Impact of Slaughterhouses Effluent on Water Quality of Modjo and Akaki River in Central Ethiopia

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Abstract: ***The objective of this study was investigating the impact of effluents of Kera and Luna slaughterhouses on the water quality of receiving Rivers Akaki and Modjo respectively. Water samples from effluents of both slaughterhouses and both Rivers were examined using standard procedure over the duration of two months period of dry season. It was found that except temperature and pH, the levels of DO, TS, TSS, BOD_5, COD, NH_3-N, NO_2^--N, NO_3^--N, S^{-2}, $SO4^{-2}$, PO_4^{-3}, TP, FC, TC and FOG of both rivers and both effluents did not comply with standards of the country. Again the addition of discharges has caused many fold increase in most of the analyzed parameters at downstream of both rivers. The result has revealed that there was an adverse impact on the physiochemical and bacteriological characteristics of the receiving rivers as a result of the discharge of these effluents. There is a need of remediation of both Rivers as well as an intervention of regulatory bodies to ensure production of high quality treated final effluents by the slaughterhouse industries.***

Keywords:-Bacteriological, Effluent, Impact, Physicochemical, Rivers, Slaughterhouses, Water quality

1. Introduction

Freshwater is a scarce resource, essential for agriculture, industry, and human and animal life existence. We depend on our streams and rivers to deliver much of these water uses. Without adequate quantity and quality of freshwater sustainable development will not be true for all countries of our globe. In Ethiopia from the increasing human population, uncontrolled urbanization and waste disposal cause serious quality degradation of surface waters. Now a day's water pollution from disposal of industrial wastewater is becoming an environmental concern in Addis Ababa city and its vicinity areas. Of these industries slaughterhouse industries such as Kera slaughterhouse in Addis Ababa and Luna slaughterhouse in Modjo are exemplary. Slaughterhouse industries consume large amount of water resource for washing of carcasses after hide removal from cattle, goats and sheep; carcass washing after evisceration; equipment and facilities washing; cooling of mechanical equipments. These activities result to generate large amount of wastewater along with other by-products.

Untreated slaughterhouse wastewater comprises a mixture of fats, proteins and fibers, resulting in a high content of organic matter and causes a contaminating effect to the rivers and sewage systems. It also increases nitrogen, phosphorus, solids and BOD5 levels of the receiving water body, potentially leading to eutrophication [1,2,3, and 4]. It has been reported that discharge of large quantities of wastewater is common environmental issue to all slaughterhouses [5]. However, untreated effluent of Kera (in Addis Ababa) and partially treated effluents of Luna slaughterhouse (in Modjo) from the thousands of animals slaughtered daily throughout the year flows into Little Akaki River and Modjo River, respectively. These effluents may cause pollution over the rivers and also create other environmental stresses in the downstreams and nearby residential areas.

It is also reported that surface water bodies in developing countries are under serious threat as a result of indiscriminate discharge of polluted effluents from industrial, agricultural, and domestic activities [6]. Surface waters in Addis Ababa and Modjo are also not protected from such problem. As indicated by Samuel Melaku et al [7]. Little Akaki River water has been polluted because of industrial and intensive agricultural practices as well as indiscriminate disposal of domestic wastes. These situations have also been true to Modjo River [8]. However the contribution of the effluents of slaughterhouse industries is not left known. So that knowing the effect of slaughterhouse effluents on the water quality of the receiving rivers is essential. Therefore, this study aimed at investigation of the impact of the untreated and partially treated discharged slaughterhouses (Kera and Luna) effluents on the water quality of the receiving water bodies, Akaki and Modjo Rivers respectively.

2. Materials and Methods

2.1 Description of Study Area

The study areas were two rivers, Akaki and Modjo River found in central Ethiopia. Both Rivers are tributary of the Awash River and located in Addis Ababa city and Modjo town, in the central rift valley of Ethiopia respectively. Akaki River drains to the western part of the city. Addis Ababa, the capital city of Ethiopia is found at the central part of the country. Modjo town is the administrative center of Lomie Woreda and is located in the East Shewa Zone of the Oromia Regional State and 75 km Southeast of Addis Ababa. Those rivers are receiving effluents of Kera and Luna slaughterhouses (Figure 2 and 3) their location map is as shown in Figure 1.

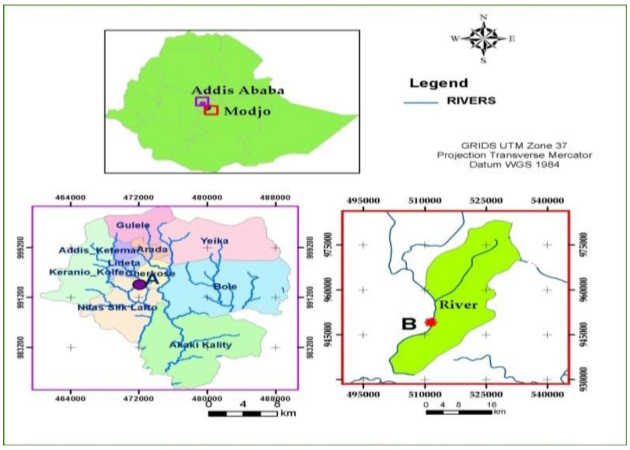

Figure 1: Location map of Akaki River (A) in Addis Ababa and Modjo River (B) in Modjo

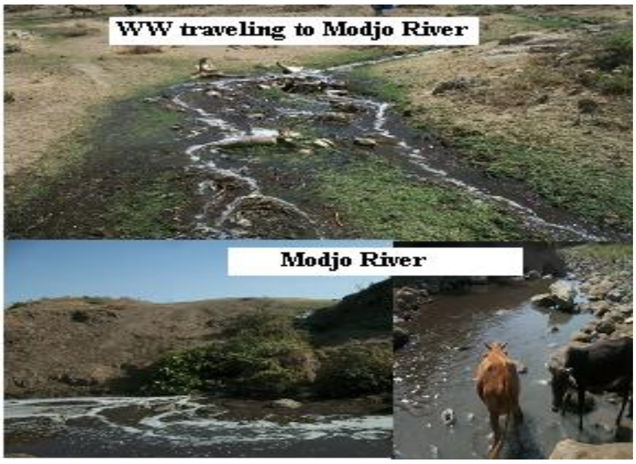

Figure 2: Discharge of partially treated waste water in to Modjo River

Figure 3: Direct discharge of untreated Kera slaughterhouse effluent in to Little Akaki River

2.2 Sampling Techniques

Triplicate sampling was conducted from January to February, 2011. Nine water samples designated by P_1 to P_5 (Luna slaughterhouse and Modjo River) and K_1 to K_4 (Kera slaughterhouse and Akaki River) were collected from both sites. The types of samples were raw effluent (from both slaughterhouses); treated effluent (only from Luna slaughterhouse) and river water (effluent receiving water bodies in both sites). Each of these sampling points are clearly described in detail in Table 1.

Table 1: Description of sampling points location of the two sites

Name of the Site	*Designation*	*Type of water sample*
Akaki river and Kera slaughterhouse	K_1	Raw wastewater
	K_2	Discharge point (mixing point)of slaughterhouse wastewater with Little Akaki River
	K_3	Upstream of Little Akaki River (above the discharge point)
	K_4	Downstream of Little Akaki River (below the discharge point)
Modjo River and Luna slaughterhouse	P_1	Raw wastewater
	P_2	Treated Wastewater leaving the biological wastewater Lagoon (Outlet of wastewater Lagoon)
	P_3	Discharge point (mixing point) of slaughterhouse effluent with Modjo River
	P_4	Upstream of Modjo River (above the discharge point)
	P_5	Downstream o of Modjo River (below the discharge point)

2.3 Slaughterhouses Wastewater Sampling

Triplicate composite samples of raw effluent were collected from both sampling sites designated as P_1 and K_1 from Luna and Kera slaughterhouses, respectively. In addition to this, in the case of Luna export slaughterhouses a treated wastewater sample i.e. effluent passing through the three floatation and sedimentation chambers, and leaving the wastewater treatment lagoon (P_2) were also collected, but not from the Kera slaughterhouse since it does not have any treatment facilities. The triplicate samplings were collected from both sites during four hours of production time two weeks interval. The samples from each period during four hours were mixed to produce half to one half liter representative samples in each sampling date. Each sampling points location map is displayed in Figures 4 and 5.The reason for the selection of four hour is in order to produce representative samples. The selection of dry season and two weeks gap were in order to produce average data on the characteristics of those slaughterhouses by taking in to consideration the time limit given to complete this work.

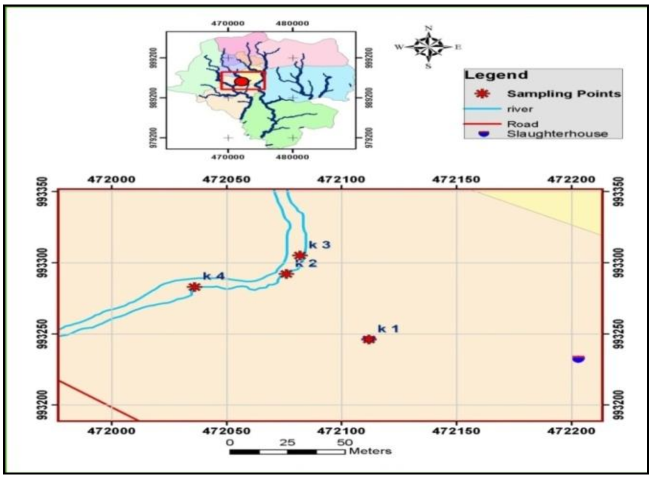

Figure 4: Location map of each sampling points of Kera Slaughterhouse and its effluent receivingLittle Akaki River

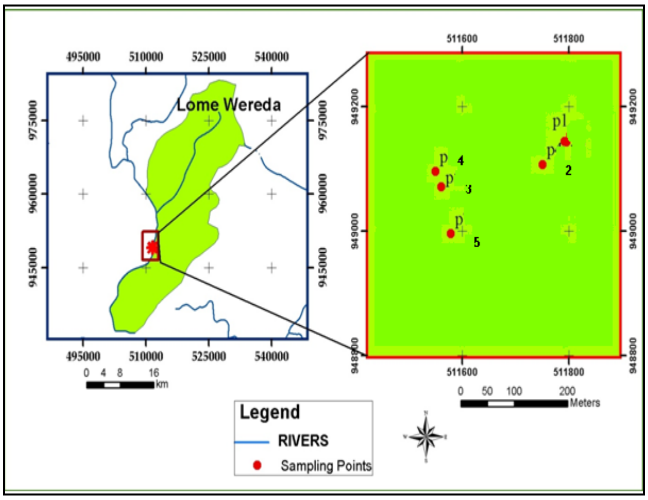

Figure 5: Location map of each sampling points of Luna slaughterhouse and its effluent receiving Modjo River

2.4 River Water Sampling

Water samples from the effluent receiving water bodies i.e. Modjo River, receives partially treated effluent from Luna slaughterhouse and Little Akaki River, receives untreated effluent from Kera slaughterhouse, were also collected by little modification of the techniques used by EPA for preliminary analysis of selected industry effluents and the respective receiving streams in Addis Ababa [9]. Modification was done sampling from the discharge points into the rivers in addition to samples from up streams and down streams of the rivers.

Water samples from those rivers were collected at the discharge points (mixing points), upstream and downstream of the discharge points in both rivers during the sampling periods of the wastewater. Six samples were collected from both rivers i.e. P_3, P_4, and P_5 along the Modjo River course and samples K_2, K_3 and K_4 along the Little Akaki River course as displayed in the map (Figure 4 and 5) above.

P_3 and K_2 samples were slaughterhouse effluent mixing points into the Rivers which were designated as 0 meter distance. P_4 and K_3 were collected at a distance of 10 to 15 meters upstream of P_3 and K_2 respectively, while P_5 and K_4 were taken at a distance of 50 to 100 meters downstream of the corresponding discharge point. The upstream and downstream sampling points were carefully placed base on the rivers flow and entrance of other sewer lines to the rivers. In all sampling points three 500 ml of grab water samples were collected then all the three bottles were mixed to produce 1500 ml polyethylene bottle of composite samples to reduce the analytical cost.

At each sampling points samples were collected in one polyethylene bottles and two glass bottles. The two glass bottles were used to collect samples for bacteriological and FOG analysis. The polyethylene bottles are used for the rest physicochemical parameters. All the bottles were previously washed with detergent and further rinsed with deionized water prior to usage. Finally, before sampling was done, the bottles were rinsed with the water sample at the point of collection. Samples for bacteriological analyses were kept in well capped glass bottles that have been sterilized in an autoclave for 15 minutes at 121ºC. All samples were brought to laboratory within ice box for physicochemical and bacteriological test and analyzed as soon as possible after sampling. In general, Sample collection and handling procedure were performed according to the standard procedures recommended by APHA [10].

2.5 Physicochemical and Bacteriological Analysis of Water and Wastewater Samples

The analyses of slaughterhouse wastewater and river water were done both in situ and laboratory as explained below.

Onsite water analysis

The parameters such as conductivity (EC), temperature, pH, turbidity and dissolved oxygen (DO) of the wastewater and rivers were measured immediately on the sampling sites. It was done using a conductivity meter (Wagtech International N374, +M207/03IM, USA) to measure conductivity (EC), portable DO meter (Hach P/N HQ30d, Loveland. CO, USA) to measure both the dissolved oxygen and temperature, a portable pH meter (Wagtech International N374, M128/03IM, USA) was used to determine pH and Jackson Candle Turbidimeter (in JTU) to measure turbidity. These equipments were calibrated one day before each sampling period.

Laboratory water analysis

The Chemical oxygen demand (COD), color, nitrate nitrogen (NO_3^--N), ammonia nitrogen (NH_3-N), nitrite nitrogen(NO_2-N), Total phosphorus (TP), Orthophosphate (PO_4^{-3}), Sulfide (S^{-2}) and Sulfate (SO_4^{-2}) were measured by using spectrophotometer (Hach model DR/2400 portable spectrophotometer, Loveland, USA) according to Hach procedures [11]. Fat, oil and grease (FOG), Five-day biochemical oxygen demand (BOD_5), total solids (TS), total suspended solids (TSS), *Total coliform (TC)* and *Fecal coliform (FC)* were determined using the standard methods of APHA [10]. Except for the FOG determination, which was done in the JIJE Laboglass analytical service laboratory, Addis Ababa, all the parameters analysis were done in the Environmental Science Program Laboratory, College of Science, Addis Ababa University.

Data analysis

The obtained data were analyzed by using SPSS version 16.0 and origin version 8.0 softwares, and microsoft office excel.

3. Results and Discussions

Physicochemical and Bacteriological Characteristics of Slaughterhouse Wastewater

Wastewater characteristics based on the analysis of the composite sample from raw (untreated) wastewater of both slaughterhouses are shown in Table 2. This Table summarizes the mean, range and standard deviation of the physicochemical and bacteriological properties of wastewater of both plants. Except for fat, oil and grease (FOG) was analyzed in only one sample of the three sampling period, all the rest parameters were analyzed in each sampling period.

Table 2: Average physiochemical and bacteriological characteristics of the raw slaughterhouse wastewater and outlet effluent discharged in to rivers

Parameter	*Mean ± SD and range of raw wastewater*		*Mean of outlet effluent discharged in to rivers*	
	Kera	**Luna**	**Kera**	**Luna**
pH	7.3±0.43 (6.8-7.6)	7.24±0.74 (6.81-8.108)	7.30	6.81
Temperature (°C)	26.55±6.84 (21.85-34.4)	28.12±7.27 (22.36-36.3)	26.55	22.09
EC (μScm^{-1})	1614.66±166.1 (1452-1784)	1251.33±160.05 (1116-1428)	1614.66	3850
Turbidity (JTU)*	566.66±28.86 (550-600)	436±172.12 (238-550)	566.66	160.33
TS (mg/L)	7885.33±4537.94 (2658-10814)	3246±2099.52 (850-4764)	7885.33	1176
TSS (mg/L)	3835.33±2072.57 (1856-5990)	1111±811.84 (260-1877)	3835.33	125.66
Color (TCU)	19733.33±18941.3 (8400-41600)	1682±1118.37 (391-2355)	19733.33	728.66
TP (mg/L)	202±37.72 (160-233)	55.4±13.20 (42.4-68.8)	202.00	61.73
PO_4^{-3} (mg/L)	67.33±27.06 (44-97)	13±3.60 (10-17)	67.33	28.26
Nitrite (mg/L)	1513.33±393.10 (1220-1960)	315±78.58 (245-400)	1513.33	49.33
Nitrate (mg/L)	1450±1255.74 (720-2900)	615±121.34 (515-750)	1450.00	13.66
Ammonia (mg/L)	103.33±57.79 (41.5-156)	41±5 (36-46)	103.33	345.66
Sulfate (mg/L)	693.33±70.23 (620-760)	290±110 (180-400)	693.33	31.33
Sulfide (mg/L)	1.83±0.53 (1.51-2.45)	0.24±0.31 (0.04-0.6)	1.83	0.14
DO (mg/L)	3.75±0.92 (2.7-4.44)	4.73±0.69 (4.32-5.53)	3.75	0.97
COD (mg/L)	11546.67±4130.19 (6900-14800)	4752.66±1156.27 (3538-5840)	11546.66	431.66
BOD_5 (mg/L)	3980±1055.13 (2990-5090)	2110±602.24 (1420-2530)	3980.00	177.33
FOG (mg/L)	1825.31	1019.6	1825.31	344.76
FC(cfu/100 mL)	$2.08 \times 10^5 \pm 5.460 \times 10^4$	$1.35 \times 10^6 \pm 3.722 \times 10^5$		
TC(cfu/100 mL)	$1.35 \times 10^6 \pm 3.722 \times 10^5$	$4.40 \times 10^6 \pm 1.114 \times 10^6$		

N.B: *The value in parenthesis in the above Table is the range of the corresponding parameter*

**JTU: Jackson turbidity unit*

4. Slaughterhouse Effluent Impact on the Quality of Receiving Water Bodies

The data obtained can be believed to provide enough information regarding the impact of the slaughterhouse effluent on the hydrosphere to which the effluent is released. Human beings and other animals that might use the water contaminated with slaughterhouse effluent are highly exposed (susceptible) to various types of health problems. The results of the physicochemical and bacteriological parameters assessment of both rivers are discussed below.

As explained in the above discussion pH is the indicator of acidity and alkalinity status of water. The mean values of upstream of both rivers were identical, which were slightly basic with pH value 7.47 and 7.46 for Akaki River and Modjo River respectively. These values were within the Ethiopian drinking water standard limit 6.5-8.5 [12]. However, a slight drop in mean pH value to 6.84 (Akaki River) and 6.91 (Modjo River) at discharge points and 7.33 (Akaki River) and 7.41 (Modjo River) at the downstream were observed. This could be attributed to the addition of the slaughterhouse effluents along with the eroded soil and trash materials end up in these rivers. But these change is not serious still the pH values of both rivers remain within the Ethiopian drinking water standard limit and may not cause an adverse effect on the survival of aquatic organisms.

Temperature is the most important factor which influences the chemical and biological characteristics of the aquatic system. The temperatures of both rivers in each of the sampling points varied from 21.4 to 24.84° C in Little Akaki River and from 19 to 29.9 ° C in Modjo River. These values were found within the range of surface waters temperature, 0° C to 30° C [13]. The Little variation in each sampling points of the rivers could be influenced by air circulation, flow and depth of the water body [13]. It is obvious that unpolluted water is a colorless so that Color can be used as one parameter in measuring pollution status of water. The mean color values in the discharge point, upstream and downstream of Little Akaki River were 2030, 676, and 1530 units Pt-Co respectively. Similarly, the color levels in the discharge point, upstream and downstream of Modjo River were 523.33, 116, and 1973.66 units Pt-Co respectively. The increment in the downstream of both rivers was arising from discharge of slaughterhouses wastewater dominated by blood and other organic substances. Regardless of the sampling points, in both rivers the levels of color were found above the WHO drinking water guidelines limit (less than15 TCU) [14].

As regard to the means of total solids (TS), total suspended solids (TSS), and turbidity values of both slaughterhouses outlets were tremendously high as present in Table 2. Upon introduction of these effluents into the rivers, the values had been changed from 725.33 mg/L to 913.33 mg/L of TS in Akaki River and 932.00 mg/L to 1504.66 mg/L of TS in Modjo River; again from 304.33mg/L to 456.00 mg/L of TSS in Akaki River and 154.00 mg/L to 323.00 mg/L of TSS in Modjo River. Similarly, turbidity values had been changed from 350.00 JTU to 420.00 JTU and 134.66 JTU to 285.53 JTU in Akaki River and Modjo River respectively. The increment in the magnitude of these parameters at downstream compared to the values at upstream is due to the influence of the slaughterhouses wastewater on the receiving water bodies. The presence of such high concentration of TS, TSS and turbidity reduce the aesthetic value of the receiving water bodies and also reduce DO of the river.

Similarly, the conductivity (EC) values also changed from1245.33 μScm^{-1} to 1290.33 μScm^{-1} (Akaki River) and 1564.66 μScm^{-1} to 2676.66 μScm^{-1} (Modjo River). However, the conductivity of most freshwaters ranges from 10 to 1, 000 μScm^{-1} and in polluted water may exceeds 1,000μScm^{-1} **[**13**]**. The EC values obtained in both rivers also exceeds 1,000μScm^{-1}, indicates that both rivers are polluted. The addition of the slaughterhouses effluent exacerbates the situation. However, it has been observed that the rivers being used by the nearby residents for irrigating of vegetables (Little Akaki River) and bathing in Modjo River (Figure 6).These may cause human health risk.

Figure 6: Modjo River used for bathing by the nearby resident

Dissolved oxygen is a very important parameter for the survival of aquatic organism and is also used to evaluate the degree of freshness of a river. However, the DO concentration of both rivers examined (Table 4) were found below the value that can support survival of aquatic organisms (5 mg/L) as well as at a concentration that can lead to death for most fish, below 2 mg/L [13].

Again the dissolved oxygen concentrations of both rivers follow dissimilar trends (Figure 7). The DO levels of the upstream of both rivers were lower than that of the discharge points, and these values also found below the value of downstream in Modjo River. These situations were caused due to difference in flow of the water throughout the course of rivers. The flow in the upstream of Modjo River was extremely slower than its discharge point and downstream. This might have led to be hardly aerated. On the other hand the discharged effluent from the slaughterhouses may be reaerated on its way of travel before mixing with the corresponding river; this may contribute little increment in DO concentration at the discharge point. Besides flow variation, DO in the upstream of both rivers might be depleted due to the continuous discharge of effluent from different sources such as both municipal and industrial wastes of Addis Ababa city into Little Akaki River [7]. and Modjo town into Modjo River [8].

Both biological oxygen demand and chemical oxygen demand are highly related to DO as well as to each other. Since BOD and COD directly affect the amount of DO in the river. Both BOD and COD are important water quality parameters and are very essential in water quality assessment [13]. These are important parameters, used to determine whether a water body is polluted or not. The higher the BOD and COD values would be depleting the higher DO concentration in the receiving rivers by organic and inorganic pollutants present in the effluents. The mean BOD and COD concentrations of both rivers along with the outlets of both slaughterhouses follow similar trend as illustrated in Figure 8. The lowest values were recorded in the Luna slaughterhouse outlet and the highest values in Kera slaughterhouse outlet. These values were large enough to cause damage on the normal functions of the receiving rivers. These magnitudes were much higher at Little Akaki River than Modjo River. This is attributed to the difference in the concentration of effluent discharged from both slaughterhouse industries to the corresponding rivers.

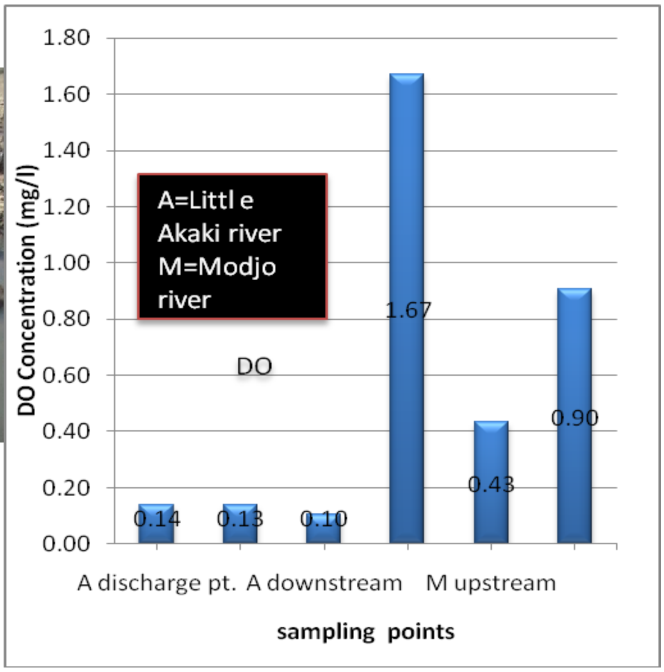

Figure 7: Trends of DO concentration in both rivers

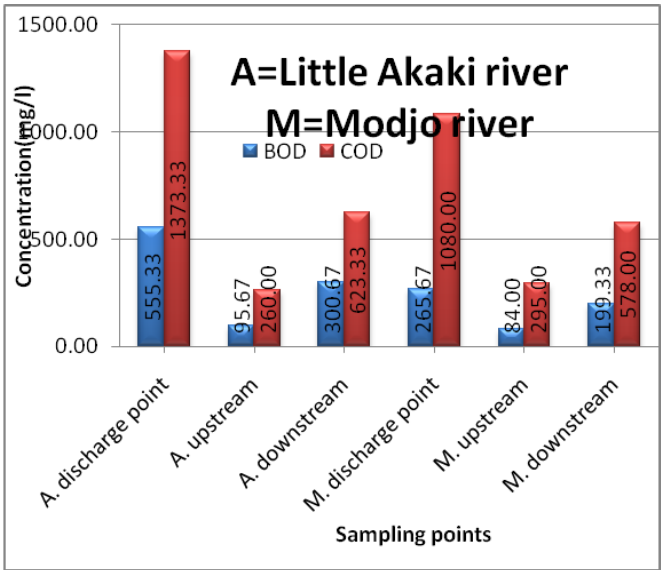

Figure 8: Trends of average COD and BOD concentration in both rivers

The observed BOD and COD levels (Figure 8) were also noticed to be above the WHO limit value for undisturbed river which is less than 2mg/L and 20 mg/L [15]. These high levels of BOD and COD could deplete the DO in the water system. The result indicated that the water bodies sampled were deteriorated due to continuous discharge of untreated and partially treated slaughterhouse effluents.

The COD and BOD also have a direct relationship with TS and turbidity throughout the course of both rivers since these parameters increased or decreased in similar manner in each sampling points of the rivers as shown in Figure 9 and 10. It showed that water with high amount of TS and turbidity could lead to high concentration of COD and BOD. Moreover, the presence of high concentration of TS and turbidity also reduce the aesthetic value of both rivers.

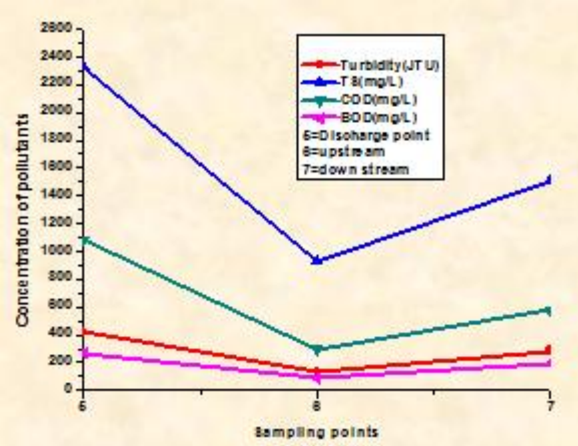

Figure 9: Trends of Turbidity, TS, COD and BOD in Modjo River

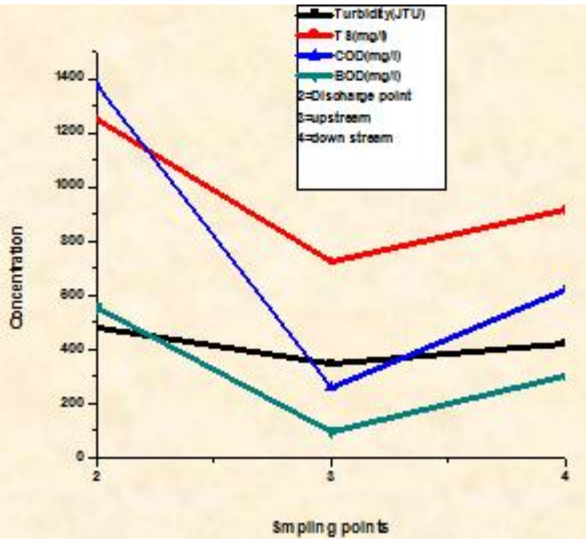

Figure 10: Trends of Turbidity, TS, COD, and BOD in Little Akaki River

The average orthophosphate (PO_4^{-3}) and total phosphorus (TP) level ranging from 0.46 - 67.33 mg/L and 0.85 - 202 mg/L respectively in the entire sampling points. The major peaks in orthophosphate and total phosphorus concentrations were found at the outlets of both slaughterhouses, followed by a decline from the discharge points to the downstream and the lowest concentration were registered in the upstream of Modjo River. However, a slight deviation of orthophosphate and TP was observed in Akaki River (Figure 11). This deviation might happen from the variation of the organic matter decomposition which accelerates the conversion of organically bound phosphorus to orthophosphate at the downstream of this river. Discharges of the slaughterhouse effluents with high phosphate content might be responsible for the increased levels observed in Modjo River. Possible sources of phosphate and orthophosphate might be from the phosphorus rich liquid and solid by-products of slaughterhouses activities such as blood, bone and manure. In addition to this extensive uses of phosphate based detergents for cleaning purposes in these slaughterhouses industries may also have considerable contribution. Total phosphorus levels in undisturbed rivers are generally less than 25µg/L, phosphorus concentration greater than 50µg/L are attributed to human activities and contamination rise to excessive growth of algae [16]. So that the effluent discharged from both slaughterhouses was enough to cause eutrophication on receiving rivers.

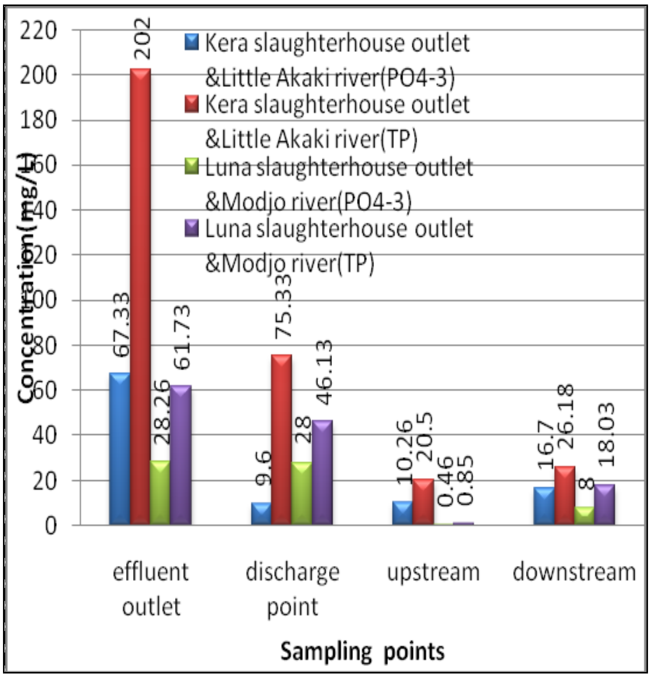

Figure 11: Mean concentrations of orthophosphate and TP in both sites of outlets and receiving streams

The other nutrients like ammonia nitrogen and nitrite nitrogen follow similar trend as orthophosphate and TP in both sites. However, the nitrate nitrogen concentrations follow different trend in both sites (Figure 12). In the case of Kera site nitrate major peaks were found at the slaughterhouse outlet and followed by a decline at the upstream (Little Akaki River) and then lowest concentration was registered at the discharge point. However, higher nitrate concentration was observed at upstream of Little Akaki River than downstream and discharged point during the sampling periods. It is suggested probably due to diffused sources (non point sources) of pollution entering into the receiving water body (Little Akaki River) such as nearby latrines of the residential and commercial areas, industrial discharges in the far upstream of the river. Where as in the second sampling site higher concentration of nitrate was observed at the downstream, followed by a decline at the discharge point and further decrease at the outlet of the slaughterhouse, and the lowest concentration at the upstream of Modjo River (Figure 12). The observed unusual trend probably due to the end product of aerobic decomposition of organic nitrogenous matter is nitrate. So that its concentration is expected maximum at highly aerated zone of the river (since the downstream of Modjo River is well aerated than its downstream as discussed above). Its present in high concentration in drinking water has a health risk for young children causing methemoglobinaemia (blue babies syndrome) [16].

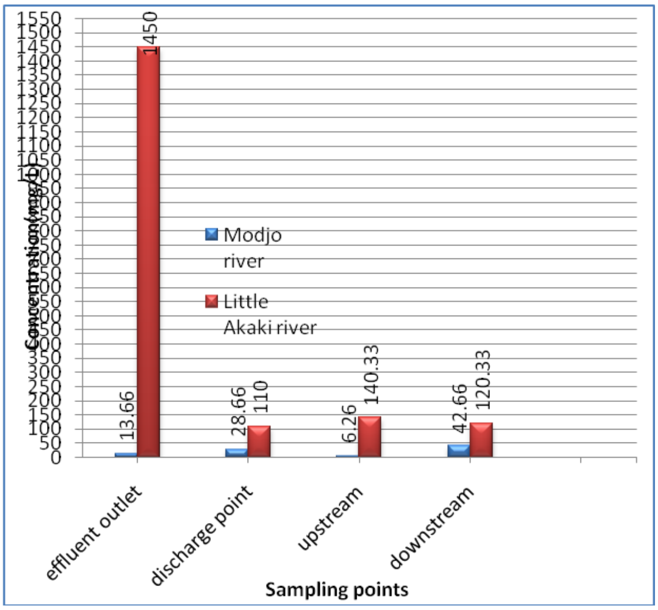

Figure 12: Average nitrate nitrogen concentrations of both slaughterhouse outlets and receiving rivers

The mean sulfide level of both rivers was higher than the WHO taste and odor thresholds limit value estimated between 0.05 and 0.1 mg/L [16]. This result may be due to the very low dissolved oxygen level of both rivers which led to subsequent reduction of sulfate to sulfide by bacterial action. The mean values in Modjo River were found unexpected trend. This could be due to the flow variation in the course of the river that is the upstream of Modjo River had relatively low speed of flow led to be less aerated and subsequent reduction of sulfate to sulfide. However, sulfide can only oxidize to sulfate in well aerate zone of the river which led to low concentration of sulfide in the downstream and discharge point of the river which was a little bit well aerated (Figure 13).

The mean sulfate levels of upstream discharge point and downstream of both rivers is displayed in Figure 14. These levels were higher than the natural background sulfate levels of 1.0-3.0 mg/L reported for unpolluted rivers [15]. The elevated levels of sulfate upstream of Little Akaki River may be attributed to increased utilization of cement for building and construction purposes around this area since the river is surrounded by residential and commercial buildings and due to flow variation in Modjo River. In polluted waters the dissolved oxygen is very low and sulfate is readily reduced to sulfide causing noxious odors [17]. The fat, oil and grease level in both rivers was observed that at the upstream of Akaki River (316.83 mg/L) was considerably higher than that of Modjo River (169.07 mg/L). This may be due to the urban runoff which conveys great amount of oil and grease from various automobile workshops and oil depot sited further upstream of the river. These levels became considerably elevated in the discharge point of both rivers suggesting possible contribution from slaughtering processes, while the values were decreased downstream due to the dilution effect of the rivers. FOG have a high BOD and discharging of it creates a thin film on the surface of water, which impedes the exchange of air and water, thereby increasing oxygen demand [18].

Another concern arising from slaughterhouse effluent discharge to rivers is the possibility of pathogenic bacteria in the river. *Fecal coliform* and *total coliform* bacteria were used as indicators of bacterial contamination of the rivers. The data for *fecal coliform* and *total colifrom* bacteria of both rivers is presented in Table 3.

It was observed that in the case of Little Akaki River the highest count was found rather than the Kera slaughterhouse outlet. High bacteriological population in this river may reflect the input of microorganisms from extra sources mainly municipal sewer lines entered to the river. However, the addition of the slaughterhouse effluent aggravates the problem. The bacteria loads were generally high in all samples. This would be limit variety uses of the rivers water including recreation, drinking water sources, and aquatic life and fisheries.

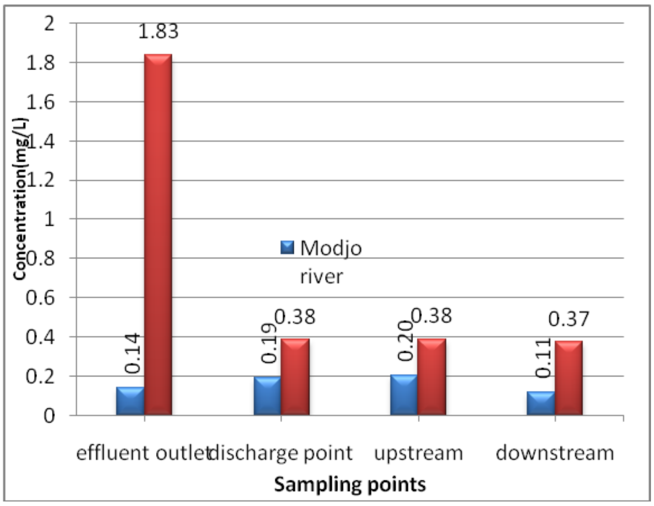

Figure 13: Average concentration of sulfide in both rivers

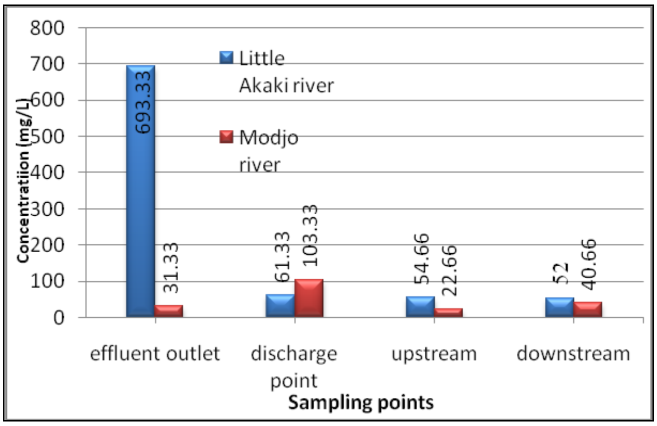

Figure 14: Average Sulfate concentrations of both rivers

Table 3: Average bacteriological load in both rivers

Ri **River**	Coliform (cfu/100mL)	Discharge point	Upstream	downstream
Modjo River	FC	$9.73 \times 10^4 \pm 1.102 \times 10^4$	$3.77 \times 10^4 \pm 4.447 \times 10^4$	$4.93 \times 10^4 \pm 3.950 \times 10^4$
	TC	$3.58 \times 10^5 \pm 4.131 \times 10^4$	$4.73 \times 10^4 \pm 5.508 \times 10^3$	$1.03 \times 10^5 \pm 6.531 \times 10^4$
Little Akaki River	FC	$6.83 \times 10^6 \pm 4.726 \times 10^5$	$6.70 \times 10^6 \pm 4.583 \times 10^5$	$6.97 \times 10^6 \pm 4.933 \times 10^5$
	TC	$2.13 \times 10^7 \pm 1.528 \times 10^6$	$2.10 \times 10^7 \pm 2.000 \times 10^6$	$8.73 \times 10^7 \pm 1.149 \times 10^8$

5. Comparison of Slaughterhouse Effluent Discharged With Standard Permit Limits and Both River With Each Other and Drinking Water Quality Standards

The relative concentrations of pollutants of both slaughterhouse effluent with standard permit limits and both rivers water quality with WHO and Ethiopian drinking water quality illustrated in Table 4. It was observed that concentration of most of pollutants were highest at the discharge points due to the increased discharges of both slaughterhouses wastewater and fall down at the down streams due to the assimilation and dilution effects of the rivers. The lowest concentration was recorded at upstream of both rivers. This clearly showed that both slaughterhouses wastewater plays substantial role in deterioration of water quality of the corresponding river.

Regardless of the sampling point, all of the parameters examined except pH, were found much higher than the national and international drinking water recommended standards (Table 4). This could be attributed to discharge of diffused sources from both municipal and industrial liquid and solid waste of Addis Ababa city to Little Akaki River [7] and from Modjo town to Modjo River [8] in addition to the slaughterhouses effluents.

As it can be seen from Table 4 most of the physicochemical parameters, excluding EC, TS, TSS and NH3 at the discharge point; EC, TS and COD at the upstream and EC, TS, color and NH3 at downstream of Modjo River were found in high concentration, but all the rest parameters were registered highest in the corresponding sampling points of Little Akaki River than Modjo River. This variation of pollutants concentrations of the two rivers might be attributed to the variation in amount of discharged effluent, i.e. effluent of municipal and industrial wastes from Addis Ababa city is much higher due to the high population, urbanization and industrialization in the city than the small town Modjo. As a result the water quality of Little Akaki River is highly deteriorated than Modjo River, and this situation was aggravated by the discharges of untreated Kera slaughterhouse wastewater.

Again from Table 4 except pH and Temperature, all the physicochemical parameters of the untreated wastewater (Kera slaughterhouse) and partially treated wastewater (Luna slaughterhouse) do not comply with the EEPA and UNIDO slaughterhouse effluent discharge limit into surface waters [17]. This indicates that discharging such effluents devastate the receiving environment.

Table 4: Comparison of the mean value of physicochemical parameters slaughterhouse effluent discharged with standard permit limits and both Rivers water quality with WHO and Ethiopian drinking water quality

Parameters	*Slaughterhouses discharged effluent*		*Discharge Permit limit*	*Modjo River*			*Little Akaki River*			*Drinking water quality standards*	
	Luna	*Kera*	*EPA*	*P_3*	*P_4*	*P_5*	*K_2*	*K_3*	*K_4*	*Ethiopian (QSAE,2001)*	*WHO (2008)*
Sulfide (mg/L)	0.144	1.837	-	0.19	0.20	0.11	0.38	0.38	0.37	-	-
Color (TCU)	728.667	19733.333	-	523.33	116.00	1973.66	2030.00	676.66	1530.00	15	<15
PH (pH units)	6.81	7.300	6 – 9	6.91	7.46	7.41	6.84	7.47	7.33	6.5-8.5	6.5-8
Temp ( )	22.092	26.550	40 °C	24.93	22.45	21.50	23.63	23.71	23.20	-	-
DO (mg/L)	0.979	3.753	-	1.67	0.43	0.90	0.14	0.13	0.10	-	-
EC(Scm^{-1})	3850	1614.667	-	2930.00	1564.66	2676.66	1235.33	1245.33	1290.33	-	-
Turbidity (JTU=NTU)	160.333	566.667	-	416.66	134.66	285.53	483.33	350.00	420.00	5	5
TS (mg/L)	1176	7885.333	-	2331.33	932.00	1504.66	1248.66	725.33	913.33	-	-
TSS (mg/L)	125.667	3835.333	80	886.00	154.00	323.00	456.00	304.33	456.00	-	-
TP (mg/L)	61.733	202.000	5	46.13	0.85	18.03	75.33	20.50	26.18	-	-
PO_4^{-3}(mg/L)	28.267	67.333	-	28.00	0.46	8.00	9.60	10.26	16.70	-	-
NO_2^- - N (mg/L)	49.333	1513.333	-	220.00	26.66	144.00	283.00	153.33	597.0	3	3
NO_3^- - N (mg/L)	13.667	1450.000	-	28.66	6.26	42.66	110.00	140.33	120.33	50	50
NH_3 – N (mg/L)	345.667	103.333	-	212.33	10.66	115.00	47.33	41.25	47.91	-	-
SO_4^{-2} (mg/L)	31.333	693.333	-	103.33	22.66	40.66	61.33	54.66	52.00	250	-
COD (mg/L)	431.667	11546.667	250	1080.00	295.00	578.00	1373.33	260.00	623.33	-	-
BOD (mg/L)	177.333	3980.000	80	265.667	84.000	199.333	555.333	95.666	300.66	-	-

FOG (mg/L)	344.76	1825.31	15	389.05	169.07	317.65	739.52	316.83	652.0	-	-
FC (cfu)	1.08 $x10^5$±2.103 $x10^4$	1.35 $x10^6$±3.722 $x10^5$	-	9.73 $x10^4$	3.77 $x10^4$	4.93 $x10^4$	6.83 $x10^6$	6.70 $x10^6$	6.97 $x10^6$	0	0
TC (cfu)	4.01 $x10^5$±1.241 $x10^5$	4.40$x10^6$±1.114 $x10^6$	400	3.58 $x10^5$	4.73 $x10^4$	1.03 $x10^5$	2.13 10^7	2.10 $x10^7$	8.73 $x10^7$	0	-

6. Conclusion and Recommendations

The untreated and inadequately treated effluents from both slaughterhouses have a considerable effect on the water quality of the receiving water bodies. The levels of most parameters monitored were generally higher in the discharge point of both rivers. Thus cause many fold increase at downstream of both rivers. This study suggests that there is a need of remediation of the rivers. There should also be an intervention of appropriate regulatory bodies (EPA) to ensure production of high quality treated final effluents by the slaughterhouses industries and protect the natural surface waters quality.

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