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ASSESSMENT ON THE PERFORMANCE OF WASTEWATER TREATMENT PLANTS AND THEIR IMPACT ON THE SURFACE WATER QUALITY OF AWASH RIVER, ETHIOPIA

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Abstract

The Awash River, (AR) is used for different purposes such as drinking, industrial supply, hydropower, and agriculture. These uses of the water have resulted in the rapid deterioration of water quality. The performance of wastewater treatment plants (WWTPs) situated with the river catchment area have been assessed together with the impact on the surface water quality of the Awash River. The study has been completed using five years water quality data from 5 sampling stations and wastewater data from more than 30 industries and 2 flower farms. In addition, questionnaires, interviews, and wastewater sampling have been used to evaluate pollution causes. Most of the surveyed industries use partially operated treatment plants and accumulated high amounts of sludge. This is due to different reasons, including lack of facilities, poor management, limited capital, limited technical manpower, and, poor maintenance. All these have contributed to the inefficiency of wastewater treatment plant. Out of the 30 industries sampled, 23% of them did not have well-constructed treatment plant and 73% of industries discharged their untreated effluents directly into the river without treatment. Consequently, the wastewater samples analysis showed extremely high value of EC (14,000µS/cm), TDS (10,000 mg/L) and EC (12,030 µS/cm), TDS (8,060 mg/L) were seen in the first and second survey respectively. In line with these, the five years of spatial and temporal physico-chemical trend data also showed an increasing pollution in the river system. Based on this investigation, it is possible to conclude that the untreated industrial wastewater disposal and agricultural runoff strongly degraded the quality of the AR. Thus, it is time to make urgent improvements to deal with the poor performance of WWTPs and to limit the untreated waste being discharged into the river system.

Key Words: *Inefficient Treatment Plant, Untreated Waste Disposal, Effluents, Source of degradation*

Introduction

In Africa, lack of water is aggravated by insufficient treatment of water and wastewater, particularly with rapid population growth and urbanization (UNEP, 2011). In Ethiopia, human settlement, urbanization and industrialization have increased over time, especially in the Awash River basin downstream of key cities and towns such as; Addis Ababa, Dukem, Gelan, Bishoftu, and Modjo. Most industries (Tanneries, textiles, abattoirs, breweries, paints and other) are located near to the adjoining water bodies because of the groundwater potential, infrastructure, raw material availability, and discharge accesses. Study has shown there are over 2,000 registered industries in Addis Ababa which account for 65% of all industries in the country and most of them are located along the river banks (Van Rooijen and Taddesse, 2009).

Currently in Ethiopia, because of the poor national wastewater management policy, poor regulations and enforcement of rules, most industries discharge their wastewater into the environment without any form of prior treatment. Moreover, lack of wastewater treatment, weak performance and irregularities (on-off) in the treatment plant, or lack of power supply also hinders water and wastewater treatment to a great extent in Africa (Omasa *et al.*, 2012).

In the last ten years, the growing population, industries, agricultural practices, and rising economy in the Awash Basin (AB), have resulted in increased consumption of water and discharge of wastewater, which causes pollution of the main tributaries of the Akaki and Modjo Rivers (Abraha *et al.*, 2013; Omosa *et al.*, 2012; Eguabori, 1998). Discharge of untreated or partially treated sewage water into surface water bodies can have a profound influence on the receiving water bodies, which reduces the potential uses of water for various purposes, lead into contamination of upper soil surfaces, sewage drainage facilities, surface water and ground waters (Shirajavu, 2011).

In fact, pollution causes the water to become unsuitable for various uses and becomes difficult and more expensive to treat to an acceptable quality for use (Paul and James, 2011) and thus the use of poor quality water for agricultural activities can affect crop yield and cause food insecurity (Owa, 2014; Omasa *et al*., 2012; Shirajavu, 2011; Shobha, 2004). Water pollution of rivers is one of the most significant problems in Ethiopia, especially in the Awash Basin. Studying the water quality deterioration of the AR is important to ensure sustainable development in the basin because the river is used for various purposes; drinking, livestock watering, irrigation, industries, fisheries, and bathing purposes.

The objective of this study is to assess the impact of poor performance of the existing industrial wastewater and the treatment plant performance in the surrounding environment and analyze it with a set of data of the water quality of AR over 5 consecutive years. It helps to focus the water quality deterioration of the river and enables to understand the main source of pollution at upstream Koka of AR.

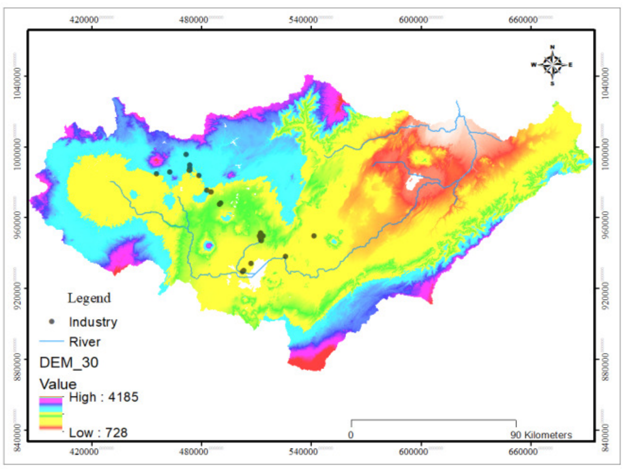
Description of the Study Area

The Awash River, (AR) is the most utilized river in Ethiopia (AAiT, 2016). It starts on the high plateau to the west of Addis Ababa, at an altitude of about 3,000m. The river runs approximately 1280 km from its origin in a place commonly known as "Keta" that is Western Showa Zone, through Dandi Woreda below the Mountain Worke and terminates at saline

Lake Abbie, which has a basin area of 113,467 Km^2. The mean annual rainfall over the entire western catchment is 850 mm and in Awash-Awash sub-basin is 600mm. The mean annual temperature in Addis Ababa is 16.7°C compared to nearly 30°C at Dubti. Akaki and Modjo Rivers are the major tributaries situated in the study area and received untreated domestic and industrial waste from different industries and towns that are carried into the main river (Table 1 and Fig 1a and1b).

Table 1: Surface water quality monitoring and sampling stations

SID	Description	UTM-X	UTM-Y
SATB	Akaki @ Trunesh Bejing Hospital	476354	981107
SAZR	Awash River @ Zeway Road	509432	944969
SMDF	Modjo River after factory	502812	931647
SAKD	Awash @ Koka Dam	517216	936157
SAWB	Awash @ Wonji bridge	525435	937268
SABB	Awash before Lake Beseka	600365	978746



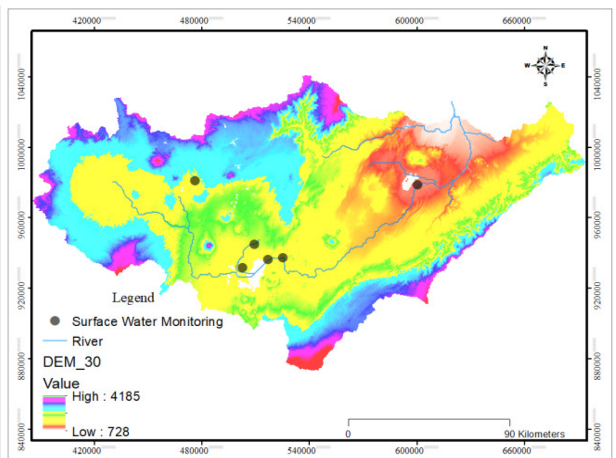


Fig. 1a: Map of Surveyed Industries in Upstream Koka Fig. 1b: Map of Sampling Stations (Study Area)

Materials and methods

Methods of Data Collection

An integrated approach was used to assess the performance of the wastewater treatment plant and its effect on the surface water quality of AR. The researcher has been engaged in a total of 3 and above years (i.e. June-2016 up to December-2019) for four round inspections of more than 30 industries in different towns to look at their waste management and wastewater treatment status. Out of the surveyed and inquired 32 industries, 43.3% were tanneries, 16.7% textiles, 13.3% Slaughter Houses, 13.3% Soap and detergents and the remaining 13.3% alcohols and soft drinks. In addition, questionnaires and interviews were also prepared, and used for 30 randomly selected industries (except flower farms). The questionnaires were given emphasis to look at the industries waste management, the efficiency of treatment plants and their wastewater and solid waste dumping area.

Sampled Collected and Analysis

Samples were collected and stored by considering the standard methods of APHA (1999) under the adopted methods of Ethiopian Water Works Design and Supervision Commission. Chemicals like buffer solutions were used to calibrate the instruments in pH determination and 0.01M KCl, to calibrate EC meter. Analysis was done as per standard for the examination of water and wastewater manual (AOAC, 1995) using portable field instrument kit 5 series portable Cond/TDS/Salinity meter (Table 2).

Surface Water and Industrial Wastewater Sampling

To determine the source of water quality deterioration of the AR, the Awash Basin Authority has regular surface water and industrial waste monitoring stations. In this study water quality samples were collected monthly for consecutive 5 years from 5 sampling stations distributed alongside the AR, dam and its tributaries (Fig. 1b), and industrial wastewater were collected randomly from 14 industries (Fig. 2 and 3), in addition to questionnaires and interviews.

Table 2: The water quality parameters and their analytical method in this study

Parameters	Units	Instruments/Apparatus
pH	Unit less	Z-WAG-WE 30020 pH/Temperature
EC	µS/cm	5 Series Portable Conductivity/TDS/Salinity meter
TDS	mg/L	5 Series Portable Conductivity/TDS/Salinity meter
TH	mg/L	Titration with 0.05 N EDTA
Mg^{2+}, Ca^{2+}	mg/L	Titration with 0.05 N EDTA
Na^{+}, K^{+}	mg/L	Flame Photometer
Fluoride, F^{-}	mg/L	Spectrophotometer HACH
Chloride, Cl^{-}	mg/L	Titration using 0.014 N $AgNO_3$ (Argentiometric)
Alkalinity	mg/L	Titration with 0.01 N H_2SO_4
Bicarbonate, HCO_3^{-}	mg/L	Titration with 0.01 N H_2SO_4
Ammonia, NH_3	mg/L	Spectrophotometer Hach Company
Nitrate, NO_3^{-}	mg/L	Spectrophotometer Hach Company
Sulfate, SO_4^{2-}	mg/L	Spectrophotometer Hach Company
Phosphate, PO_4^{3-}	mg/L	Spectrophotometer Hach Company
DO	mg/L	Azide modification Water proof Hand-held DO 300 meter
BOD	mg/L	Azide modification Water proof Hand-held DO 300 meter
COD	mg/L	APHA 5220B. Open Reflux Methods
N.B Salinity	%	5 Series Portable Conductivity/TDS/Salinity meter

Data Analysis

The water quality data that was obtained from the Awash Basin (AB) was characterized using different exploratory data analysis tools, descriptive analysis was done using statistical software SPSS version 16 and Microsoft-Excel 2008 to determine the water quality status of the river.

Results and Discussion

Surface Water Quality Trend Evaluation (Secondary data)

The water quality data analysis of physico-chemical parameters namely; alkalinity, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), ammonia (NH_3), sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2+}), magnesium

(Mg^{2+}), nitrate (NO_3^-), bicarbonate (HCO_3^-), and Phosphate (PO_4^{3-}) showed an increasing trend in almost all sites over the past 5 consecutive years. Thus, the trend analysis obtained in Table 3 indicate that the river water qualities with regard to the above-mentioned parameters had fallen from the slight to moderate degree of deterioration; the same findings were also reported by AAiT (2016)

Table 3. Five Years Water Quality Trend Analysis

WQP	Units	Awash up-stream Koka sub-basin	Awash-Awash sub-basin
TDS	mg/L	Increasing Trend	Increasing Trend
EC	µS/cm	Increasing Trend	Increasing Trend
pH	-------	No Trend	Decreasing Trend
Ammonia	mg/L	Increasing Trend	Increasing Trend
Sodium	mg/L	Increasing Trend	Increasing Trend
Potassium	mg/L	Increasing Trend	Increasing Trend
TH	mg/L	Increasing Trend	Increasing Trend
Calcium	mg/L	Increasing Trend	Increasing Trend
Magnesium	mg/L	Increasing Trend	Increasing Trend
Fluoride	mg/L	No Trend	No Trend
Chloride	mg/L	Increasing Trend	Increasing Trend
Nitrate	mg/L	Increasing Trend	Increasing Trend
Alkalinity	mg/L	Increasing Trend	Increasing Trend
Bicarbonate	mg/L	Increasing Trend	Increasing Trend
Sulfate	mg/L	Decreasing Trend	Increasing Trend
Phosphate	mg/L	Increasing Trend	No Trend

Analysis of Industrial Wastewater Salinity (EC), TDS, and pH in Surface Water

During the survey, it was also observed that out of the surveyed 30 industries 1 textile, 1soap, 1 detergent, 1 East Africa tiger brand industry, 2 international slaughter and abattoir houses (ISAH) and 1 tannery in total 7 or 23.3% did not have properly constructed treatment plants, excepting treatment ponds and/or lagoons. For instance, out of the four ISAH observed in Modjo town, two ISAH discharged their untreated gut and blood waste effluents directly without any kind of treatment.

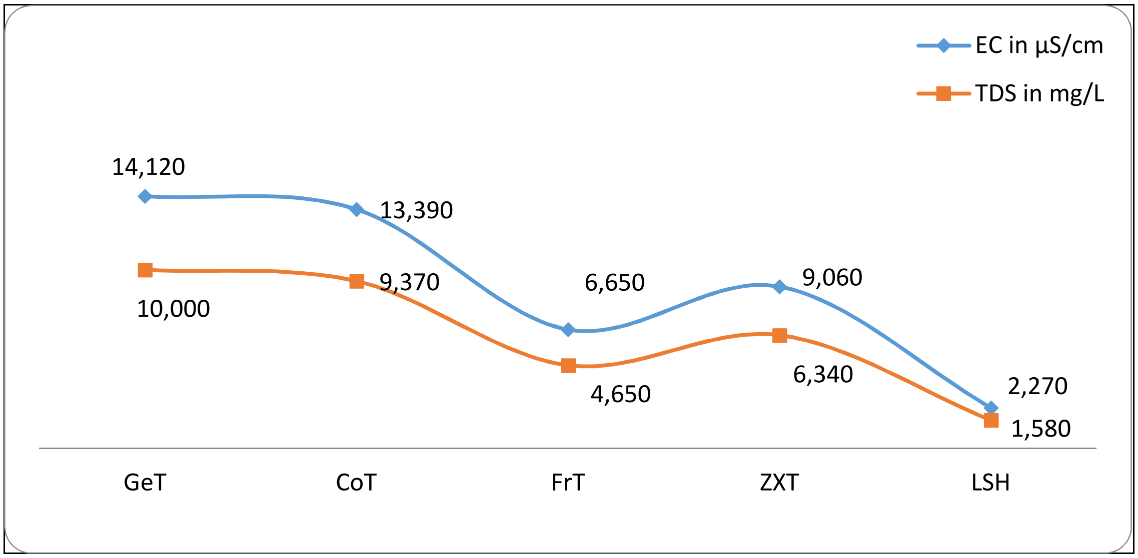


Fig. 2: Industrial wastewater analysis from selected industries at Modjo Town
Key: ***GeT,*** *Gelan tannery;* ***CoT,*** *Colba tannery;* ***FrT,*** *Friendship tannery;* ***ZXT,*** *Jianxinz Zhang tannery;* ***and LSH,*** *Luna slaughter houses* ***(from Nov. 01-10, 2017)***

In order to assess the pollution load of industrial liquid waste, wastewater samples were collected in two rounds before they entered into the surrounding water bodies (Modjo and Akaki Rivers), from November 01-10/ 2016 (Fig. 2), and from June 02-06/2018 (Fig. 3). Figures 2 and 3 show results of wastewater analysis, high values of EC (14,120µS/cm) and TDS (10,000 mg/L) were recorded at Gelan Tannery and the lowest values of EC (2,270 µS/cm) and TDS (1,580 mg/L) were observed at Luna ISAH.

The wastewater analysis result shows that almost all sampled effluents exhibited very high concentration of conductivity and total dissolved solids. The highest EC (12,030µS/cm) and TDS (8,060 mg/L) values were recorded in Friendship and Hora tanneries in Modjo town (Fig. 3). Correspondingly, EC recorded in Colba Tannery 13,390 µS/cm in fig. 2 and 10,720 µS/cm in fig. 3, and Friendship Tannery 6650µS/cm in fig. 2 and 6460µS/cm in fig. 3. This might be due to the poor management of salt used to preserve rawhide and skin which was found to be washed away as effluents (Zeleke, 2011). This is an indicative of the pollution load of industrial wastewater on water bodies.

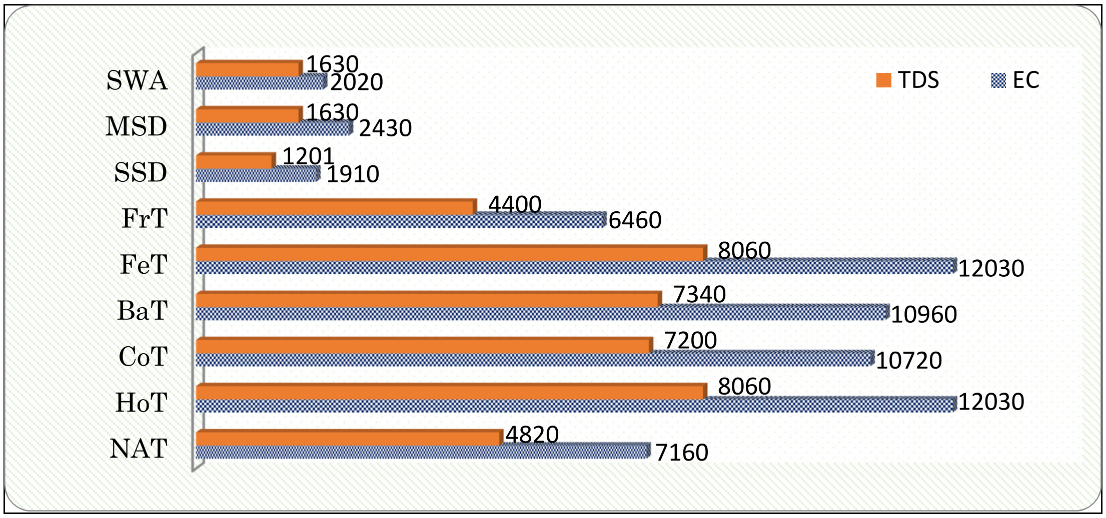
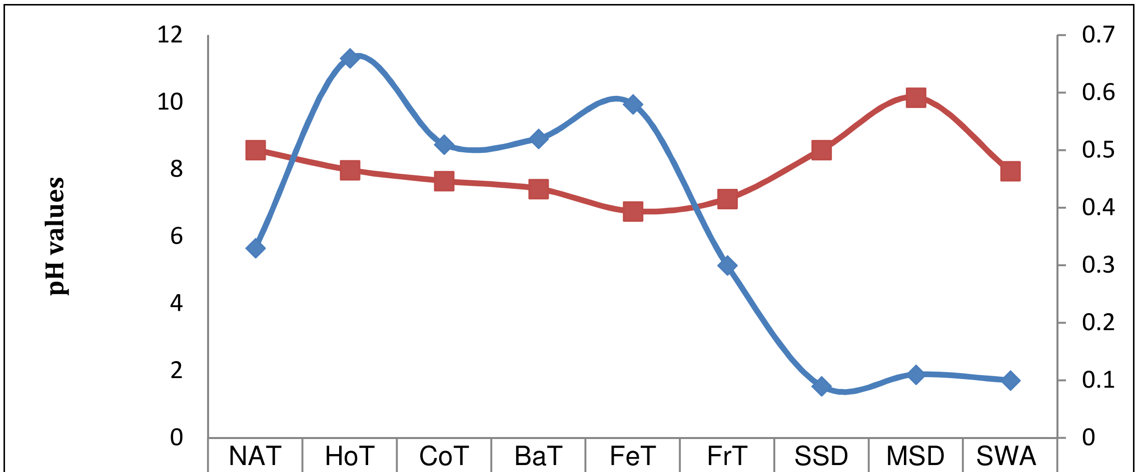


Fig. 3: Some Water Quality Parameters in Surveyed Industries
Key- **NAT**, New wing Addis tannery; **HoT**, Hora tannery; **CoT**; Colba tannery; **BaT**, Batu tannery; **FeT**, Ferida tannery; **FrT**, Friendship tannery; **SSD**, Star soap and detergents; **MSD**, MOHA soft drink company; **SWA**, Silvana water bottling and alcoholic company.

According to Nadia (2006) discharge of wastewater with a high TDS level would have adverse impact on aquatic life, rendering the receiving water unfit for drinking and domestic purposes, and reduce crop yield if used for irrigation. Figure 3 reflects the pollution strength of the wastewater and the practice of very poor liquid wastewater management existence in the surveyed industries and there has also been no significant improvement in wastewater management in most surveyed industries in the last 2 years. As seen in Fig. 2, 3, & 4 the chemical composition of the wastewater discharge varied from industry to industry. Some industries discharge hard wastewater with a pH value range 7.6 to 8.2 and soft wastewater with a pH value range 6.7 to 7.5 and some others above these range 8.58 and 10.14 were recorded (Sulaiman *et al*., 2016). The total hardness exhibited in NAT, HoT, CoT, BaT, and FeT was 370 mg/L, 500 mg/L, 410 mg/L, 380mg/L and 200 mg/L respectively. In fig. 4 the highest salinity value 0.66% and the lowest value of salinity was 0.09% recorded. This might indicate that most of the surveyed industries released untreated (partly treated) and highly saline wastewater into the neighbouring water bodies.

The discharge of effluent from wastewater treatment plants (WWTPs) has major detrimental effects on the health of aquatic ecosystems. Waste from WWTPs outfall can deposit large amounts of organic matter and nutrients into the receiving water bodies (Steven *et al*., 2008; Alexandera and Jeroen, 2006). Due to rapid industrialization new chemical compounds are continuously being developed and brought to the market and sooner or later they will emerge into the aquatic systems (Harikishore *et al.*, 2012). During the time of the visit, the physical observation of the Modjo River indicated a high level of pollution downstream of the point sources with an unusual smell, highly colored (black), turbid, and the river water showed a high salinity hazard (EC, 2606 µS/cm and TDS, 1689 mg/L) and the water became unsuitable for various uses.



	NAT	HoT	CoT	BaT	FeT	FrT	SSD	MSD	SWA
pH	8.58	7.98	7.65	7.42	6.75	7.12	8.58	10.14	7.95
Salinity	0.33	0.66	0.51	0.52	0.58	0.3	0.09	0.11	0.1

Fig. 4: Salinity and pH values in surveyed industries
N.B: pH has unit less, Salinity in % (1ppt=1,000ppm=1000mg/L= 0.1 Percent; https://science.com

However, farmers surrounding the river were pumping polluted water from the river Modjo. Remarkably farmers knew that the water was polluted, but still used it as a source of water for their farms. Moreover, they knew vegetables grown in this polluted water would be harmful to health, but used it as a source for farming as there were no other alternative water sources in their areas (Selamawit, 2008). Similarly, farmers near Trunesh Beijing Hospital were pumping the river water from little Akaki and some farmers who farm at the back of Eastern Industrial Zone (i.e Dukem town) used wastewater discharged from Eastern Industrial Zone for irrigation purposes.

In addition to the above itemized and unlisted industries, agricultural activities such as horticulture and floriculture might affect the water quality and causes serious pollution in nearby water bodies due to the usage of fertilizers and pesticides (Shunthirasingham, *et al.*, 2010; Brown, *et al.*, 2009). There are a number of floriculture and horticulture farms around the AR. Among these, Red-Fox Flower, Syngenta, Flourensis Abyssinia and other International flower farms are found near to the AR and Koka dam and also used the river water for flower farming. However, the wastewater effluents of the industries were discharged back to the AR and Koka dam without proper treatment. However, the remaining salty water that consists of high EC value was discharged into wetlands or/and into the AR. Water that is drained from these farms consists of fertilizers, insecticides, and pesticides that when discharged into the river, degrade the water quality of the river. Some insecticides, like DDT are particularly dangerous when allowed to enter into bodies as they result in increased concentrations along the food chain (Owa, 2014).

Organic Matter (DO, BOD & COD) Analysis

Organic matter water samples were collected from 4 sampling to assess the existing water quality of organic matter load in the stations situated at the upstream of Koka. All sampling sites (i.e SATB, SAZR, SMDF, & SAKD) revealed dissolved oxygen (DO) below 3 mg/L which is very detrimental to most aquatic organisms. For instance, DO in the Modjo River, MR downstream of the factory was nil. The low level of DO was due to the discharge of industrial effluents and the toxicity of the combined effects of chemical and heavy metals (Jonathan *et al*., 2008). Biological oxygen demand (BOD) value varies from 3 mg/L in the great Akaki River near Trunesh Bejing Hospital to 63 mg/L at the Modjo River. The concentration of BOD obtained in the Modjo River was high due to the industrial discharge of untreated wastes from tanneries and slaughter houses that contained extra organic loads. Due to the presence of toxic metal like chrome (VI) from the tannery discharge, BOD is directly and indirectly affected by the presence of toxic metals (Mittak and Ratra, 2000).

In addition to the above SW stations, samples also collected from industrial point sources (Fig. 5). All sample showed a higher COD level than WHO limit (2008). Water with high COD value in the MR station downstream of the factory also indicates the presence of inadequate oxygen in the water samples. In the same station, (MR) high values of BOD, 63 mg/L and COD, 200 mg/L were recorded. According to Anil (2017) less than 20 mg/l is the recommended (BIS limit) limit of COD for inland waters. In general, the high values of BOD and COD show high amount of untreated wastewater discharged into the MR.

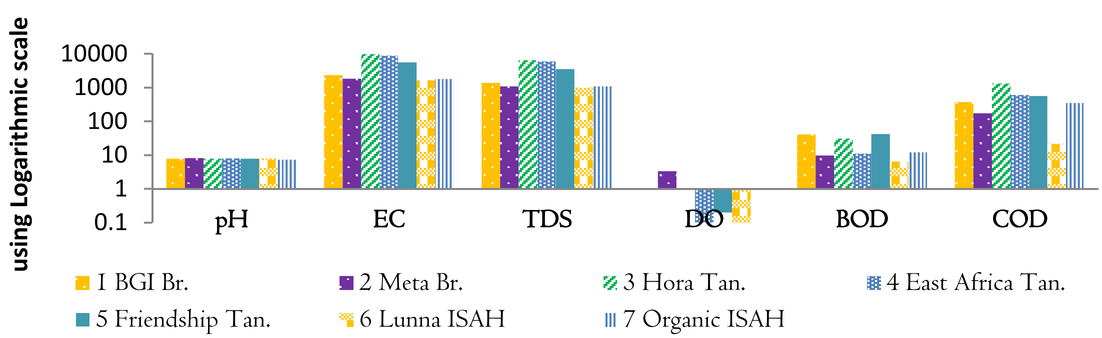


Fig. 5: IWW Samples collected on December, 2019

Similarly samples were taken from the industrial WW discharge points before entering the river and hence the result of EC, DO, COD and BOD value exhibited indicates that the IWW drained into the rivers was poorly treated (seems untreated) which has a profound influence on the receiving water bodies. As seen in Fig 5, COD is high; normally its value is higher than BOD due more organic compounds can be chemically oxidized than biologically oxidized. This includes chemicals toxic to biological life, which can make COD tests very useful when testing industrial sewage as they will not be captured by BOD testing. The higher the BOD/COD the more oxygen stripping capacity the discharged effluent has when discharged into receiving waters (oxygen is used biologically/chemically to break down the organic matter) and the more potential for damage to biological life in those waters. As seen in the above figure the maximum ratio of BOD:COD was 54.73 in East Africa Tannery while the best ratio exhibited 3.44 in Luna ISAH.

Astonishingly most of the surveyed industries´ treatment plant and facilities were not working properly and regularly during the visit. It was also observed that in most of the industries the willingness to show the treatment plant was a deliberate act. During the time of observation, most observed industries did not have a wastewater quality laboratory, and most industries did not have efficient wastewater treatment plants. This indicated that the existing wastewater management systems of most industries are poor. Yet, some industries like Silva water bottling; BJI, Heineken, and Meta Abo Breweries were working relatively better than the others. However, in most of the surveyed industries poor screening of solids, sewer collection systems and sludge management were observed.

Based on the results of observation and interview, it is concluded that lack of facilities, ownership and capital, technical manpower, poor maintenance and capacity of experts, lack of responsibility and other reasons, resulted in inefficient treatment in most industries. This idea is supported by Zeleke (2011) the tannery wastewater treatment plant performance efficiency monitoring system was weak. Thus, they discharged their wastewater without proper treatment and polluted the receiving water bodies**.**

Cr (III) is essential nutrient for animal and essential to ensure human and animal lipids' effective metabolism but Cr (VI) is carcinogenic. Out of surveyed industries on june-2018, samples were taken from five tanneries wastewater discharged into the river and the result showed beyond the WHO limit (Fig 6). In this study the value of Cr^{+6} ranged maximum 0.22 mg/L in BaT and minimum 0.09 mg/L in FeT. Cr-VI is the most toxic form of chromium and having equivalent toxicity to cyanides. It can cause skin ulcer, convulsions, kidney and liver damage. The toxicity of chromium through drinking water is the major problem for human health (Javaid and Chaudhary, 2008). It has also been reported that intensive exposure to Cr compounds may lead to lung cancer in man (Jordao *et al*., 2002). In addition to this the concentration of sulfide varies from 0.01mg/L (HoT) to 0.5mg/L (BaT). The level of sulfide at BaT was high; the noxious odor of the river Modjo water might be due to the high sulfide values being there.

The Current Status of Wastewater Treatment Plants

The wastewater generated from all surveyed industries was disposed into neighboring water bodies without proper treatment. The following questions were distributed to a selected sample of respondents on the existing performance and efficiency of the wastewater treatment plant, wastewater dumping area, and wastewater management systems of the industries. Accordingly, respondents were asked to give their opinions on whether "experts in environmental protection authority (EPA) have done much on industrial waste management problems" (item number 1). As seen in figure 6, out of the interviewed respondents, 63.3% replied that there had been no work done by the EPA. In contrast, 36.7% of respondents agreed that EPA experts tried to create awareness of the industrial waste management system.

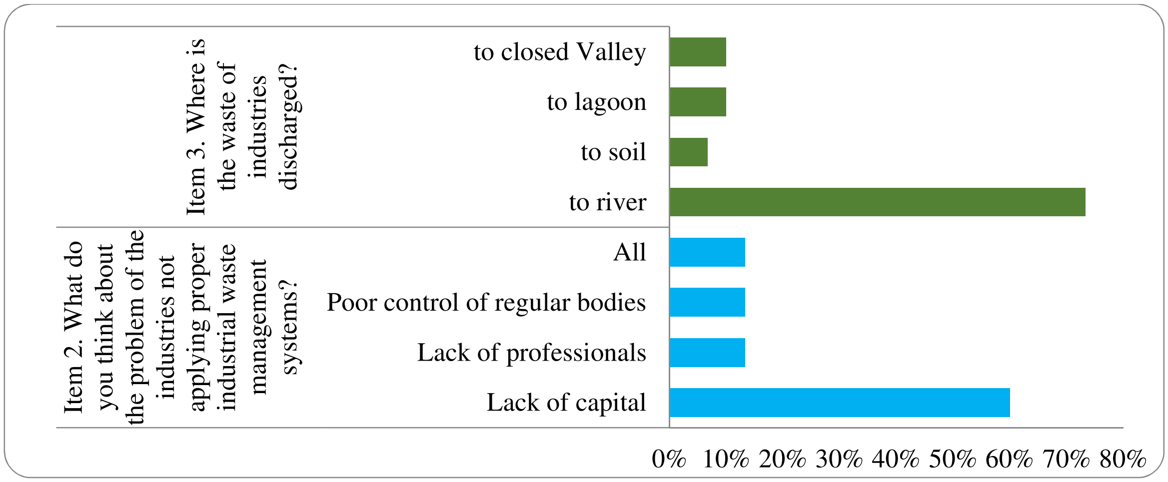


Fig. 6: The respondents´ view with regard to the waste disposal site

With regard to item number 2, "Why do you think industries do not apply proper industrial waste management systems?", 60% of respondents replied that it was due to lack of capital, 13.3% due to lack of professionals, 13.3% due to lack of poor control of regulatory bodies and the remaining 13.3% due to lack of professionals and capital, poor control of regulatory bodies and carelessness or poor practices of the management systems (Fig. 6). This is supported by Selamawit, (2008) the problem of industrial waste is not properly investigated because of a lack of awareness and technology.

To know where industries discharge their industrial waste, the question of "Where is the waste from industries discharged? (Item 3) was raised to the respondents. Accordingly, 73.3% of respondents replied that their industries discharged wastewater into the river, 10% replied that they discharged into the closed valley, 10% replied that they discharged into lagoons and the remaining 6.7% agreed that they discharged their industries effluent into land (Fig. 6). Ghirmay (2000) indicated that ten industries out of twenty-five disposed of their untreated wastewater into little Akaki River and three more disposed of it into its tributaries, while the rest disposed of their liquid waste into the open drainage of the city.

In addition, respondents were also asked their opinions on how the industries treat the effluents (item 4; Fig 7). Accordingly, in number 12 or 40% of respondents were agreed that their industries discharged well and adequately treated wastewater into water bodies. On the contrary, 60% of respondents replied that their industries did not treat their wastewater well and enough. A study on effluents of selected industries in and around Addis Ababa indicated that all the industries generate wastes that carry pollutants which are beyond the internationally accepted pollution standards (UNIDO & ESID, 2001). Concerning the question on the status of wastewater discharge by the industries (Item 5, Fig. 8), 43.3% of respondents replied that their industries discharge partly treated waste, 26.7% agreed that their industries discharge untreated wastewater and 30% responded that they discharge properly treated wastewater into the River.

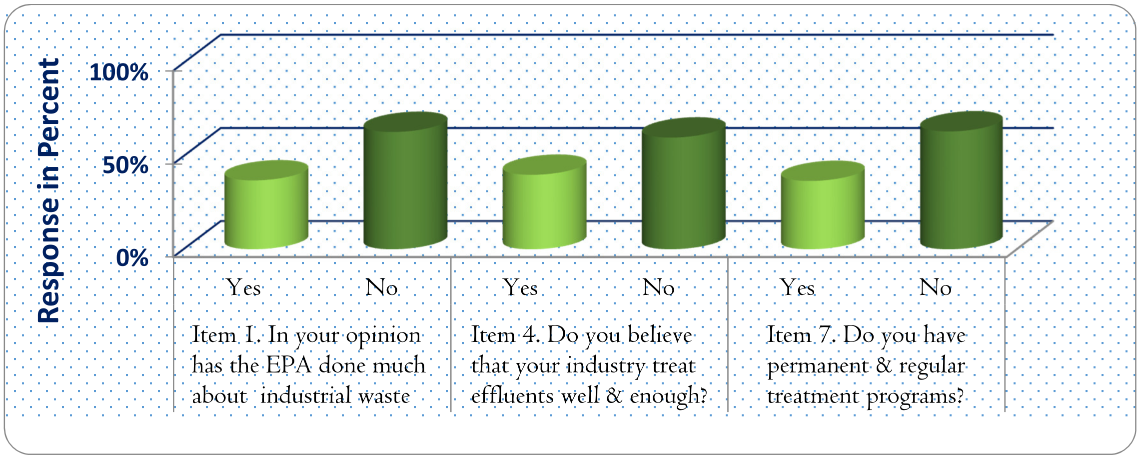


Fig. 7: The respondents´ view with regard to the wastewater treatment plant efficiency

With regard to the treatment method used prior to the discharge of industry' waste (Item 6), about 46.3% of respondents replied that they discharged primarily treated wastewater (i.e sedimentation, coagulation, and flocculation takes place using chemical like coagulants) into the environment, 26.7% agreed that they released secondarily treated wastewater into the water bodies, 23.3% responded that they discharge preliminarily treated wastewater (i.e removal of heavy inorganic solids such as sand, gravel, large suspended or floating solids, coarse of screening) and the remaining (6.7%) responded that their industries discharge tertiary treated wastewater into the environment and water bodies (Fig. 8).

Industrial wastewater needs to be adequately treated prior to its disposal or reuse in order to protect the receiving water bodies from contamination (Edokpayi *et al*., 2015). Yet, especially in Modjo town, out of the surveyed industries, 87.5 % of tanneries, slaughter and abattoir houses, and textile and garment industries discharge their industrial wastewater without applying proper treatment into the adjoining water courses, open spaces, canals, streams, and lagoons. Similarly, (in item 7 Figure 7), 63% of respondents replied that their industrial treatment plants didn't work regularly due to problems associated with maintenance, power interruptions, and lack of facilities. Other findings also indicated that lack of a power supply hinders water and wastewater treatment to a great extent in Africa (Wang *et al*., 2012). The remaining 36.7% agreed that their treatment plants were working regularly. This was also confirmed by other scholars indicating most of the industries didn't manage their wastes properly (Selamawit, 2008; WHO/FAO/IWMI/IDRC/CRDI, 2010).

With regard to the result of the interview, farmers who lived adjacent to the industries at the Modjo River expressed their feelings that the pollution level of the river was dramatically increasing from year to year over the last 10 years due to the expansion of industries around the river. However, farmers surround the Modjo River after downstream of factory were pumping polluted water from the river at the time of the sampling was made with high salinity hazard (high TDS & EC). They agreed that the use of untreated wastewater for irrigation purpose can affect the land and its value of productivity in the long term. Similar thought was reflected by farmers studied by Shobha (2004) in Tunisia.

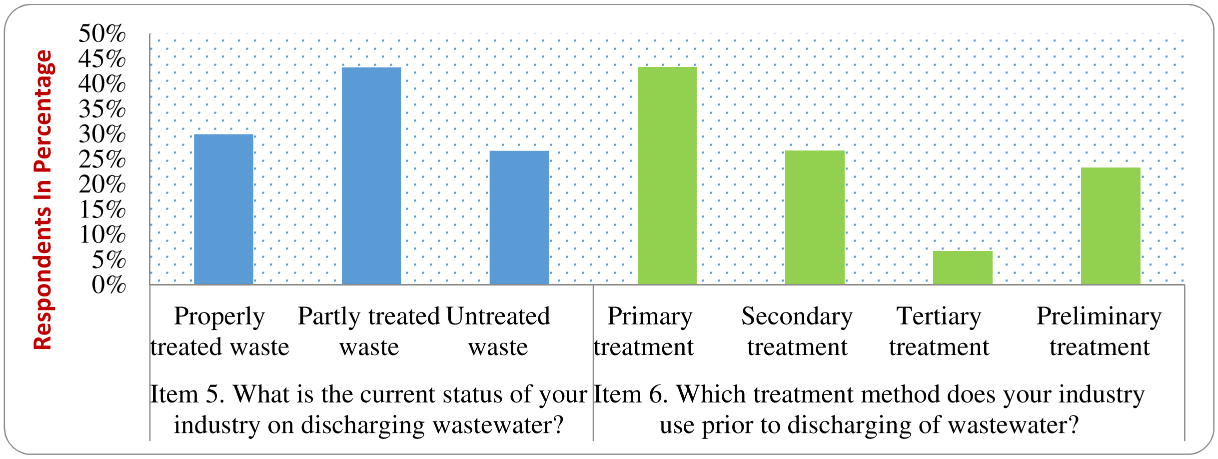


Fig. 8 The respondents´ view with regard to the treatment methods and status

Similarly, farmers near Trunesh Bejing Hospital and contiguous to Eastern Industrial Zone pumping the river water from little Akaki and wastewater discharged from Eastern Industrial Zone used for irrigation purpose. In fact, large number of vegetables (Cabbage, onion and tomato) farming site in Akaki, Modjo and Dukem (i.e. Ethiopia) where polluted streams and rivers of Modjo and Akaki water are their one and only possibility of irrigation source. Similar findings were seen in Sir Lanka by Alexandera and Jeroen, 2006. Those interviewed also added that they are vulnerable to health problems; the presence of unusual smell indicates the environmental pollution has increased due to the poor waste management system of the industries. Studies also indicated that untreated industrial discharge including tannery wastewater, poses a major threat to the environment and human health (Zeleke, 2011). The discharge of poorly treated wastewater usually affects water users downstream and contaminates groundwater (Edokpayi *et al*., 2015). Pathogenic microorganisms enter waterways through untreated sewage, runoff farms, and from various industries, especially the tanning and meat packing industries (Harikishore *et al*., 2012).

The same interview questions were also raised to EPA experts in the towns of Modjo, Dukem and Gelan to know their monitoring role and the existing industrial waste management systems. All of them agreed that industrial waste and the waste management systems of most industries were common problems. Thus, the EPA experts have carried out very few activities on protecting the environment. Besides, the EPA experts also agreed that most of the industries were following improper industrial waste management practices. Therefore, most of the industries discharge untreated wastewater into the environment. This could be due to the financial shortage challenged the tannery industries to construct a better treatment plant and provide all the necessary facilities. Thus, responsible bodies need to give great attention to the industries in supporting them to construct the advanced common wastewater treatment plant for better waste management systems.

Conclusion

This multi assessment approach, which considers the questionnaire, interview, observation, and grab samples of wastewater analysis, enables a more complete picture to become evident in looking for the impact of the inefficient wastewater treatment plant and their untreated effluents on the water quality of AR. From this finding, some of them didn't have well-constructed treatment plants, most of them discharged their untreated effluents directly into the river without treatment and in most; they didn't treat their wastewater properly.

In addition, most of the surveyed industries only partly operated their treatment plant and accumulated huge amounts of sludge. Besides, the five years spatial and temporal physicochemical trend data also showed the increasing trend of EC, TDS, NH_3, K^+, Na^+, NO_3^-, HCO_3^-, PO_4^{3-}, and alkalinity. This could be due to lack of facilities, lack of capital and technical manpower, poor maintenance and capacity of experts, lack of responsibilities and others resulting in most industries to facing the inefficiency in the treatment plant. Generally, from the observations, questionnaires, and interviews used during the study, most treatment plants were not work properly and regularly. This implies that the management of domestic and industrial waste is very poor. Thus, most of the surveyed industries discharged their waste without treatment and degraded the water quality of the AR.

Recommendations

Based on the investigation of the study, the following recommendations were forwarded:

- Industries should improve and upgrade their treatment plants and design their production process in a way to minimize environmental pollution before releasing their industrial waste into the environment.
- EPA should monitor and control the waste management systems of industries and encourage industries to use an alternative technology for waste minimization and by installing solid landfill. In addition, they should implement setting up limits, types of discharge and the enforcement of environmental laws.
- The government should make provision for the improvement of surface water quality and implement realistic standards and regulations. In addition, governmental bodies should construct common treatment infrastructure (plant), especially in Modjo town for the tannery. Moreover, the government should introduce a pay principle for polluters and discharge fee.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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