of the average characteristics. Table 2 gives the BOD and COD removal efficiencies for the laboratory model anaerobic pond.

Table 1. Summary of the characteristics of the Brewery Wastewater

Parameter	Range	Average
pH	4.7 - 9.8	6.3
Alkalinity	37 - 245	115
Ammonia	20 - 160	64
Chloride	4 - 52	24
SS	96 - 4800	1900
DS	890 - 5500	2400
BOD	3000 - 5800	4500
COD	4800 - 10 000	8300

All parameters in mg/l except pH

Table 2. Performance of the model anaerobic pond

Parameter	Average Influent Value (mg/l)	Average Effluent Value (mg/l)	Removal Efficiency (%)
BOD	4500	1700	62
COD	8300	3300	60

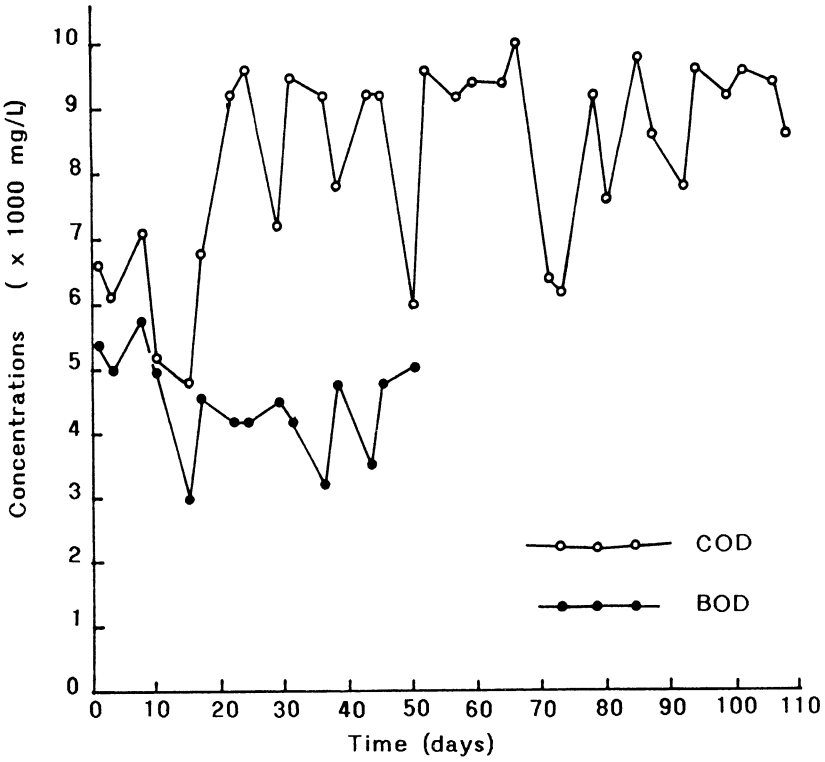

Fig. 1 Variations in BOD and COD of the Brewery wastewater

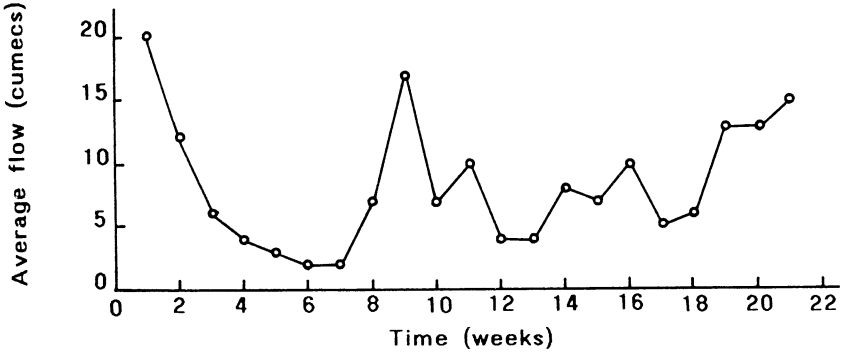

Fig. 2 Variations in river flow during the investion period

Variations in flow of the river.

The data obtained from routine measurements of river flow at a section just above the point of brewery effluent discharge shows the variations in average weekly flow of the river during the period of the investigation (Figure 2). Since the period of the investigation is relatively short, Figure 2 may not be representative of the seasonal variations in flow of the Ruaraka River. However, in the absence of long term flow measurement records, the minimum average weekly flow recorded during this investigation was used to simulate the most critical BOD profile of the river.

Water quality profile

Figures 3, 4, and 5 show the variations in BOD, COD and SS respectively at the upstream and downstream sections of the point of discharge of the brewery effluent. The effect of discharging the untreated brewery wastewater into the river is clearly visible from the figures. The average BOD of the river water at the section upstream of the wastewater discharge point was about 7 mg/l as compared to an average downstream value of 115 mg/l. The BOD of the river water at the upstream section was never higher than 16 mg/l while the BOD at the downstream section sometimes rose to a value as high as 200 mg/l. Mass balancing analysis shows that if the brewery wastewater was pretreated in an anaerobic pond system prior to discharge, the average BOD at the downstream section could be reduced to a value as low as about 65 mg/l as compared to the downstream average BOD value of 115 mg/l for the untreated wastewater discharge scenario.

Analysis of BOD decay down the river channel for the two scenarios produced the BOD profiles shown in Figure 6. It is clear from the analysis that with the current practice of discharging the effluent untreated, the river would only attain a BOD level of 65 mg/l at a distance of more than 7 km from the point of discharge, assuming that its assimilative capacity is not already exceeded by the heavy organic load. Sampling of the river water at different sections further downstream is a major highlight of an ongoing investigation.

CONCLUSION

It was generally observed that the management of Tusker Brewery plant had little or no knowledge of the characteristics of the wastewater being generated from the industry. This study has shown that the brewery wastewater is biodegradable and the organic strength could be reduced by up top 60 per cent using a simple anaerobic pond system. Treatment of the wastewater in such a system prior to discharge is sufficient to avert the serious pollutional problems currently caused to the Ruaraka River by the discharge of the untreated wastewater.

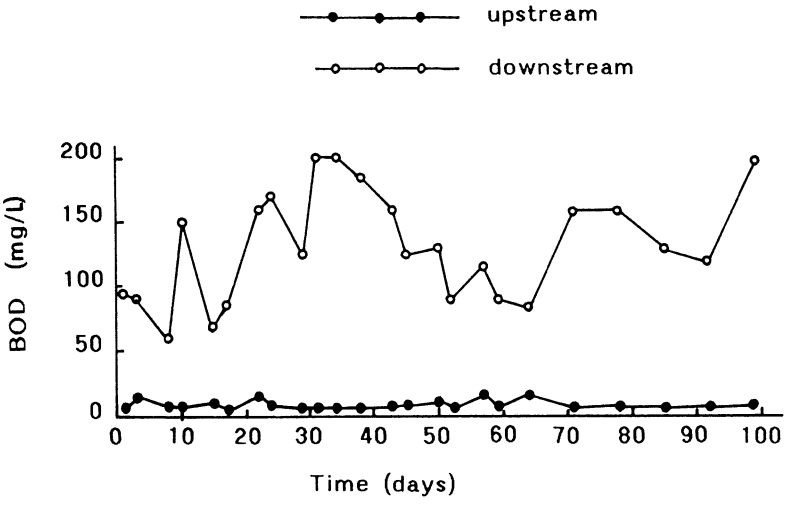

Fig. 3 Variations in BOD at the upstream and downstream sections

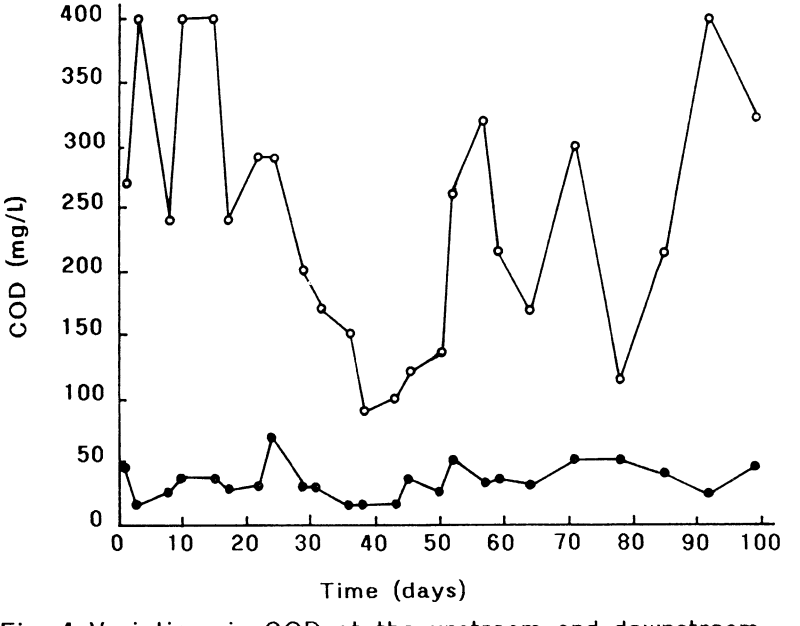

Fig. 4 Variations in COD at the upstream and downstream sections

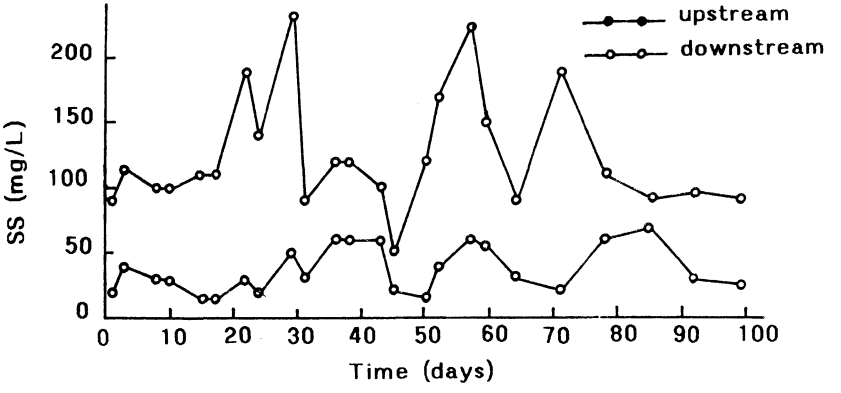

Fig. 5 Variations in SS at the upstream and downstream sections

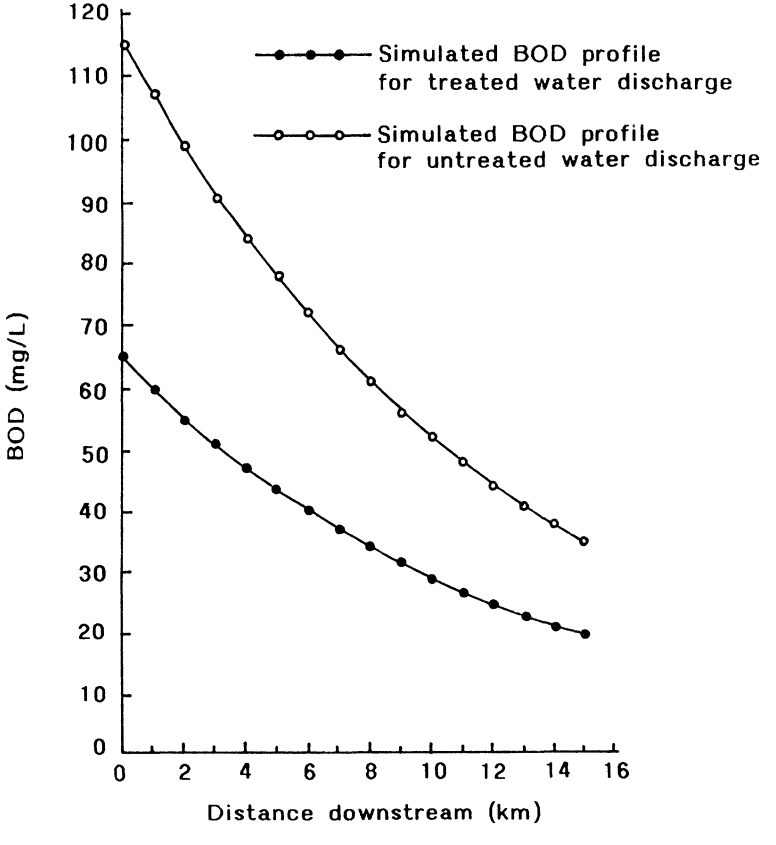

Fig. 6 Simulated BOD profiles for Ruaraka River

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