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Full Length Research Paper

Water quality changes due to abattoir effluent: A case on Mchesa Stream in Blantyre, Malawi

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Abattoir effluent is known to degrade the quality of receiving water bodies. This study assesses the impact of effluent from Shire Valley Abattoir on the physico-chemical parameters of Mchesa Stream in Blantyre. Water samples were collected from five sampling sites along Mchesa Stream located at progressive distances from the discharge point. Sampling was done three times over a period of four months (June to September 2008). The physico-chemical parameters tested were: pH, biochemical oxygen demand (BOD), dissolved oxygen (DO), suspended solids (SS) and electrical conductivity (EC). The mean values of the measured parameters were as follows: BOD (381.1 mg L^{-1}); DO (3.6 mg L^{-1}); SS (312.8 mg L^{-1}); pH (7.6); and EC (105.6 µs cm^{-1}). The highest concentrations of BOD and SS were 612.3 mg L^{-1} and 477.3 mg L^{-1} respectively and were obtained at a point of effluent discharge into Mchesa stream. One-way ANOVA showed significant deviation from WHO standards for BOD, SS and DO ($p < 0.05$). This study shows that effluents from the Shire Valley Abattoir have partially contributed to the pollution of Mchesa Stream to levels which pose health and environmental hazards to the surrounding communities.

Key words: Abattoir, effluent, water quality, physico-chemical parameters, Mchesa stream, hazard.

INTRODUCTION

Abattoirs are known all over the world to pollute the environment either directly or indirectly from their various processes. Wastewater from an abattoir is a particularly concentrated source of oxygen consuming waste (Girards, 2005). In Malawi, abattoir operations are generally unregulated. Moreover, abattoirs are usually located near water bodies in order to gain unhampered access to water for processing. Abattoirs generally use large quantity of water for washing meat and cleaning process areas (Kuyeli, 2007). The disposal of effluent into drains and stream of Blantyre is a common practice which poses health and environmental hazard to the people downstream. The Department of Environmental Affairs (DEA) is mandated under Environment Management Act (EMA) (Government of Malawi, 1996) to inspect premises of commercial institutions to determine if any activities carried out within operation yard are negatively affecting the environment. The jurisdiction of their power extends to monitoring the water quality of streams which is supposed to be done at least once a year.

Abattoir effluent contains high levels of organic matter due to presence of manure, blood, fats, grease, hair, grit and undigested feeds. It can also contain high level of salts, phosphate and nitrates. Blood and fats contribute mostly to organic load. Blood is also a major contributor of nitrogen content in the effluent. At those plants where rendering occurs, the effluents from rendering typically represent the single most significant source of pollutant load in the abattoir effluent. Since abattoirs produce large quantities of solid wastes, wash water and process wastewater containing organic matter, suspended solids

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Abbreviations: BOD, Biochemical oxygen demand**; DO,** dissolved oxygen; **SS,** suspended solids; **EC,** electrical conductivity; **DEA,** Department of Environmental Affairs; **EMA,** Environment Management Act.

Table 1. Sampling location description.

Designation	Characteristics
S_{-10}	Sampling point located 10 m upstream with respect to abattoir discharge point. It served as reference point.
S_0	Sampling point at abattoir effluent discharge point.
S_{10}	Sampling point located 10m downstream from effluent discharge.
S_{50}	Sampling point located 50m downstream from effluent discharge.
S_{100}	Located 100 m downstream of the point of discharge.

and a wide variety of contaminants that are generated during different processing stages.

Total amount of waste produced per animal slaughtered is approximately 35% of its weight. Studies by Verheignjen et al. (1996) found that for every 1000 kg of carcass weight, a slaughtered beef produces 5.5 kg of manure (excluding rumen contents or stockyard manure) and 100 kg of punch manure (partially digested food). Similar results were obtained by Scahill (2003) and Cannon et al. (2004).

The pollution load on a water body from abattoir effluent can be quite high. For example studies done in Canada (Mittal, 2004) and Nigeria (Adie and Osibanjo, 2007) showed very high contaminant levels in abattoir effluent. Most of these contaminants are known to be hazardous to human beings and aquatic life. Likewise, improper disposal of effluent from slaughterhouses could lead to transmission of pathogens to humans and cause diseases such as Coli, Bacillus, Salmonella infections, Brucellosis and helminthic diseases and infections (Cadmus et al., 1999).

Akuffo (1998) also observed that water quality degradation interferes with vital and legitimate water quality uses at any scale. Pollution of water resources reduces the availability of clean and safe drinking water to most of the world's population. Keating (1994) reported that in developing countries an estimated 80% of all diseases and over one third of deaths are caused by consuming contaminated water. In Malawi, nearly 50% of all illnesses are related to water borne diseases (Kalua and Chipeta, 2005; Palamuleni, 2001). It is interesting to note that Kachala (2010) relates the prevalence of oesophageal cancer to environmental degradation especially in Sub-Saharan Africa. The availability of safe water in Malawi is worsened by poor sanitation, improper disposal of industrial waste and chemical inputs from agriculture (Government of Malawi, 2001). Majority of the people living along and down the course of Mchesa stream depend on untreated stream water supply and chances are that they are drinking unclean, polluted water. Mchesa stream can be classified as an inland surface water body according to the Malawi Bureau of standards and Malawi government classification. Water from Mchesa is mainly used for domestic purposes and sometimes for drinking. This study therefore was conducted to assess the impact of effluent from Shire Valley Abattoir on the physico-chemical parameters of Mchesa Stream in Blantyre, Malawi.

MATERIALS AND METHODS

Study area

Mchesa Stream (15° 51' S, 34° 58' E) is located in Blantyre district in the southern region of Malawi. The stream is perennial and it emanates from Ntonda hills (15° 85'S, 34°98'E). It passes through several villages but particularly Kadam'manja and Beni villages along Chikwawa road. Blantyre is Malawi's commercial capital and has a population of over one million people. The mean annual rainfall is 834 mm. Rain normally falls between October and March but sometimes extends to April. The seasonal variation in the rainfall patterns has effects on water quantity and quality and it would be scientifically prudent to sample at different times of the year during both the dry and wet seasons. However due to financial and other constraints, the data presented in this paper only reflects the dry season.

Sampling design

The study was conducted in Blantyre, Malawi from June to September, 2008. Sampling was done three times from each of the five strategic points along Mchesa stream using random grab sampling. All samples were collected in triplicate to improve reliability of data. Samples were collected from the mid-width of the stream using one-litre plastic bottles that had previously been cleaned, soaked in 10% nitric acid and rinsed thrice with distilled water. Three one-litre samples were collected at each of the five sampling points designated S_{-10} - S_{100}. pH values were recorded at Polytechnic laboratories within two hours after sample collection. The full description of sampling locations is shown in Table 1.

Sample analysis

The standard analytical methods that were used for determination of physico-chemical parameters of water and wastewater were from American Public Health Association series of Standard Methods of Examination of Water and Effluent (APHA, 1998).

Statistics

The results of laboratory analysis were subjected to data analysis using SPSS, version 12. To analyse changes in the levels of BOD, SS, DO, pH, and EC that might be attributed to abattoir effluent discharged into Mchesa stream, one-way Analysis of Variance (ANOVA) at 0.05 significance level was employed. In this test, the hypothesis was that there is no difference among means of five

Table 2. Biochemical Oxygen Demand (BOD) in Mchesa Stream (given as means and standard errors of the means) compared to WHO and MBS standards.

Sample station	BOD in Mchesa Stream (mg L^{-1})	Acceptable WHO levels (mg L^{-1})	Acceptable MBS levels (mg L^{-1})	WHO and MBS standards exceeded by (mg L^{-1})
S_{-10}	257.3 ± 8.3	20	20	237.3
S_0	612.3 ± 15.0	20	20	592.3
S_{10}	487.0 ± 1.2	20	20	467.3
S_{50}	308.7 ± 3.5	20	20	288.7
S_{100}	240.0 ± 16.1	20	20	220.0

samples obtained for each parameter under study; this expression is presented mathematically as:

H_0: $\mu_{-10} = \mu_0 = \mu_{10} = \mu_{50} = \mu_{100}$

H_i: means not equal.

RESULTS AND DISCUSSION

A summary of the results is presented in the following set of tables which also compare each of the parameters with the acceptable levels. A discussion of each parameter follows the tables.

At S_{-10}, a point upstream, the BOD value was 257.3 ± 8.3 mg L^{-1}. The BOD concentration went higher to 612.3 ± 15.0 mg L^{-1} at S_0 (Table 2). This was because of the effluent discharged by the abattoir on the stream at this point and therefore not completely mixed. At point S_{10}, the mean value of BOD was reduced to 487.0 ± 1.2 mg L^{-1}. This can partially be attributed to dilution due to mixing and partially as a result of settling along the stream course and dilution. Furthermore, some part of BOD may decrease due to microbial degradation during course of flow from S0 to S10. However, the time required for water to travel S0 to S10 is too small to get any significant degradation. The flow of the water in the stream may increase the amount of dissolved oxygen in water that subsequently increased the microbial degradation of organic matter. At S_{50} and S_{100}, the mean BOD values further decreased to 308.7 ± 3.5 and 240.0 ± 16.1 mg L^{-1} respectively. This, again, may be due to extensive dilution occurring in the stream during mixing of the effluent as it moves away from S_0. Nevertheless, the mean values of BOD at S_{50} and S_{100} remained higher and may be due to other non point sources of pollution. Results (Table 2) from all the sampling points indicate that BOD levels far exceed the acceptable levels of 20 mg L^{-1} as stipulated by both the World Health Organisation (WHO), (1984) and Malawi Bureau of Standards (MBS) (2000). The high levels of BOD at S_{-10} indicate that Mchesa stream is already heavily polluted even before the discharge of effluent from Shire Valley abattoir. There is, however, a marked increase at the point of the abattoir effluent discharge indicating a considerable contribution of the effluent to the degradation of water quality. The month of June had the highest BOD and SS (Table 4) values probably because it is relatively closer to the wet season (which sometimes ends in April) than the other months, hence the dilution effects that result in lower pollution.

The DO concentration from the study (Table 3) ranged from 1.8 ± 0.3 - 6.1 ± 0.3 mg L^{-1}. DO is the measure of the degree of pollution by organic matter, the destruction of organic substance as well as self-purification of the water bodies. It reflects interaction with the overlaying air because oxygen from the atmosphere is dissolved in the water (Chiras, 1998) and it is one of the most significant tests for measuring the quality of water. The standard for sustaining aquatic life is stipulated to be 5 mg per litre (Horne and Goldman, 1994). Concentration below 2 mg L^{-1} adversely affects aquatic and biological life while the concentration below 2 mg L^{-1} may lead to death of fish. The lowest mean value of 1.8 ± 0.3 mg L^{-1} was detected at S_0 (a point where the effluent is discharged into the stream). There is a decrease in concentration from 3.8 ± 0.4 mg L^{-1} found at S_{-10}. The low DO concentration at S_0 could be due to high organic load as shown by BOD and suspended solid values (Table 2). At S_{10}, the mean DO level increased to 2.4 ± 0.3 mg L^{-1} probably due to mixing and re-aeration along the stream. The mean value of DO concentration continued to improve down the stream to 3.7 ± 0.2 and 6.1 ± 0.3 mg L^{-1} at S_{50} and S_{100}, respectively. This could be attributed to both the flow and recovery capacity of the stream. At S_{100}, it may be suggested that the stream recovered from the organic load and could have been a better status to support aquatic life.

The concentration of suspended solids ranged from 264.7 ± 19.4 to 477.3 ± 51.1 mg L^{-1}. The highest value of 477.3 ± 51.1 mg L^{-1} at S_0 (Table 4) could be due to lack of proper sedimentation facility to separate the solid waste from liquid waste before the effluent is discharged. Both WHO and MBS recommend a maximum of 30 mg L^{-1}, and certainly the excessive 447.3± 51.1 mg L^{-1} suspended solids being loaded into the stream is leading to the degradation of water quality. High concentrations of suspended solids can also cause problems to aquatic life such as by reducing water clarity and clogging fish gills (Kuyeli, 2007).The levels of suspended solids remained almost the same at S_{10}, S_{50}, and S_{100}, which clearly indicate

Table 3. Dissolved Oxygen (DO) in Mchesa Stream (given as means and standard errors of the means) compared with minimum levels to support aquatic life and fish.

Sample station	DO of Mchesa Stream (mg L^{-1})	Minimum value for fish life (mg L^{-1})	Standard for sustaining aquatic life (mg L^{-1})	Minimum value for fish life exceeded by (mg L^{-1})	Standard for sustaining aquatic life exceeded by (mg L^{-1})
S_{-10}	3.8 ± 0.4	2	5	Not exceeded	1.2
S_0	1.8 ± 0.3	2	5	0.2	3.2
S_{10}	2.4 ± 0.3	2	5	Not exceeded	2.6
S_{50}	3.7 ± 0.2	2	5	Not exceeded	1.3
S_{100}	6.1 ± 0.3	2	5	Not exceeded	Not exceeded

Table 4. Suspended Solids (SS) in Mchesa Stream (given as means and standard errors of the means) compared to WHO and MBS standards**.**

Sample station	SS in Mchesa Stream (mg L^{-1})	Acceptable WHO levels (mg L^{-1})	Acceptable MBS levels (mg L^{-1})	WHO and MBS standards exceeded by (mg L^{-1})
S_{-10}	286.0 ± 5.8	30	30	256.0
S_0	477.3 ± 51.1	30	30	447.3
S_{10}	272.0 ± 31.8	30	30	242.0
S_{50}	264.7 ± 19.4	30	30	234.7
S_{100}	264.0 ± 6.0	30	30	234.0

that there is hardly any change after S_{10}. The changes between S_0 and S_{10} can be attributed partially to dilution and partially to settling.

Electrical conductivity (EC) values (Table 5) ranged from 83.0 ± 7.0 to 177.7 ± 1.5 µS cm-1. WHO recommends 400 µS cm^{-1} while MBS recommends 150 µS cm^{-1}. At S^{-10} an average of 99.3 ± 13.9 µS cm^{-1} was recorded. The value rose to 128.3 ± 2.0 µS cm^{-1} at S_0. At S_{10}, the recorded conductance value of 177.7 ± 1.5 µS cm^{-1}. During sample collection, it was observed that women wash their clothes a few meters upstream and the high EC was probably due to salts from detergents. Electrical conductivity decreased to 99.7 ± 1.9 µS cm^{-1} at S_{50}.

Further down at S_{100}, the minimum value of 83.0 ± 7.0 µS cm-1 was reached. This may be due to little amounts of dissolve solids in water due to dilution. Electrical conductivity is used to indicate the dissolved solids in water because the concentration of ionic species determines the conduction of current in an electrolyte (Hayashi, 2004). The high values of electrical conductivity therefore suggest that Mchesa Stream has a considerable loading of dissolved salts although most values except at S_{50} are below the minimum acceptable levels as stipulated by WHO and MBS.

Hydrogen ion concentration or pH is the indicator of acidity or alkalinity of water. It is a measure of the effective concentration (activity) of hydrogen ions in water. Water having a pH range of 6.5 -8.5 will generally support a good number of aquatic species. Only a few species can tolerate pH values lower than 5 or greater than 9 (Harrison, 1999). The mean values of pH obtained (Table 6) ranged from 7.4 ± 0.1 - 7.7± 0.1. These pH values were normal to unpolluted freshwater (Sawyer, 2003). They were also within the recommended ranges (6.5-9.5) as stipulated by both WHO and MBS.

One way ANOVA test showed that only BOD, SS, DO had significant difference ($P<0.05$). This implies that BOD, DO and SS were the parameters of water quality of the stream that had been significantly affected by pollution.

Similar studies done in Mudi River (Masamba and Chimbalanga, 2001) and in several streams and rivers in Blantyre (Kuyeli, 2007) found that industrial activities are contributing greatly to the degradation of ecosystem health.

Conclusion

This study shows that most of the parameters in

Table 5. Electrical conductivity (EC) in Mchesa Stream (given as means and standard errors of the means) compared to WHO and MBS standards.

Sample station	Electrical conductivity of Mchesa Stream (µS cm^{-1})	WHO recommended value (µS cm^{-1})	MBS recommended Value (µS cm^{-1})	WHO Standard exceeded by (µS cm^{-1})	MBS standard exceeded by (µS cm^{-1})
S_{-10}	99.3 ± 13.9	400	150	Not exceeded	Not exceeded
S_0	128.3 ± 2.0	400	150	Not exceeded	Not exceeded
S_{10}	177.7 ± 1.5	400	150	Not exceeded	27.7
S_{50}	99.7 ± 1.9	400	150	Not exceeded	Not exceeded
S_{100}	83.0 ± 7.0	400	150	Not exceeded	Not exceeded

Table 6. The pH in Mchesa Stream (given as means and standard errors of the means) compared to WHO and MBS standards.

Sample station	pH of Mchesa Stream	WHO and MBS recommended range
S_{-10}	7.4 ± 0.1	6.5-9.5
S_0	7.7 ± 0.1	6.5-9.5
S_{10}	7.5 ± 0.2	6.5-9.5
S_{50}	7.6 ± 0.3	6.5-9.5
S_{100}	7.7 ± 0.2	6.5-9.5

Mchesa Stream are above those recommended by both WHO and MBS. The results of the study show that although Mchesa stream is already polluted from upstream activities, there is a significant increase in the levels of BOD, SS and DO at the point where Shire Valley Abattoir discharged effluent. Therefore activities at Shire Valley Abattoir are partially contributing to the pollution of Mchesa stream and endangering the health of the people who rely on the stream as their water source and the ecosystem. The Shire Valley Abattoir needs to improve the management of waste from its industrial activities so as to pose minimum danger to the environment and to people. The government of Malawi should embark on regular monitoring activities of streams and rivers to ensure the safety of its human population and the environment. It is recommended that further research should be done in the wet season.

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