THE EFFECT OF SEWERAGE WATER TREATMENT PLANT ON THE WATER QUALITY OF MZIMNENE RIVER, IN SWAZILAND

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ABSTRACT

A study to determine the effect of the Nhlambeni wastewater treatment plant on Mzimnene River water quality was undertaken between September 2011(dry season) and January 2012 (wet season). Three sampling sites were selected along the river. Site 1 was located some 200 m upstream the wastewater treatment plant and site 2 was located at the point of discharge. Site 3 was located some 2 km downstream the treatment plant. Water samples were collected and analysed for temperature, pH, Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), total hardness, chloride, ammonia, turbidity, conductivity, colour, total coliform and faecal coliform. The results were analysed using SPSS software for ANOVA and t-test. The results were further compared with the permissible levels for drinking water. The results showed that the river was highly polluted in terms of total coliform and faecal coliform, as counts of up to 84150/100 ml and 5883/100 ml were reported respectively. The differences in water parameters for the three sites were not significantly different ($p > 0.05$). The results showed a significant difference ($p < 0.05$) for temperature (30.50 and 24.83 ^{o}C), pH (8.87 and 7.30), DO (20.70 and 25.56% saturation), ammonia (0.86 and 0.180 mg/l) and total coliform (15668 and 121500 counts/100 ml) for dry season and wet season. It was recommended that households that rely on water from the Mzimnene River should be educated and informed about the quality of the water that it has bacterial counts above the permissible limit for drinking water. The water should be treated by boiling before it was used for drinking.

Keywords: Contamination, portable water quality, sewerage discharge, sustainable development goals.

INTRODUCTION

The Sustainable Development Goal (SDG 6) aims to ensure access to safe water sources and sanitation for all by 2030. The targets of the goal include improving water quality by reducing pollution, eliminating dumping and halving the proportion of untreated wastewater (UN, 2015). About 2.4 billion people in the world do not use improved sanitation (UNICEF, 2016). Globally about 1.8 billion people use a source of drinking water that is faecally contaminated and more than 80% of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal. In Swaziland, the proportion of population with access to safe drinking water and improved sanitation is 74% and 58% respectively (WHO/UNICEF, 2015).

Water pollution is a major problem in the global context and the problem of water pollution is being experienced by both developing and developed countries (Sangodoyin, 1991). The effluents from industries have a great deal of influence on pollution of water body by altering the physical, chemical and biological nature of receiving water body. The effluents further results in vast degradation of the surface waters and makes worse their use for agricultural, drinking, industrial, recreation and other purposes (Simeonov *et al.*, 2003; Jarvie *et al.*, 1998). Seasonal variations in precipitation, surface runoff, ground water flow, interception and abstraction strongly affect river discharge and consequently the concentrations of pollutants in the river water (Khadka and Khanal, 2008; Mtethiwa et al., 2008; Vega *et al*., 1998). Sewage discharge is one of the problems facing developing countries and efforts are being vigorously pursued to control it (Okoh *et al*., 2007). Water contaminated by effluents from various sources is associated with heavy disease burden and this could influence the current shorter life expectancy in the developing countries compared with developed nations (WHO, 2002).

Evaluating water quality is critical to understanding the health of a wetland (Yi *et al*., 2009). Water quality can be evaluated through physiochemical measurements and use of biological indicators. Physical parameters may include temperature, pH, turbidity, total dissolved solids, total suspended solids, dissolved oxygen, air saturation, and flow rate. Chemical parameters may include ammonia, nitrogen, nitrate, nitrite, iron, chlorine, bisphthalate, and phosphorous. Biological indicators of water quality include faecal coliforms, macroinvertebrates, microinvertebrates, and toxicity tests using biological organisms (Hall, 2004).The actual parameters evalutated in a specific assessment for water quality will depend on a number of factors that include the intended use of the assessment results and availability of resources to undertake the assessment. Most of the water resources in Swaziland are polluted by faecal contamination due to the fact that 42% of the population do not use improved sanitation (Vilane and Dlamini, 2016; Manyatsi and Tfwala, 2012). Rapid drinking water quality assessment often involve assessment total coliform and faecal coliform The World Health Organisation (WHO) provide gudelines on drinking water quality assessment, and threshold values for safe driniking water (WHO, 2011).

The objective of the study was to determine water quality of Mzimnene River in terms of biological, chemical and physical parameters, and the effect of the sewerage water treatment plant on the water quality

MATERIALS METHODOLOGY

Description of study area

Mzimnene River runs through Manzini city centre in Swazilnd where it collects a lot of pollution from the town and the settlements around the city centre. Nhlambeni wastewater treatment plant is located downstream, about 12 km from the city. The wastewater treatment plant that is based on the activated sludge system recieves about about 30 l/s of domestic sewage waste (SWSC, 2012). The wastewater is discharged to the Mzimnene River, after passing through the treatment plant. The flow rate for Mzimnene River measured before discharge average 42 l/s at off peak and 93 l/s during peak (Government of Swaziland, 2016). The water from Mzimnene River is used by rural communities for agricultural and domestic purposes without treating it.

Location of sampling sites

Three sampling sites were selected along the Mzimnene River. Site 1 was located some 200 m upstream the wastewater treatment plant, and site 2 was located at the point of discharge. Site 3 was located some 2 km downstream the treatment plant (Table 1).

Table 1 Coordinates of sampling sites

Site Number	X- Coordinates	Y - Coordinates
1	31.3784 ^{o}E	26.5759 ^{o}S
2	31.3641 ^{o}E	26.5794^{o}S
3	31.3769 ^{o}E	26.5797 ^{o}S

Sampling and water quality analysis

Water sampling was done during two periods, one in the month of September 2011 (during low river flow) and another in the month of January 2012 (during high river flow) from each site.Water samples were collected in 500 ml sterilised polyethylene plastic bottles. They were stored in cooler boxes filled with ice cubes during transportation from sampling sites, and before analysis. Analysis was done at the Swaziland Water Services Corporation laboratory (Mbabane, Swaziland) for dissolved oxygen, colour, electrical conductivity, turbidity, total hardness, ammonia, chemical oxygen demand, chlorides, total coliform and faecal coliform. Temperature was measured in the river, before sampling, using a hand held thermometer. The HQ40d portable meter was used to determine pH, and conductivity (Hach, 2013). Turbidity was determined in the laboratory using the 2100N Laboratory Turbidimeter (Hach, 1999). The DR 5000 Spetrophotometer (Hach, 2005) was used to determine Chemical Oxygen Demand, Dissolved Oxygen, Total Hardness, Colour, Ammonia and Chloride following methods shown in Table 2, as described in the DR 5000 Spectrophotometer procedure's manual.

Table 2. Methods for determining parameters using DR 5000 Spectrophotometer.

Parameter	**Procedure**
Ammonia	830/831/832 Ammonia method 10205
Chloride	Method 8113 mercuric Thioyanate method
Colour	Method 8025 Platinum-Cobalt Standard method
Total Hardness	Method 8374 calcium and Magnesium method
Dissolved Oxygen	Method 8166 HRDO method
Chemical Oxygen Demand	Method 8000 Reactor Digestion method

Source: Hach, 2005.

The Membrane Filtration Method 8074 was used to determine total coliform and faecal coliform (Hach, 2010).

Data analysis

The results from water quality analysis were entered into the Statistical Package for the Social Science (SPSS) software for analysis (IBM, 2016). The analysis of variance (ANOVA) was used to determine the statistical significance for the results from the different sampling sites. The t-test was used to determine the statistical significance of results between the different sampling periods. The results of the analysis were compared with the permissible levels of the different parameters (WHO, 2011). The results were then presented in tables.

RESULTS AND DISCUSSION

Water quality for sites

The results for parameters that were analysed are presented in Table 3.

Temperature

Water temperature has effect on the metabolism of aquatic organisms, and each species of aquatic organism has its own optimum water temperature (Sun and Chen, 2014). If the water temperature changes considerably from the optimum, the organism suffers. Cold-blooded animals cannot survive temperatures below 0^oC and only rough fish like carp can tolerate temperatures much warmer than about 36^oC (Kentucky River Authority, 2000). Mean temperature was within the acceptable limit of

35^o C for the sites. The temperature decreased at site 2, which is attributed to the effluent influx and subsequently, increased at site 3 (Table 3). The mean values for temperature were not significantly different for all the sites ($p > 0.05$).

pH

pH is the negative logarithm of the hydrogen ion concentration of a solution and it is a measure of weather the liquid is acid or alkaline (Water Research Center, 2016). Extremes of pH can affect the palatability of water. The extreme values of pH may lead to mortality of fish (Water Research Center, 2016). The results indicate that the pH of the water in the three sites was within the acceptable range of between 6.5 and 8.5 (WHO, 2011). The mean pH values were not significantly different for all the sites ($p > 0.05$).

Table 3. Water quality results for the diferent sites

Parameter	Site 1	Site 2	Site 3	Permissible level
Temperature (^{o}C)	28.25	27.25	27.5	35
pH (pH units)	8.16	8.12	7.99	6.5-8.5
Chemical Oxygen Demand (COD, mg/l O_2)	16.00	16.50	20.00	<10
Dissolved Oxygen (mg/l O_2)	22.65	22.75	24.00	5
Total hardness (mg/l)	85.11	78.13	95.00	<500
Tubidity (NTU)	46.80	48.90	45.54	<500
Conductivity (uS/cm)	260.75	252.00	320.20	<250
Colour (TCU)	61.00	51.50	27.50	20
Chloride (mg/l)	32.50	37.50	40.00	<250
Ammonia (mg/l)	0.55	0.46	0.56	1.5
Total coliform (counts/100 ml)	57202	64400	84150	0
Feacal coliform (counts/100 ml)	3015	5883	46378	0

Chemical Oxygen Demand (COD)

COD is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate (Chapman, 1996). It provides an index to assess the effects discharged wastewater will have on the receiving environment. Higher COD levels mean that there is a greater amount of oxidisable organic material in the sample, which will reduce dissolved oxygen levels (Realtech, 2016). Chemical Oxygen Demand increased from site 1 to site 3 (Table 3). This indicates that the Mzimnene River was being polluted progressively as the water flows downstream. An increase in COD could be attributed to an increase in the addition of both organic and inorganic substance from the environment, as well as organic contaminant entering the systems from the municipal sewage treatment plants (Ogunfowokan *et al.*,2005).. The difference in COD levels were not significant for all the sites ($p > 0.05$). However, COD was above the permissible levels for all the sites.

Dissolved oxygen

The concentration of dissolved oxygen in a stream is affected among other factors by temperature, flow, aquatic plants, altitude, dissolved or suspended solids, and human activities. Dissolved oxygen is essential to the respiratory metabolism of most aquatic organisms (APH, 1995).There was an increase in dissolved oxygen from site 1 to site 3. This was partially due to the decrease in temperature from site 1 to site 3. Temperature decrease increases the amount of dissolved oxygen in water. DO is an important factor in determining the self-purification capacity of a stream. In order to achieve and maintain a healthy aquatic environment, DO content of river water should be kept above 5 mg/l and at no time of the day should it drop below 4 mg/l (Ramakar, 2007). The DO levels were within the permissible levels of > 5mg/l for all the sites. The mean values for DO were not significantly different for all sites ($p > 0.05$).

Total hardness

Hardness is frequently used as an assessment of the quality of water supplies. The hardness of a water is governed by the content of calcium and magnesium salts (Sa'eed and Amira (2013). Decreased hardness is related to stream flow (EPA, 2001). Total hardness was within the permissible levels of < 500 mg/l for all the sites. Total hardness levels were not significantly different for the different sites sites ($p > 0.05$). From this one may conclude that the Mzimnene River was less polluted with calcium and magnesium.

Turbidity

Turbidity in water arises from presence of very finely divided solids which are not filtered by routing methods. Turbidity in water will affect its acceptability to consumers and its utility in certain industries and direct health effects depend on the composition of the turbidity-causing matrial (EPA, 2001). The values were below the maximum permissible value of 500 NTU. The mean turbidity values for all the sites were not significantly different ($p > 0.05$).

Conductivity

Conductivity is a measure of how well water can pass an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, iron and aluminium (EPA, 2001). A high concentration of dissolved solids, can cause water balance problems for aquatic organisms and decrease dissolved oxygen levelsMunicipal, agricultural, and industrial discharges can contribute ions to receiving waters or can contain substances that are poor conductors (organic compounds) changing the conductivity of the receiving waters (Stoddard *et al.*, 1999). The conductivity was above the permissible level of 250 uS/cm for all the sites, indicating high levels of dissolved inorganic solids.

Colour

Natural colour of water reflects the presence of complex organic molecules derived from vegetable matter such as peat, leaves and branches (EPA, 2001). Natural colour may arise from the presence of colloidal iron/manganese in water. Objections to colour are generally on aesthetic grounds rather than on the bais of a health hazards. Colour may be indicative of dissolved organic material, inadequate treatment, high disinfectant demand and the potential for the production of excess amounts of disinfectant by products. The values for colour were above the acceptable limit of 20 TCU. The mean values for colour for the different sites were not significantly different ($p > 0.05$).

Chloride

Chloride exists in all natural waters with varying concentration, reaching a maximum in sea water (up to 35000 mg/l Cl). Sewerage and industrial effluents contain large amount of chloride (EPA, 2001). Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability. Sewage is considered to be a rich source of chloride. The general trend was an increase in the chloride content of the rivers from Site 1 towards Site 3 (Table 3). The chloride levels were within the permissible value of < 250 mg/l for all the sites. The mean values for chloride were not significantly different for all the sites ($p > 0.0.5$).

Ammonia

Ammonia is one of the most important pollutants in the aquatic environment because of its relatively highly toxic nature. It is discharged in large quantities in industrial, municipal and agricultural wastewaters (EPA, 2001; Moyo and Mtetwa, 2002). When above 0.1 mg/l N, sewage or industrial contamination may be indicated (WHO, 2003). Mean ammonia concentration decreased from Site 1 to Site 2. It increased again in Site 3.This was an indication that the river had high concentration of ammonia, and the sewage waste discharge had a dilution effect. The effluent seemed to be less contaminated with ammonia and it diluted the river system The ammonia levels were within the permissible level of 1.5 from all the sites. The ammonia content for all the sites was not significantly different ($p > 0.05$).

Total coliform and faecal coliform

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in soils, plants and in intestines of warm-blooded (humans) and cold-blooded animals, aiding in the digestion of food (Ohio Department of Health, 2004). Most coliform bacteria do not cause illness. However, their presence in drinking water system is a healthy concern because of the potential for disease-causing organisms (WHO, 2003). Faecal coliforms originate in human and animal waste. On the other hand total coliforms include faecal coliforms and also other bactiria with similar properties which originate in soil and are none faecal (EPA, 2001).The coliforms are thus used as indicators of contamination of water by sewerage (Hassan et al., 2016). The total coliforms and faecal coliforms were detected and the counts were very high for all the sites (Table 3). This could be a sign that the river water was highly contaminated due to poor sanitation within the catchment area. In a study conducted by Vilane and Dlamini, they found that Groundwater from boreholes in an informal settlement in Swaziland were found to have up to 14000 counts/ 100 ml of total coliform, and up to 1354 counts of faecal coliform/100 ml (Vilane and Dlamini, 2016). The informal settelements and rural settlements in Swaziland are characterised by use of pit latrines, and in some cases there is open defication (Manyatsi and Thwala, 2014). There was however no significant difference between the mean values for all the sites ($p > 0.05$).

Comparison of parameters for different seasons

The parameters that had values which were significantly different for the different periods were temperature, pH, Dissolved Oxygen, Ammonia, and total coliform (Table 4). The temperature values were significantly higher for the dry period. Significant increases in water temperature is caused by industrial discharges of warm water, or by reduction of water flow where dams are operating (Environmental and Health International, 2006). The pH values were significantly lower for the wet period. Rainwater is naturally acidic at about 5.6. This could be the reason for the lower values during the wet period.

Table 4. Comparison of water quality for different periods

Parameter	Dry season	Wet season
Temperature (oC)	30.50^{a*}	24.83^{a*}
pH (pH units)	8.87^{b*}	7.30^{b*}
Chemical Oxygen Demand (COD, mg/l)	10.33	24.67
Dissolved Oxygen (DO, % saturation)	20.70^{c*}	25.56^{c*}
Total hardness (mg/l)	95.35	76.81
Tubidity (NTU)	18.8^{d*}	75.36^{d*}
Conductivity (uS/cm)	220.53	334.77
Colour (TCU)	23.33	70.00
Chlorine (mg/l)	36.67	36.67
Ammonia (mg/l)	0.86^{e*}	0.18^{e*}
Total coliform (counts/100 ml)	15668^{f*}	121500^{f*}
Feacal coliform (counts/100 ml)	2731	34193

*Parameters with same alphabet were signicantly different for the two periods ($p < 0.05$).

The DO values were significantly higher for the wet period. The flushing effect of the increased water levels in Mzimnene increased the dissolved oxygen content of the rivers. Unfortunately, during the dry summer month of September, the rivers are virtually dead because the water becomes stagnant with the much-reduced flow (EPA, 2001). Ammonia values were significantly lower for wet period. The concentration of ammonia is dependent on water temperature and pH, along with the dissolved oxygen and carbon dioxide levels. For instance, ammonia increases with increased temperature and pH (Knepp and Arkin, 1973). Since there was a decrease in pH and temperature during the wet period, it resulted in significant low levels of ammonia. The turbidity values were significantly higher for wet period. There was a significant deterioration of the streams in the second period. Turbidity may be caused by a wide variety of suspended materials, such as clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and other microscopic organisms and similar substances (WHO, 2011).

CONCLUSIONS

The results showed that the Mzimnene River was highly polluted as total coliform and faecal coliform were detected in large quantities. This could be attributed to poor sanitation within the river catchment, as the majority of people in informal settlements use pit latrines or open space for faecal disposal. The other parameters were within the acceptable limits for drinking water. The total coliform counts were significantly higher during the wet season, as compared to the dry season. The water temperature, pH and ammonia were signicantly higher during the dry season bacause of low flow rates. The sewerage water treatment plant contributed to pollution of the river. Based on the study it is recommended that households that rely on the raw water from the Mzimnene River should be educated and informed about the quality of the water that has bacterial counts above the permissible limit for drinking water. Government should also look at alternative sources of domestic water such as boreholes or connecting the area to the Swaziland Water Services Corporation pipeline.

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