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Heavy metal pollution and microbial water quality of Tafo and Dadi Rivers in Lega Tafo Lega Dadi Town, Ethiopia

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ABSTRACT

Industrial effluents entering a water body represent a heavy source of environmental pollution and affect the water quality. This study characterized the physicochemical and microbial features of Tafo and Dadi River water and examined pollution its status. Primary methods of data collection, such as in situ measurements, laboratory analysis and observation have been carried out. Secondary data were collected from different sources to obtain detailed information in addition to data collected through primary methods. Data were analyzed using both quantitative and qualitative methods. Both the upper stream and downstream sampled water from the selected points were analyzed for the color of water, which was dark black color and emitted a noxious smell. The other water parameters also analyzed such as: - temperature (ranged from 21.4 to 23.4^{o}C), pH (ranged from 7.9 to 8.4), EC (ranged from 221 to 2410 µS/cm), turbidity (ranged from 0.9 to 21 NTU), Dissolved Oxygen (ranged from 4.4 to 5.52 mg/l), Biological Oxygen Demand (ranged from 15.84 to 38.82 mg/l), Mg^{2+} (ranged from 27 to 156 mg/l), Ca^{2+} (ranged from 31 to 1130 mg/l), Na^{+} (ranged from 26 to 637 mg/l), Pb (ranged from 0.30 ± 0.32 to 2.2 ± 1.13 mg/l), different value observed for cations and anions, total Coliforms (ranged from 1600000 to 8900000 CFU/100ml) and fecal coliforms (ranged from 400000 to 5400000 CFU/100ml). The study concluded that, the lower stream of the rivers was slightly polluted and it affected the river water quality.

Key words: Effluent, Water quality, Pollution, Influent, Heavy metal, Coliform

1. Introduction

Industrialization has given a rise to a number of environmental problems such as waste water generation and its collection, treatment, and disposal in urban areas. In most cases, water is let out untreated and it either percolates into the ground or in turn contaminates the ground water or discharged into the river water and causing pollution into lower stream areas. Thus, the rivers traverse across major urban centers are polluted by different industries and urban economic activities while at the same time serve as a source of livelihoods for a major part of the urban community and the rural population located at lower stream (Oluseyi et al., 2011).

The deterioration of water quality has led to the destruction of ecosystem balance, contamination, and pollution of ground and surface water resources. Water quality degradation worldwide is due to many anthropogenic activities which release pollutants into the river water, thereby having an adverse effect on aquatic ecosystems and general community livelihoods. The quality of water can be regarded as a network of parameters such as pH, oxygen concentration, temperature, etc. and any changes in these physical and chemical variables can affect aquatic biota in a variety of ways (Olatunji et al., 2011). The utility of River water for various purposes is governed by physicochemical and biological quality of the water (Yogendra et al., 2013).

In many developing countries more than 70 percent of industrial wastes are dumped untreated into River waters where they pollute the usable water supply (WWAP, 2009). Industrial discharge can contain a wide range of contaminants and originate from a myriad of sources. Unmanaged industrial wastewater is a vector of disease, causing child mortality and reduced labor productivity, but receives a disproportionately low and often poorly targeted share of development aid and investment in developing countries. At least 1.8 million children under five years die every year due to waste water related disease, or one every 20 seconds (WHO, 2004).

Lega Tafo Lega Dadi town is one of the areas of industrial development in the Oromia special zone, Ethiopia. The industrial activities in this area among others include factories of Textile, Foods, plastics, paints and the other like the slaughter house, Country Club Developers (CCD) and Ropak House Construction institutions release their effluents into the River water. Effluents from the above industries and institutions are disposed into the water almost exclusively without adequate treatment, which is likely to affect the water quality of the receiving River and subsequently that of River Akaki, given the fact that the discharges pass through Tafo and Dadi River in the town is being catchments of Akaki River and finally discharged into Awash River. This study aimed to assess the heavy metals and microbial contents, concentrations and degree of pollution of Tafo and Dadi rivers.

2. Materials and methods

2.1 Setting sampling points for water samples

The study was carried along Tafo and Dadi Rivers, involving the selection of sampling points based on the objectives. By taking into consideration the point at which effluents discharged enter the River water, the total numbers of four sampling points were planned.

The locations of sampling sites in Universal Transverse Mercator (UTM) coordinate system were collected from the field using GARMIN Handle Global Position System (GPS). These were Dale (A) site, Kura (B) site, Gawasa (C) site, Wobor (D) site. They reflect the different activities along the water course of Tafo and Dadi Rivers. They reflect the different activities along the water course of Tafo and Dadi Rivers. As they are shown on Figure 1, Wabor site and Gawasa site sampling points were below downstream of the river Dadi and Tafo, respectively. Whereas the others sampling points are found above the industries at the upstream part of the two rivers.

2.2 Collections of water samples

All water samples for laboratory analysis were collected in sterilized and distilled plastic bottles. The samples were placed in a cool box and later transported to the laboratory for analysis. The water samples for heavy metal estimations were collected in separate 1-liter plastic bottles and were preserved with 5 ml Nitric Acid per liter to prevent metal adsorption on the surface of the container.

To ensure that samples representative; the sample was taken compositely from two sides of the River and middle by grab method. Because of the inaccessibility of middle part of the river, the water samples were taken by a water sampling bucket tied and fixed at the tip of long stick. Sampling was performed, during the semi-dry season, when the River flow is lower at the end of October 2016 and the level of dilution is modest. The waste water samples were obtained from the following sampling stations

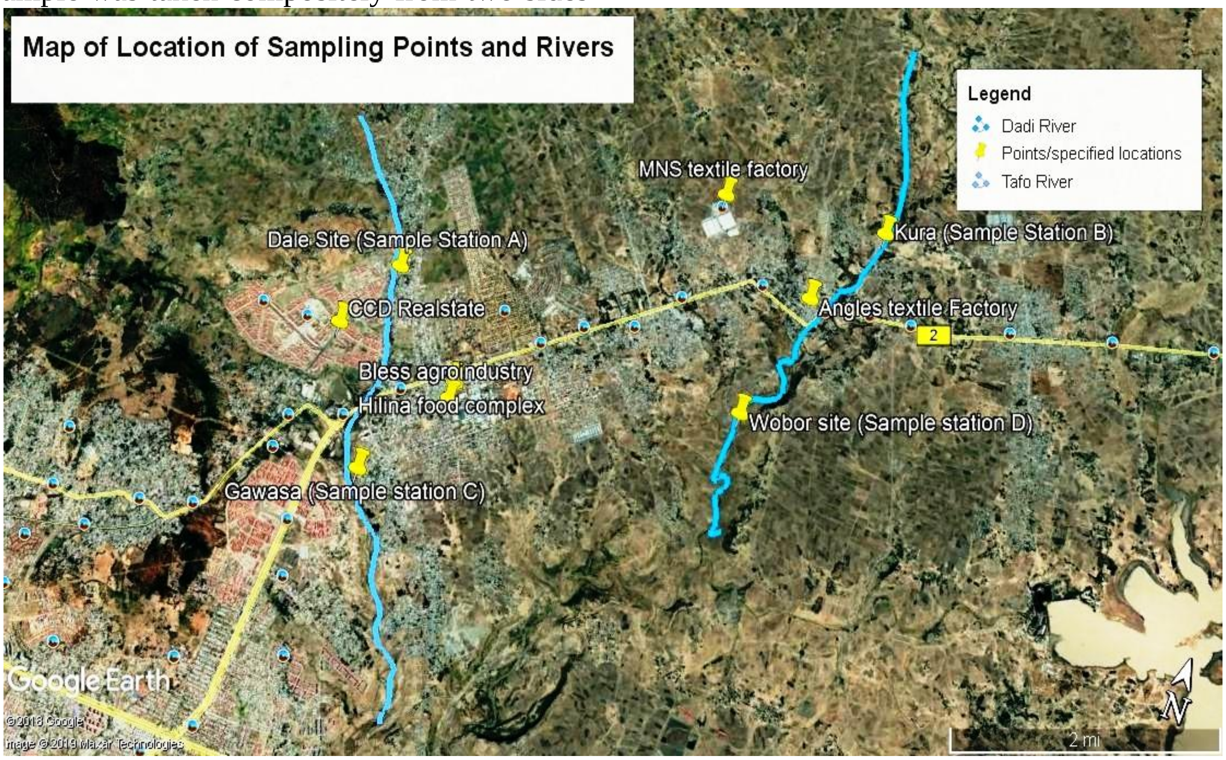

Figure 1 Study area (Location of sampling points and industries)

2.3 Hydro-metrological profile

The study area gets a lot of rain (rainy season) in the months of June, July, August and September. Whereas, a high temperature and dry weather is observed in the months of January, October, November and December. In Lega Tafo - Lega Dadi, August (wettest), December (driest), May (warmest) and November (the coolest) are months of the year. The average minimum and maximum annual temperatures observed in the area are 8.0° and 22.0° Celsius, respectively (Figure 2). The area gets an average annual precipitation of 999.9 mm (39.37 in). The trends of rainfall pattern are shown on Figure 3.

2.4 Method for data collection

2.4.1 In Situ Measurements

Primary data on the physical parameters of water quality obtained from the point of sampling as in situ measurements of water samples. A total number of four River water samples were collected from predetermined points. The water samples were analyzed for components such as temperature, EC, Turbidity, pH, color and DO.

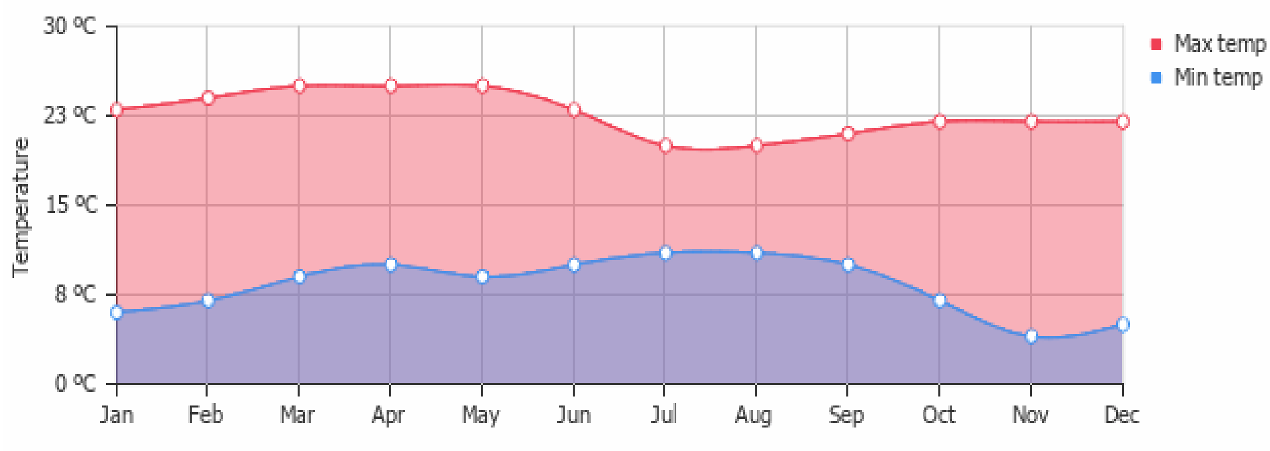

Figure 2 Mean monthly minimum and maximum Temperature of Lega Tafo Lega Dadi Town

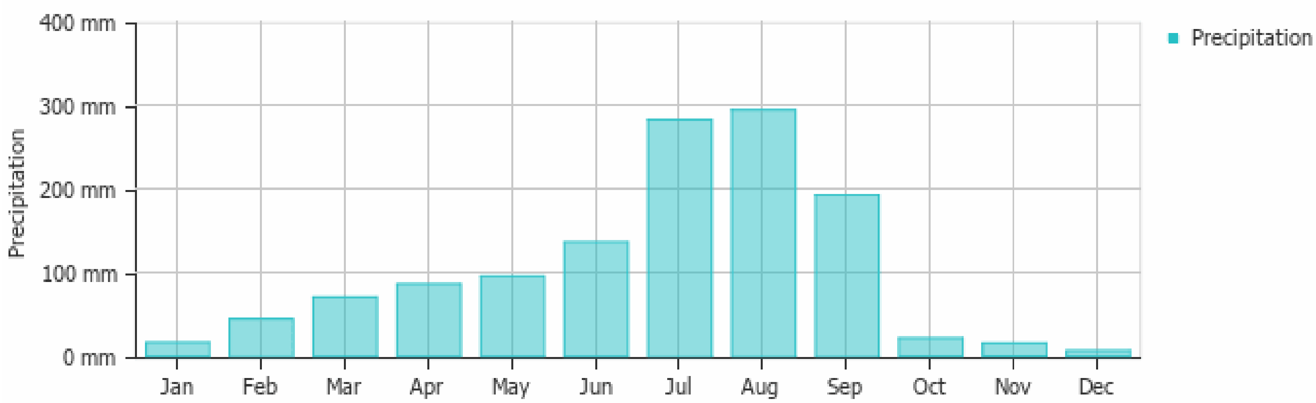

Figure 3 Mean monthly precipitation of Lega Tafo Lega Dadi Town (**Source:** ***Data from nearest weather station: Addis Ababa, Ethiopia (https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,lege-tafo-et,Ethiopia)***

2.4.2 Laboratory Analysis

Primary data on the microbial and physicochemical parameters of effluent discharged by industries is collected through laboratory analysis of water samples from the point of sampling. As a total number of 4 water samples were collected the water samples were analyzed for components such as. BOD is analyzed after 5 days incubation at 20°C and measuring of initial and final dissolved oxygen divided it to dilution factor.

Lead was measured using Atomic Absorption Spectrometer (AAS). The water samples were collected from the rivers sampling points and safely transported using PPE plastic bottles. Procedurally, the samples were then digested with aquaregia (HNO_3 67%: HCl 37% = 3:1).

Mineralization of all treated samples was performed by using a microwave digester. Then, the concentration of lead was determined by AAS. For accurate determination of the concentrations of lead in water, a multi-standard calibration method was used. Cations and anions such as Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}, chloride and sulfate were analyzed by spectrophotometer. The total coliform and fecal coliform of water samples were determined by membrane filtration (MF) method. The MF microbiological test in this research microbial examination refers to a technique where 100 ml of the water sample is filtered onto a membrane. The membrane was placed on a growth selective media for coliforms. After incubation, colonies were counted.

2.4.3 Observation

In supplement methods of *insitu measurements* and laboratory analysis, direct observation was used as an additional method during field survey to observe the situations.

3. Result and Discussion

3.1 Physicochemical analysis and degree of pollution

Results of physico-chemical and Microbial parameters of Tafo and Dadi River water were analyzed for different water parameters and laboratory results of the mean value and standard error were presented in Table 1. Temperature result of Tafo River was 21.4±0.30 and 21.7±0.21$^0{}_C$ respectively upper to downstream and Dadi River result was 21.5±0.45 and 23.4±0.10$^0{}_C$ upper to downstream respectively. For all sample stations, the temperature value was ranged from 21.4 to 23.4^{0}C. The temperature range was in the permissible range of Ethiopian drinking water quality standards as stated in the Ethiopian water quality guideline (ESA 2013) and below the maximum permissible level of WHO drinking water quality (i.e. 23.5^{0}c) (WHO 2017. The result (Table 1) indicates that there was insignificant difference in temperature at the upstream and downstream part of the river. Emission of hot wastewater to the river stream was observed during site visit. The temperature is increased downward to the stream. However, its increment was not beyond the permissible limit of WHO drinking water quality. It was also observed that the cool air exchange with the ambient atmosphere after the effluent emission tends to reduce the temperature in the stream. Assessment of water quality of Huluka and AlaltuRivers shows that the temperature of both the River water samples analyzed ranged from 16.2 to 23 °C and 17.50 to 23.10 °C, respectively (Prabu et al., 2011).

The pH value of Tafo River was 8.2±0.32 at Dale site upper stream to 8.4±0.12 at Gawasa site the lower stream and the Dadi river pH value range from 7.9±0.49 upper stream to 8.3±0.73 lower stream respectively at Kura and Wobor site.

The pH increases across downstream after the industrial discharge effluent enters the rivers which indicate the discharge was slightly basic as it got into the River; which was likely to increase base characteristic of the receiving river water and thus affect the aquatic environment and continuous application of this water to the soils within the study areas might be harmful. Similar result was found out in a study conducted by Akele and his colleagues on the Tinishu Akaki River (Akele et al., 2016

Values of the electrical conductivity of the Tafo River water ranged from 271±23 to 351±18 µS/cm from upper stream to downstream respectively and of Dadi River from 221±11 to 2410±39 µS/cm from upper stream to downstream respectively. Generally, the observed result EC at two sites of Tafo River and upper stream of Dadi River was below the maximum permissible limit of WHO (400 µS/cm) (WHO, 2017).

But at downstream of Dadi River the result was above maximum permissible limit of WHO standards (400 µS/cm) for drinking water (WHO, 2017) and 700 µS/cm for agricultural purpose (FAO, 2006) and it might be due to high amount of textile factories discharges their effluents to the River and could also due to release of blood from slaughter house which released effluents to the Dadi River which containing nitrogenous compounds and after nitrified to ammonium-nitrogen and nitrate resulting in high EC.

Table 1 Phyico-chemical characterization of the river water

parameters	Units	WHO (2017) MPL	ESA (2013) MPL	Upper Tafo Mean±S.E	Lower Tafo Mean±S.E	Upper Dadi Mean±S.E	Lower Dadi Mean±S.E
Temp.	^{o}C	23.5	-	21.4±0.30	21.7±0.21	21.5±0.45	23.4±0.10
pH	pHm	6.5-8.5	6.5-8.5	8.2±0.32	8.4±0.12	7.9±0.49	8.3±0.73
E.C	µS/cm	400	1000	271±23	351±18	221±11	2410±39
Turbidity	NTU	<5	-	1.40±0.59	8±1.23	0.9±0.09	21±2.98
DO	mg/l	5-10		5.35±0.54	4.4±0.23	5.52±0.76	4.58±0.65
BOD	mg/l	10		15.84±0.98	25.52±1.12	17.16±2.15	38.82±4.23
Lead	mg/l	<0.01	0.01	1.02±1.32	2.2±1.13	0.30±0.32	1.28±0.89
Cr	mg/l	<0.05	0.1	<0.05	<0.05	<0.05	<0.05
Mn	mg/l	0.1	0.5	ND	ND	ND	1.11±0.05
Mg^{2+}	mg/l	-	150	27±2.21	42±3.78	156±12	130±7.12
Ca^{2+}	mg/l	-	200	31±0.76	224±34.23	1130±13.81	265±3.27
K^{+}	mg/l	200	-	9±0.08	<0.1	<0.1	<0.1
Na^{+}	mg/l	200	200	637±9.81	44±3.45	26±5.69	80±14.53
So_4^{-2}	mg/l	<250	250	58.33±8.32	17.9±6.48	6.89±0.79	17.00±2.73
Cl^{-}	mg/l	250	250	552.31±18.13	<0.71	<0.71	<0.71
TC	CFU/ 100ml	0	0	16x105±100000	3100000±200000	1900000±100000	8900000±300000
FC	CFU/ 100ml	0	0	400000±200000	1800000±100000	1100000±200000	5400000±200000

Source: WHO (2011), ESA (2013) and Study result (2016)

Another similar study also shows that the EC values to be in the ranges from 225 to 3350 µS/cm which were similar to researcher finding of Dadi River result (Fitsum et al., 2015).

The study shows the turbidity of water is 1.40±0.59 upstream and 8±1.23 NTU lower stream of Tafo River and 0.9±0.09 upstream and 21±2.98 NTU at the lower stream of the Dadi River. This indicates that the entire River is generally polluted and posing problems to aquatic lives, domestic and irrigation use. Similar turbidity values are also recorded by many workers as compared to the limit set by WHO (Akan et al., 2011; Mebrahtu and Zerabruk, 2011)

DO value of Tafo River was 5.35±0.54 and 4.4±0.23 mg/l at upper stream Dale to downstream gawasa site respectively. For Dadi River, the result was 5.52±0.76 and 4.58±0.65 mg/l from upper stream Kura to downstream Wobor site respectively. Dissolved Oxygen value recorded decrease at downstream of the Rivers after different effluent discharged entering to the River. This indicates that the industrial effluents discharge to the River had an impact on the dissolved oxygen concentrations of river water. The result of BOD indicates that the value increases toward the downstream of the rivers. The sample of Dadi River shows that the highest Biological Oxygen Demand value recorded 38.82±4.23 mg/l at Wobor site downstream than the upper part of the River which released from nearby textile factories and slaughter houses.

The concentration of Lead (Pb) value of Tafo River water at ‘Dale site’ upper stream was 1.02±1.32 mg/l and 2.2±1.13 mg/l at ‘Gawasa site’ downstream. The result of Dadi River water was 0.30±0.32 and 1.28±0.89 mg/l upper stream ‘Kura site’ to downstream ‘Wobor site’ respectively. Lead concentrations at all sampling sites of the two rivers was generally above the maximum permissible limits for WHO and ESA standard of 0.01 mg/l for drinking purpose but below the maximum permissible limits of FAO (5.0 mg/l) for agricultural use (FAO, 2006).

Calcium (Ca^{2+}) contents in mg/l were also ranged from 31±0.76 to 224±34.23 mg/l and 1130±13.81to 265±3.27 mg/l upper to lower stream of Tafo and Dadi Rivers respectively. The high value of calcium recorded in lower Tafo, upper and lower Dadi could be high due to the wastes and sewage released to the River and weathering Calcium- rich rocks or cementing materials indicating that Tafo and Dadi River are unsuitable for drinking and irrigation purposes.

Overall, the study has shown that the effluents from the industries have a big impact on the water quality of the receiving river. Although the values in some cases were lower than the allowable limits, the result of lead, DO and BOD analysis showed the continued discharge of the effluents in the river may result in severe accumulation of such contaminants. The result has shown that both rivers pollution severity has increased dawn stream of the river courses. Similar result was also reported by river pollution studies in India, Kali river by Sirohi and Tyagi (2014).

The lead accumulated in the river water may enter to diet through bioavailability in fish and other human dietary fruit and vegetables. As a result of this, it might cause serious cancer to human health. As it was reported in previous studies shown that metal concentrations in fillet and gill of parrotfish (*Scarus ghobban*) from the highly heavy metals polluted Persian Gulf has implied a serious human health issue (Yadolah et al., 2018). Similar study that was also reported by Mirer et al. has warned the toxicity resulted from the biologically accumulated and available heavy metals including lead in fish (Miri et al., 2017). Hence, all point contaminant sources including industries and service sectors need be warned and manage their effluent according to the permissible compliance limit.

3.2 Microbial analysis and degree of river water pollution

The microbial concentrations of Tafo and Dadi River show that the total coliforms were 1600000±100000 and 3100000±200000 CFU/100ml for the upper stream to downstream of Tafo River respectively and the total coliforms of Dadi River was also 1900000±100000 and 8900000±300000 CFU/100ml for the upper stream to downstream respectively. The total coliform and the fecal coliform counts for Tafo and Dadi River exceeding acceptable limits are indicative pollutions of domestic wastes from ropack real-estate for Tafo River and pollution from slaughter house institution for Dadi River located along the River bank. As it is clearly demonstrated in the result, the contaminant level of water at the downstream of industries was high; this showed a clear disposal of untreated effluent to river water bodies. A similar case was reported in Iran where the downstream water bodies showed higher pollution profile where the settlement in the upstream release its effluent and untreated sewage to the river course and caused to have higher microbial pollutants profile.

4. Conclusion

There were significant variations in the water quality parameters evaluated among the different locations of Tafo and Dadi Rivers. In general, the physicochemical parameters of the Rivers water which include: pH and temperature, was within the limits recommended by WHO for drinking purposes and other physical parameters were beyond the standards. The downstream water quality was highly degraded and results in dark color, harmful odor, low dissolved oxygen and high conductivity. Chemical parameters such as BOD, Pb, Mn and Ca value for downstream of the rivers were beyond the WHO and ESA standard for domestic and drinking purposes. The pollutant composition indicated industries at the upper stream were the main pollutant sources. Also, the microbial pollution indicated the presence of release of untreated sewage into the upstream part of rivers.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors have contributed in data collection, analysis and manuscript preparations.

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5. References

Akan, J., Abdulrahman, F., Dimari, G., and Ogugbuaja, V. (2011). Physicochemical determination of pollutants in wastewater and vegetable samples along the Jakara wastewater channel in Kano Metropolis, Kano State, Nigeria. *European Journal of Scientific Research*, 23, 122-133.

Akele, M.L., Kelderman, P., Koning, C.W., and Irvine, K. (2016). Trace metal distributions in the sediments of the Little Akaki River, Addis Ababa, Ethiopia. *Environ Monitoring and Assessment*. 188: 389. https://doi.org/10.1007/s10661-016-5387-z

Ethiopian Standard Agency (ESA) (2013). Ethiopian Drinking Water Quality Standard. https://apps.who.int/iris/bitstream/handle/10665/254637/9789241549950eng.pdf?sequence=1

FAO (Food and Agriculture Organization). (2006). Water quality Standards for agricultural uses. https://www.fao.org/docrep/003/T0234E/T0234E00.htm

Ftsum, G., Abraha, G., Amanuel, H., and Samuael, E. (2015). Investigations of Physico-Chemical Parameters and its Pollution Implications of Elala River, Mekelle, Tigray, Ethiopia. *Momona Ethiopian Journal of Science*, 7(2), 240-257 http://dx.doi.org/10.4314/mejs.v7i2.7

Mebrahtu, G., and Zerabruk, S. (2011). Concentration and Health Implication of Heavy Metals in Drinking Water from Urban Areas of Tigray Region, Northern Ethiopia. *Momona Ethiopian Journal of Scienc*, 3(1), 105-121. https://dx.doi.org/10.4314/mejs.v3i1.63689

Miri, M., Akbari, E., Amrane, A. et al. (2017). Health risk assessment of heavy metal intake due to fish consumption in the Sistan region, Iran. *Environmental Monitoring and Assessment*, 189(11), 583. https://doi.org/10.1007/s10661-017-6286-7

Olatunji, M. K., Kolawole, T. A., Albert, B. O. and Anthony, I. O. (2011). Assessment of Water Quality in Asa River (Nigeria) and Its Indigenous *Clariasgariepinus* Fish. *Int J Environ Res Public Health*, 8(11): 4332–4352. https://dx.doi.org/10.3390/ijerph8114332

Oluseyi, A., Oluseun, A.O., and Birdie, O. O. (2011). Perceived Effect of Industrial Water Pollution on the Livelihood of Rural Dwellers in Yewa Area, Ogun State, Nigeria. *European Journal of Social Sciences*, 22(1). https://connection.ebscohost.com/c/articles/67654445/

Prabu, P., Wondimu, L., and Tesso, M. (2011). Assessment of Water Quality of Huluka and Alaltu Rivers in Ambo: Ethiopia. https://jast.modares.ac.ir/article_4686_0.html

Sirohi, S., and Tyagi, P.K. (2014). Impacts of industrial effluents on water of different locations Kali River. Meerut: India. https://dx.doi.org/10.5897/JETR2014.0349

WHO (World Health Organization). (2017). Guidelines for drinking-water quality: fourth edition incorporating first addendum, 4th ed + 1st add. World Health Organization. https://apps.who.int/iris/handle/10665/254637.

WHO. (2004). The Global Burden of Disease. Geneva: World Health Organization. http://www.who.int/healthinfo/global_burden_disease/2004_report_update/en/

WWAP. (2009). The United Nations World Water Development Report 3: Water in a Changing World. Paris: UNESCO. https://unesdoc.unesco.org/images/0018/001819/181993e.pdf

Yadolah, F., Narottam, S., and Ali, M., et al. (2018). Metal concentrations in fillet and gill of parrotfish (Scarus ghobban) from the Persian Gulf and implications for human health. *Food and Chemical Toxicology*, 118, 348-354. https://doi.org/10.1016/j.fct.2018.05.041

Yogendra, S., Ramteke, P. W., Shashwat, M., and Pradeep, K.S. (2013). Physicochemical analysis of Yamuna River Water. *International Journal of Research in Environmental Science and Technology*, 3(2), 58-60. https://www.urpjournals.com/tocjnls/34_13v3i2_2.pdf