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Toxicological Impact Analysis of Industrial Loads and Microbial Contamination on the Upper Awash River, Ethiopia

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Abstract A study on Toxicological Impact Analysis of Industrial Loads on the Upper Awash River and the Surrounding Ecosystems was conducted from October 2017 to April 2019. The study covered the middle upper Awash basin which is in highly industrialized zone of the country. The samples for both physicochemical and microbial analysis were taken from different locations from the river (Koka incoming, Koka outgoing, Wonji and Awash Melkasa) sites. Physicochemical analysis was done with Wagtech photometer 7100 and the Comparator Reagents for respective parameters, Wagthech pH/temp/mV Meter and Turbidity Meter. Eijkman test (WHO, 2004), and method reference APC (aerobic bacteria Plate Count), APHA, 1995 (American Public Health Association), ICMSF, 1988 (International Commission on Microbiological Specifications for Food) were used to determine microbial population as well as level of contamination in Awash River water. The results for physicochemical water quality parameters show that all the samples were highly turbid with high amount of TSS, TDS and considerable amount of Ca-Mg hardness. Parameters such as nitrate, nitrite, chlorine and fluoride are measured to be above WHO standards. The water samples taken from Awash River were analyzed to check microbial contamination and it was found that coliforms count was >180MPN/100 ml, fecal coliforms also > 90MPN/100ml and *E.coli* was also detected in the water samples. The accepted MPN for Coliforms is < 30/100ml and for Feacl coliforms < 1MPN/100ml. The population of coliforms and fecal coliforms those were estimated are very critical to cause different waterborne diseases and the result obtained is so much far from the accepted level. The water is polluted with nitrate, nitrite chlorine and fluorine and as result it is aesthetically and heath wise unacceptable. Therefore, before Awash River becomes out of use, it needs an immediate governmental and non-governmental institutions intervention.

Keywords: *aquatic ecosystem, Awash River, chemical pollution, contamination, heavy metals, industrial waste*

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1. Introduction

In Ethiopia the last decade particularly in the last five years, there is a huge increase in both industrial activities and urbanization due to rapid development IMF [1]. This development has led to huge increase in the amount of various wastes (solids, liquids and gaseous emissions) inputs into the environment in all parts of the country in general and in the study area in particular Elizabeth [2].

The most majority of the country’s industrial zones are located in the watershed of the upper Awash River. This includes the capital, Addis Ababa and East Showa Zone of Oromia. According to Ethiopian investment agency these are taken as industrial corridors of the country. The growth and expansion of such industries and urbanization eventually leads to potential increase in the industrial and municipal wastes of all kinds that affect the water quality, human and animal health and the whole ecosystem Mill [3]. Awash River is one of the most economically exploited and utilized rivers in Ethiopia. The Awash Valley has been the major focus of medium and large scale irrigated agriculture developments since the 1950s, and presently has over 70 percent of Ethiopia's non-traditional irrigation. In addition, there are traditional and nontraditional small-scale irrigation systems within the valley, and major dams to improve the management of water for agriculture and produce hydropower have been constructed Ginna [4]. More than five million people are dependent on it both for drinking, irrigation, hydroelectric power, etc

Worldwide, aquatic ecosystems are highly affected by anthropogenic impacts and microbial contamination Cheung [6], WHO [18]. Aquatic ecosystems concerns are growing due to widespread microbial contamination of water systems. An effective water management infrastructure is lacking in most developing countries and a large portion of their population relies on untreated and highly contaminated surface water WHO [17]. This increases the outbreaks of waterborne diseases, such as diarrhea. Globally, 1.8 million people are estimated to die annually from waterborne diseases and most of them are children from developing countries. Most of those deaths are caused by unsafe water supply and poor sanitation Rochelle-Newall [13].

The potential future impact of socio-economic development and climate change on river water quality is a key concern worldwide Rochelle-Newall [13]. Increasing temperatures and change in rainfall patterns combined with socio-economic factors, such as human and animal population growth and land use changes will continue to affect flows and water quality in river systems globally Jin [9], Islam [15].

Under future climate change scenarios, tropical systems will likely be subject to increased temperature and shifts in the frequency and intensity of extreme rainfall events Rees [12]. These projected increases in precipitation and floods combined with population growth, urbanization and agricultural intensification are expected to accelerate the transport of waterborne pathogens to aquatic systems Hofstra [8], Rochelle-Newall [13] and thereby deteriorate future scenarios of contamination and increase risk of waterborne diseases.

This contamination is aggravated in the developing countries like Ethiopia, because of their high susceptibility to climate change, high population growth, rapid urbanization, agricultural intensification and poor water treatment facilities Gizaw [7]. Over the past few decades, with rapid population growth, urbanization and agricultural intensification, most Ethiopian rivers that are proximal to cities have received enormous inputs of microbial contaminants and the microbial water quality has been impaired Paul [11], Islam [15], Tadesse [16].

Awash River is one of the largest rivers in the country, which is highly contaminated with microorganisms and industrial wastes but used for irrigation. This increased the risk of waterborne diseases and expose people to carcinogenic problems. Deterioration of water quality may also influence safe food production and livelihoods of the people. In the future, the river water will be severely affected by changing climatic and socioeconomic conditions (Cheung [6], Rochelle-Newall [13]). Besides, industrial wastes pollution, Awash River is also contaminated with microorganisms (bacteria, protozoa) that can cause waterborne diseases Golimowski [5], Rees1 [2]. Therefore, besides the industrial wastes, this study investigated the microbial contamination of Awash River, the demography and species of microorganisms that can cause water borne diseases.

Therefore, this study focuses on toxicological analysis of industrial loads and microbial contamination on Awash River and the surrounding ecosystems, particularly at the middle part of upper Awash River that is locate between Addis Ababa and Matahara.

2. Materials and Methods

2.1. Description of the Study Area

Awash River originates from central plateau of Ethiopia near Ginch-West shewa. Flowing south east direction to the plains of south west Shewa, pass to the southern side of Addis joining tributaries like Akaki which originates from Addis and a collection of many streams and Municipal waste drains and Mojo River which joins Awash near Koka Dam. Awash is the only major river in the rift valley drainage system. Awash Continues its course north east direction in the Great East African Rift Valley floor 1200 km across Afar depressions and end up there at Afar desert called Lake Abbe Cheung [6].

The major geological event in the formation of the watershed of the Awash River is associated with the formation of the East African Rift System, also called Afro-Arabian Rift Valley, one of the most extensive rifts on the Earth's surface, extending from Jordan in southwestern Asia southward through eastern Africa to Mozambique Sunderman [19].

The formation of the great east African rift valley is related with the latter part of geological ages: The Cenozoic Era, which is believed to have taken place about 65 million years ago Berg [20] (Figure 1).

The upper course of Awash is influenced by rainy high lands while the middle and lower basins of the river are mainly influenced by arid and semi-arid lands Dietz [21]. The available water from rainfall in the basin is 39,845 (Mm^3 yr^{-1}), 72 % of the rainfall (28383 Mm^3yr^{-1}) is lost through evapo-transpiration, 18 % (7386 Mm^3 yr^{-1}) runoff and 10% (4074 Mm^3 yr^{-1}) is rechargeable water Viator [22]. Most part of the study area including pocket of areas of the rift floor with elevation extending 800-1500 m are being regions of tropical climate come under annual mean temperature category of 20-25°C.

Awash is probably the most highly utilized river in Ethiopia. It provides drinking water to more than five million people living in both urban areas like Adama, Wonji, Adama University and the surrounding rural populations. Some of the Pastoralist populations like Afar and Kareyu are even totally dependent on Awash River for all of their lives. Awash irrigates many large scale farm lands and plantations like Wonji, Nura Era, Merti-Jeju, Metahara and a large number of small scale farms and plantations for local population supporting millions of lives. However, Awash River is suspected to be polluted with heavy metals from industries, chemicals from agricultural fertilizers, pesticides, and also contaminated with microbial activities in the river and its surroundings.

Therefore, the current study aimed to determine the contamination levels of heavy metals and microbial contamination via laboratory analysis of samples taken from the Awash River.

2.2. Materials and Chemicals

2.2.1. Different Instrumentations and Operating Conditions for Water Quality Analysis were used

We used Wagtech Potalab water testing and monitoring kit for different chemical water quality parameters including pH, TDS/conductivity, DO meter, BOD/COD meter, turbidity etc. For chemical parameters we employ electrometric methods, spectrophotometric methods such as AAS, UV/Vis, spectrophotometer etc.

2.2.2. Reagents for Heavy Metal Analysis

Wagtech water quality test tablets were used and also other reagents and chemicals were used.

2.2.3. Reagents/Chemicals Required for Microbial Contamination Analysis

Different reagents and chemicals such as plate count agar tubes, dilution water, and buffered 99mL, sterile, buffered dilution water is prepared with magnesium chloride and potassium dihydrogen phosphate, culture media for coliforms, fecal coliforms and *E.coli* were used to determine the population of these microorganisms.

2.2.4. Water sampling Sites

Samples were collected from different areas of the Awash River. Samples were selected strategically where the river has connection with the tributaries like Modjo River which is highly polluted with industrial wastes. The samples sites were Awash Melkasa, Koka, and Wonji areas (Figure 2).

2.2.5. Sampling Procedures for Water Quality and Microbial Contamination Analysis

Six water samples for water quality analysis and two samples for microbial contamination were collected. For water quality analysis, water samples for measurement of physical and chemical parameters and determination of heavy metals were collected in separate plastic bottles and preserved with appropriate amount of HNO_3 to prevent metal adsorption on the inner surface of the container and precipitation. Samples for sulfide were separately collected and their sulfide contents fixed with zinc acetate solution on the spot (EPA). All water samples will then be stored in dark at 4°C in refrigerator.

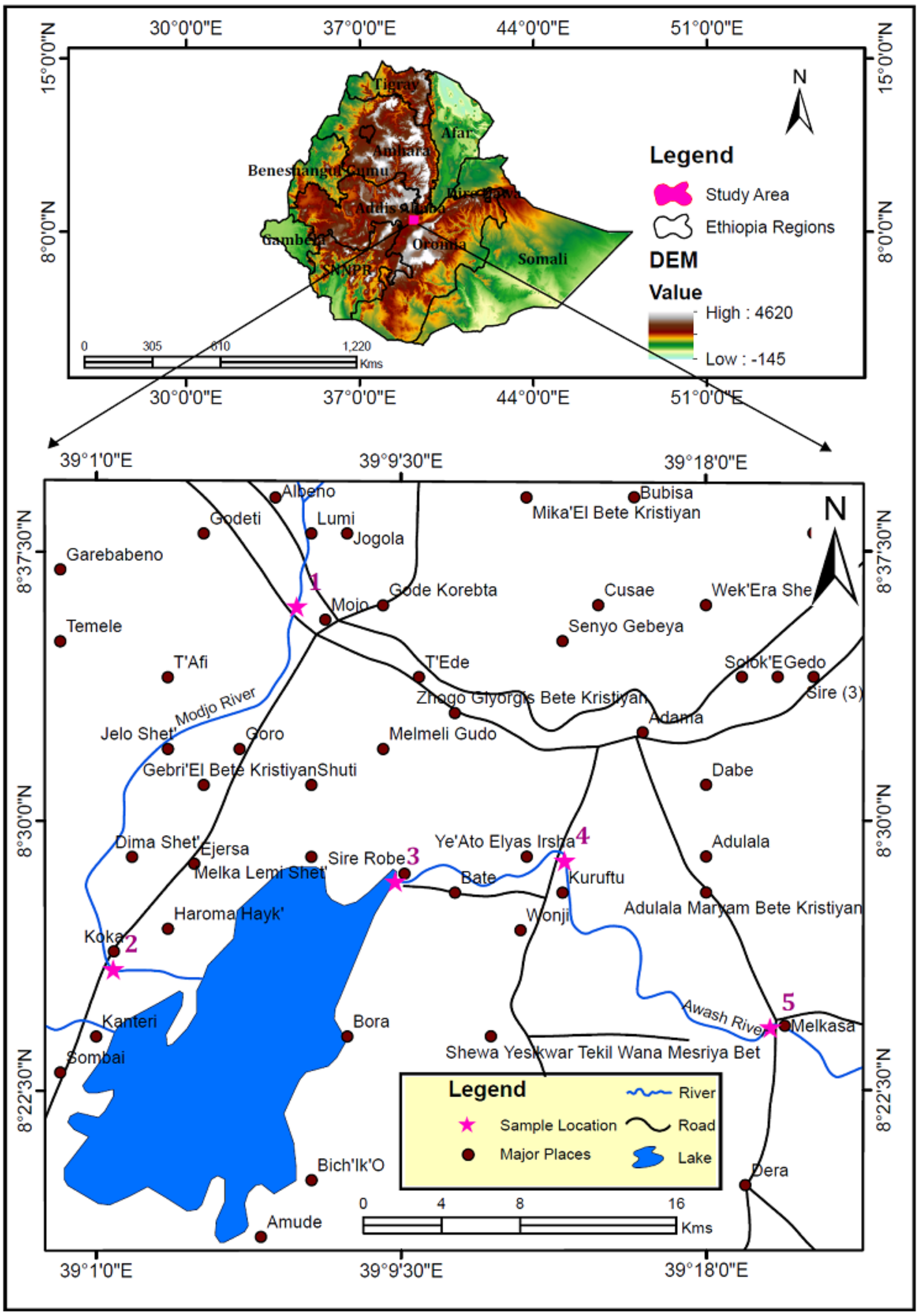

Figure 1. Map of the study area

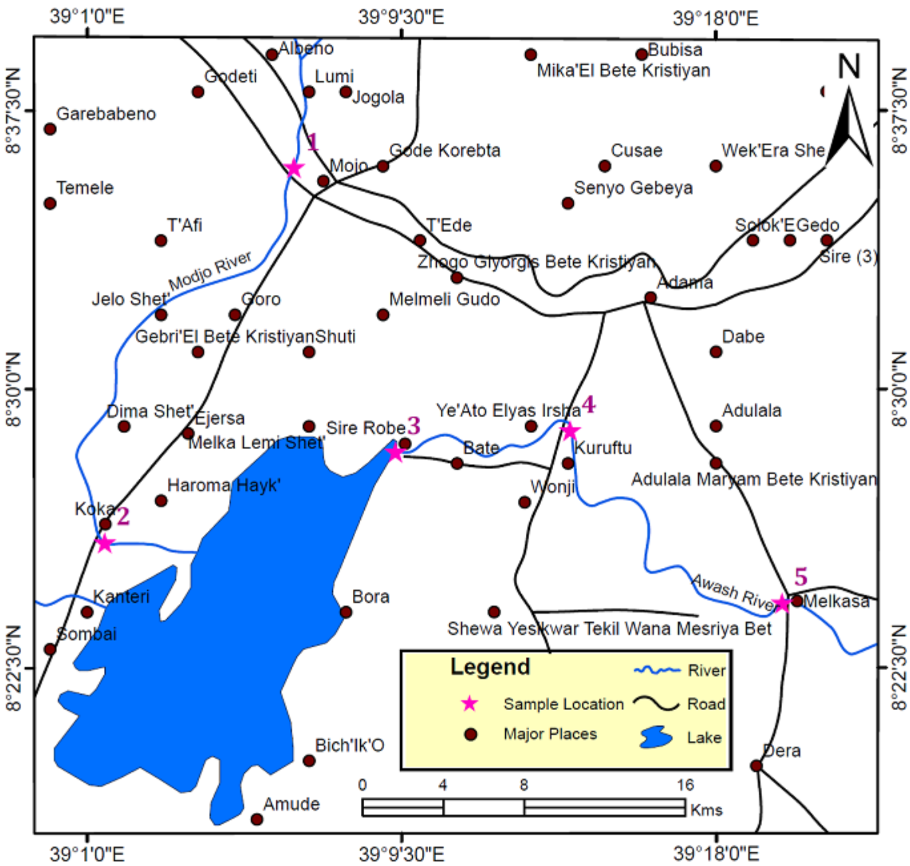

Figure 2. Sampling Sites

For microbial analysis water samples were collected, using sterile glass containers from EPI (Ethiopian Public Health Institute) that contains sterilized sodium thiosulfate to collect water samples. The sodium thiosulfate is not necessary if the sample does not contain a residual disinfectant. The samples were taken to the laboratory within few hours and immediately put in the appropriate place to avoid possible contamination. The sample containers were immediately opened before collection and closed immediately after collection of the sample of the containers. Even the sample containers were not rinsed before use to prevent contamination. During sample collection from the river, the containers were below the water surface to prevent the collection of surface scum (impurities). Enough samples were collected and the samples were given a code on the container and the analysis carried out EPI microbiology laboratory.

2.3. Testing Water Samples/Water Quality Analysis

Water samples were analyzed by applying standard method described in "Standard methods for the examination of water and wastewater" by the American Public Health Association (APHA) 1996 and US Environmental Protection Agency for the determination of various physical, chemical and heavy metals parameters in the water sample. All the reagents used in this analysis were Wagtech international certified water sample quality test tablets.

Physical parameters (temperature, appearance, odor, pH, dissolved oxygen (DO), conductivity, organic matter in the sediment, total suspended solids (TSS) and total dissolved solids (TDS) were measured on the spot by using Wagtechwagtech water monitoring and testing kit. **Total suspended solids (TSS)** of a known volume of the river water sample was calculated by filtering the samples with a pre-weighed glass fiber or cellulose acetate filter paper, repeatedly washing it with distilled water, drying the filter paper in an oven and calculating the weight difference. **Total dissolved solids (TDS)** were measured with the help of a device conductivity/TDS meter right at the field or sampling site. **Total organic matter** in the sample was determined as follows. Known volumes of the liquid samples were dried in an oven at a temperature of 105°C and the dried samples (sediments) were cooled in desiccators. Known mass of the dry sediment has been ignited with clean, dry pre-weighed crucible in a muffle furnace (525 - 550°C) for about 3 hours and the weight difference was calculated. **Chemical parameters** like Biological oxygen demand (BOD), Chemical oxygen demand (COD), Total hardness, Ca and Mg hardness as $CaCO_3$, alkalinity, Na, K, NH_3, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, Cl^- and S^{2-} and some heavy metals were determined by using Wagtech Test reagents using Wagtech Photometer 1700 and other instruments.

2.3.1. Testing Water Samples/Microbial Contamination

Use of selective and nonselective agars for growing live bacteria, yeasts, and molds requires water sampling, sample dilution, application of samples into petri dishes, pouring melted agar, incubation of solidified agar samples for a specified time at a specified temperature, and enumeration of colony forming units (CFU) per milliliter depending on the agar used and on the color, shape, size, and fluorescence characteristics of the microorganisms. Fecal coliforms also counted following similar procedures, but the presence of fecal coliforms indicated the presence of *E.coli* or the *E.coli* is determined from the fecal coliforms. Further tests of a group or type of microorganism in the water sample (i.e., total viable count, coliform count, fecal coliform count, and *E.coli* was estimated from fecal coliforms. Indeed, myriad combinations of selective and non-selective agars, time and temperature of incubation, aerobic versus anaerobic conditions, volume of sample plated, amount of agar and so forth have been used in performing viable cell counts of water. The culture media used were Lauryl tryptose (lactose) broth, Brilliant Green Lactose, Bile (BGLB) broth and *E.coli* broth to enumerate and determine the coliforms, total coliforms and to detect *E.coli*.

2.4. Data Analysis

Tabulating the data (concentrations) of all parameters and the heavy metals in its category (water, Soil, plants and animals) for each sample site and location, obtaining reference values such a WHO's reference values for each of the heavy metals, comparing the experimental values with the reference values, identifying alert level in most sensitive area and less sensitive areas and identifying area intervention threshold will be synthesized and analyzed by using appropriate Descriptive statistical data analysis methods such as percentages, mean etc.

3. Results and Discussions

3.1. Sample Analysis for Physco-chemical Water Quality Parameters

Table 1. In this determination list of parameters, reagents, instruments and methods are indicated in the table.

Water quality parameter	Wagtech test tablets	Instrument	Method
Temperature		pH/temp/mv meter(p352-234)	Direct reading
Appearance		Visual	Observation
Odor		Nose	Smelling
pH		pH/temp/mv meter(p352-234)	Direct reading
Turbidity		Wagtech turbidity meter(T820-110	Direct reading
Conductivity		pH/temp/mv meter(P352-234)	Direct reading
Organic matter (OM)		Oven, crucible, furnace, Analytical balance	Measuring
Total suspended Matter(TSS)		Filter paper beaker, oven, balance	Measuring
Total dissolved matter(TDS)		Wagtech Conductivity/TDS meter C551-210	Direct reading
Total hardness	Wag-WE10130	Wagtech photo meter 7100	Direct reading
Alkalinity	Wag-WE10130	Wagtech photo meter 7100	Direct reading
NH_3	Wag-WE10204	Wagtech photo meter7100	Direct reading
NO_2-	Wag-We10150	Wagtech photo meter7100	Direct reading
NO_3-	Wag-We10340	Wagtech photo meter 7100	Direct reading
SO_4-	Wag-WE10168	Wagtechphoto meter7100	Direct reading
So_4^{3-}	Wag-we10356	Wagtechphoto meter 7100	Direct reading
Cl-	Wag-We10310	Wagtechphoto meter7100	Direct reading
F-	Wag-WE10322	Wagtechphoto meter7100	Direct reading
S_2	Wag-we10362	Wagtechphoto meter7100	Direct reading
Al(mg/L)	Wag-WE10106	Wagtechphoto meter7100	Direct reading
K(mg/L)	Wag-WE10164	Wagtechphoto meter7100	Direct reading
Fe(mg/L)	Wag-WE10330	Wagtechphoto meter7100	Direct reading
Mn(mg/L)	Wag-WE10144	Wagtechphoto meter7100	Direct reading
Zn(mg/L)	Wag-WE10174	Wagtechphoto meter7100	Direct reading

3.2. Results for Physco-Chemical Water Quality Parameters

Table 2. Mean measurement values of water quality parameters at different sites

Water quality Parameter	Modjo outlet	Koka Incoming	Koka outlet	Wonji Incoming	Malkasa	WHO's standards	Remarks
Temperature (^oC)	32	25	25	27	27	*	
Appearance	Muddy	Muddy	Muddy	Muddy	Muddy	*	
Odor	Rotten meat	Muddy	Muddy	Muddy	Muddy	*	
pH	4.3	8.4	8.7	8.5	9.2	*	<8 for effective chlorination
Turbidity (ntu)	*	6.5	6.4	6.3	6.3	<5ntu	Aesthetic
Conductivity EC(µs/cm)	*	2709.9	2735.5	2719.7	2711.9	*	
Organic matter(mg/L	41.3	15.4	12.3	12.1	13.5	*	
Total suspended matter(TSS) mg/L	44.2	28	26.9	22.8	27.2	*	
Tota dissolved matter(TDS) (mg/L)	22.9	12.6	14.6	10.7	11.7	*	
Total hardness (mg/L)	102	89.32	97.8	85.42	91.24	*	
Total Alkalinity	5.6	9.33	8.87	8.43	8.45	*	
NH_3(mg/L)	5.82	2.3	3.2	1.4	1.45	*	
NO_2(mg/L)	80.13	67.37	77.5	79.2	83.32	5	health
NO_3(mg/L)	123.42	95.5	84.9	104.3	95.22	50	health
SO_4(mg/L)	287.22	198	202.12	217.87	238.65	*	
PO_4(mg/L)	29.68	23.07	25.76	23.54	26.83	*	
Cl^-(mg/L)	339.8	322	335.67	32.3	34.47	5	health
F^-(mg/L)	2.4	0.3	0.54	1.12	1.87	1.5	
S^{2-}(mg/L)	2.4	1.1	0.7	0.53	0.67	*	
Al(mg/L)	200.01	225	223.23	213.81	219	0.2mg/L	Aesthetic
K(mg/L)	45	34	36.2	32.5	31.4	*	
Fe(mh/L)	35	59.23	43	41.34	45.76	0.3	Aesthetic
Mn(mg/L)	0.5	0.3	0.6	0.54	0.57	0.4	health
Zn^-(mg/L)	27	29.25	34	33.85	35.64	*	

*WHO standard measurement.

3.3. Results for Microbial Analysis

Table 3. Microbial population estimated in Melkasa area/Awash River

Parameters	Method reference	Quality control (P/F)	Result	Acceptable limit
APC at 35 °C	APHA,1995 19th ed	P	TMCcfu/ ml	--------------
Coliform count	WHO,1971/2004 Eijkman test	P	180MPN/ 100ml	<30mpn/100ml
Fecal coliform	WHO, 1971/2004 Eijikman test	P	>180MPN/100ml	<1mpn/100ml
E.coli	ICMSF,1988, 2nd ed	P	Present	Absent

NB: APC = aerobic bacteria Plate Count, APHA= American Public Health Association, ICMSF = International Commission on Microbiological Specifications for Food. MPN = Most Probable Number, CFU= Colony Forming Units, P/F = Precision of Fermentation tube test

Table 4. Microbial population estimated in Wonji area/ Awash River

Parameters	Method reference	Quality control (P/F)	Result	Acceptable limit
APC at 35 °C	APHA,1995 19th ed	P	TMCcfu/ ml	--------
Coliform count	WHO, 1971 2004 Eijikman test	P	>180MPN/ 100ml	<30mpn/100ml
Fecal coliform	WHO, 1971 2004 Eijikman test	P	90MPN/ 100ml	<1mpn/100ml
E.coli	IMCSE,1988	P	Present	Absent

NB: 1. In the coliform count minimum detection level of < 1 is considered as not detected (ND). 2. In the other counts < 1 x 10^1 is the standard reporting format for plates from all dilution of the sample has no colonies (ND).

3.4. Discursion for Physco-Chemical Water Quality Parameters

Temperature: the temperature of the water samples in the most cases is very close to the ambient temperature except that of Modjo outlet which is a little higher than the ambient temperature. This might be due to the effect of the waste water from Modjo tannery.

Appearance turbidity and odor: both Modjo and Awash River samples look like muddy due to suspension of soil and other solid waste mater. This is the reason for high turbidity of the water sample at all sites. As result it will increase the treatment cost if it has to be used for drinking or for industrial purpose. The odor at all sampling site is muddy except for modjo samples which is obviously do to the release of waste water from tannery and release of blood and other meat leftovers from animal quarantine plant

pH: Modjo samples which is almost the waste water from the tannery and the quarantine sites is highly acidic which is observably affecting the health of the domestic animals like cows, goats, donkeys etc. These animals have very thin hair, rough skin with scratches and wounds. Awash sample are found to be alkaline ranging from 8.40 to 9.20 downstream. This might be due to the increasing of decomposition of organic matter and other anthropogenic activities downstream.

Conductivity/TDS: these values insignificant variation downs tream showing that the amount of dissolved minerals across the sampling sites is more or less similar. Except that of Koka outlet showing slight increment due to the hydroelectric power plant.

Organic matter and TSS: the presence of high amount of organic and inorganic maters in its suspended form is one of the reasons for high turbidity of the water samples. The trends show that both OM and TSS decrease down steam.

Total Hardness and Ca-Hardness: both are at the WHO acceptable range for potability. However it might cause scales to the boilers in the industries like sugar and ethanol industries across the river.

Ammonia, Nitrite and Nitrate: total nitrogen could not be tested due to the lack of reagent. However, independent measurement of these parameters showed that the decrease along the downstream. Especially ammonia is very high for Modjo samples and NO_2^- for Malkasa sample which is downstream. Both NO_3^- and NO_2^- are above the acceptable values according to WHO (50.0 mg/L).

Anions like SO_4^{2-}, PO_4^{3-}, S^{2-}, Cl^-, F^- : chlorine is measured to be above the WHO standard limit and Fluorine for Modjo sample is above the WHO acceptable limit. Other anions are in the range of the acceptable limits How ever increasing tendency is observed downstream for the main River.

Metals/Cations, Al, K, Fe, Mn and Zn: all the determined metals are found to be in the range of acceptable limits except for Mn at some sampling sites. This indicates that Awash River is safe for drinking in respect to these parameters.

3.5. Discussion for Microbial Analysis

According to the result of this study Awash River is highly contaminated with microorganisms particularly with bacteria such as coliforms, fecal coliforms and *E.coli*. The number of colony forming bacteria is high above the accepted or recommended number or limit. For instance, the number of coliforms accepted number is less than 30/100 ml but in this study the number of coliforms was estimated more than 180/100 ml of the sampled water taken from Awash River. The estimated number of fecal coliforms was more than 90/100 ml in the sample water but the accepted number is less than 1/100 ml of water. This study also reveals the presence of *E.coli* in the sampled water.

If fecal coliforms are available in the sampled water, it is true that *E. coli* is found in the water sampled. Total microbial count in colony forming units (TMCcfu/ml) look is critical and needs high effort or measure to protect the health of the people living near the river. However, the people living near the river still depend on Awash River for their livelihood, for instance they use the water for drinking, irrigation, washing their clothes, etc. Similarly, a study carried out in Indonesia WHO [18], suggested that effective water management infrastructure is lacking in most developing countries and a large portion of their population relies on untreated and highly contaminated surface water. From this, it is understood that Awash River is contaminated with disease causing microorganisms. WHO [17] suggested that water pollution or contamination with disease causing microorganisms threatens public health through the consumption of contaminated food or drinking water. Similarly, this study concluded that Awash River is contaminated with disease causing microorganisms, which in turn threatens the health of the people living near the river.

Why Awash River is highly contaminated with disease causing microorganisms? The reason is simple, due to weak policy and enforcement laws, sewage wastes were directly released into the river. The industrial wastes also released into the river and contributed for the reproductive activities and suitable microhabitat for the microorganisms. The direct discharge of the pollutants to downstream could entail negative effect on the quality of the river, as well as serious harm to the aquatic life and downstream users.

4. Conclusion and Recommendations

In this study the samples collected from Awash River were tested for their temperature, turbidity, pH, TDS, organic matter, total hardness, ammonia, nitrite, nitrate, metals (cations) and anions, and more or less they are in the acceptable level but some of them are beyond the acceptable level. For instance, there is high organic matter in the water; as a result the turbidity of the water is very high. Both nitrite and nitrate are above the acceptable level because of high industrial loads. Among metals (cations) Manganese is above its acceptable level and also among an ions Chlorine is above its acceptable level. From this it is understood that Awash River needs more attention to take conservation action which would be initiated by both governmental and non-governmental institutions which could involve the local community at large. Unless and otherwise Awash River may be severely polluted and it may not be used for agricultural activities as well as for any other livelihoods of millions of people living in the surrounding areas of the river.

In general Awash River is highly polluted with heavy metals and also contaminated with disease causing microorganisms, in which all these hazardous chemicals and disease causing microorganisms threatens the health and livelihoods of the people, particularly people living in the surrounding areas of Awash River either directly or indirectly. Therefore, based on these facts, the following recommendations were suggested:

- the stakeholders such as governmental and non-governmental organizations should take an immediate solutions to the problem that the community is facing by now.
- from the grass root to the top management bodies, awareness creation via training should be given and risks of water contamination should be well understood by the community
- It would be advisable if all the industries are obliged to construct sewage disposal mechanisms/ treatment plant/ before they start to produce industrial products or before they are official permitted to produce the products because if they are fail to that the disadvantage is more its advantages. It is the industrial wastes that pollute the river first and then it will be contaminated with microorganisms.

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