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Level of Contamination in Lakes and Rivers of Ethiopia: an Overview

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Abstract

Water is a resource that is required by all living things. Ethiopia is being known as the roof tower of Africa is rich with surface and groundwater resources. The status of pollution in Ethiopia water bodies is yet to be reviewed. So, in this review, the status of pollution in lakes and rivers of Ethiopia is overviewed. Ethiopia water bodies are getting pollution due to the rapid growth of small-scale and medium industries, geological routes, nutrient enrichment, and other anthropogenic activities. The high concentrations of heavy metals (As, Zn, Cr, Cu, Hg, Pb, Cd, and Ni), pesticides, and pathogens beyond permissible limits by WHO in the water bodies from different anthropogenic and natural pathways are a great problem. Their entry into the ecological food chain and the resulting health effects are of great concern for the future. Most of the studies carried out on physical, chemical, bacteriological, and invasive weeds like water hyacinth pollution issues in Ethiopia are dedicated to the characterization and the quantification of the pollution. Moreover, proper mitigation majors and interventions are required to avoid the problems that result from the contaminants for the incoming generation.

Keywords: Lakes, Rivers, Heavy metals, Pesticides, Pollution, Ethiopia.

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Article highlights

- Ethiopia is endowed with a substantial amount of water resources consisting of lakes, rivers, and groundwater.
- Worldwide contaminations of ground and surface water are the most serious problems affecting the health of the population.
- The status of pollution in lakes and rivers of Ethiopia is overviewed *via the* level of contamination in different water bodies of Ethiopia following physical, chemical, and biological contamination by different pollutants was reviewed.
- To resolve such pollution problems proper mitigation majors and interventions are required to avoid the problems that result from the contaminants for the incoming generation

1. Introduction

Potable water that all living things seek, and that is essential for life on the earth. Notwithstanding its enormous availability; it contains different kinds of contaminants-which can be natural or man-made. Natural impurities are not necessarily harmful; they contain dissolved gasses (e.g., nitrogen, carbon dioxide, hydrogen sulfide, etc.) which can be collected during rainfall [1-3].

Urban human activity practices such as urbanization, industrialization, and service sectors pollute water bodies. The most important effects influencing public safety are land and surface water pollution. Whether such a point or nonpoint cause of contamination may contaminate the water bodies [4, 5]. As stated mentioned UNDP, 2003, products that originate when humans began to farm the land. Numerous sources of pollutants could deteriorate the quality of water resources [6, 7].

Ethiopia is rich with water resources both with surface and groundwater. With changing environmental conditions under increasing anthropogenic influences, the nature of the Ethiopian water bodies is also changing. Environmental contaminants from municipal, agricultural, and industrial sources may enter the food chain; accumulate in organisms, and affect their survival [4, 8, 9]. Among the wide range of pollutants affecting water resources, some elements are of particular concern because of their toxicity even at low concentrations. Currently, water contamination by trace elements, pesticides, herbicides, pathogens, and biological materials has become a question of substantial public and scientific concerning the light of the evidence of their toxicity to humans and biota [6, 10, 11].

Most of the information in the literature on the status of contaminants on the rivers and lakes of the country is yet limited. So, it is necessary to organize and report the levels of contaminants in the water bodies to alleviate the problem. This review tries to give a more complete picture of the level of contamination in different water bodies of Ethiopia following physical, chemical, and biological contamination by different pollutants.

2. Water bodies in Ethiopia

Ethiopia is also endowed with a substantial amount of water resources. The country is divided into 12 basins; 8 of which are river basins; 1 lake basin; and the remaining 3 are dry basins, with no or insignificant flow out of the drainage system. Almost all of the basins radiate from the central plateau of the country that separates into two due to the Rift Valley. Basins drained by rivers originating from the mountains west of the Rift Valley flow toward the west into the Nile River basin system, and those originating from the Eastern Highlands flow toward the east into the Republic of Somalia. Rivers draining in the Rift Valley originate from the adjoining highlands and flow north and south of the uplift in the center of the Ethiopian Rift Valley. Since almost all river basins originate from the highlands and high rainfall areas, they have a huge amount of surface water running in the river basin systems, and Ethiopia is considered to be the water tower of the Horn of Africa [12-14].

This potential is not fully utilized and translated into development because of many factors including limited financial resources, technical challenges, and lack of good governance in the water sector. This chapter attempts to review the potential of the surface water and groundwater resources of the country, and the opportunities and challenges of the water sector development. Ethiopia constitutes 99.3 % of land area and the remaining 0.7 % is covered with water bodies [15]. The country has 12 major basins, 12 large lakes, and differently sized water bodies (Figure1).

2.1. Evaluation of Water Quality

The *evaluation* of the *quality* of *water* bodies is of fundamental importance to the study and use of *water*. Water quality of any water body can be evaluated by applying the methods, such as Physical assessment, Chemical assessment and Bacteriological assessment. The Physical assessment of water is carried out by studying physical parameters are to be evaluated to study the physical status of water body under investigation via Turbidity, Total dissolved solids (TDS), Conductance and Temperature. The chemical assessment is carried out to study the presence of chemical pollutants in the water bodies, following chemical parameters are to be considered pH, Total Hardness, Ca & Mg hardness, Heavy metals, River bed sediment analysis, dissolved oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chloride (Cl^-), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Phospahte (PO_4^{3-}), Flouride (F-), Cademium (Cd^{2+}), Mercury (Hg^{2+}) and free CO_2 [16]. Moreover, the bacteriological assessment of any water body is highly essential because the presence of pathogenic bacteria in water can create several water-borne diseases in both humans and animals. The bacteriological assessment of water includes mainly fecal coliform and total coliform.

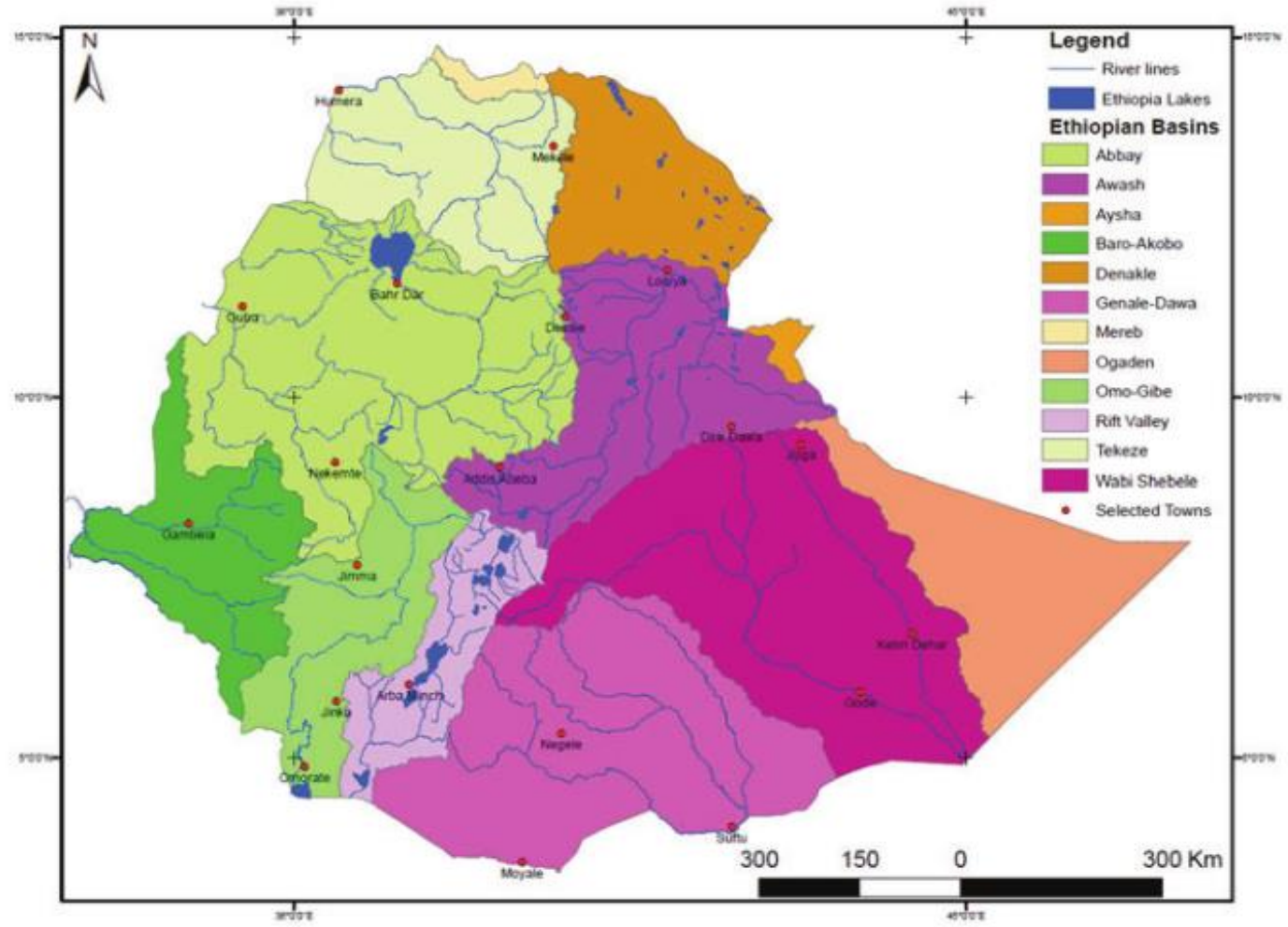

Figure 1: Summarized descriptions of major water basins in Ethiopia [13]

2.2. Water qualities in lakes and rivers of Ethiopia

2.2.1. Physical and Chemical Characteristics

Water qualities of the lakes and rivers of Ethiopia have been studied by many scholars in different regions and times of the country and are tabulated in Tables 1 and 2. Among the rivers covered by this review, the minimum pH was found to be at river kebena 4.9 and the maximum pH at the upper awash river 8.44. The pH of surface water increases with the increase of photosynthesis by autotrophs as they use dissolved CO_2 and release O_2 to the surface water and low pH at the bottom of the water surface is the consequence of decomposition of organic matters at high temperature releasing CO_2 and acids [17]. This is the reason that most of the pH determined by the scholars is neither highly acidic nor highly basic; but it ranges from slightly acidic, neutral to slightly basic for the Ethiopian rivers that were included in this review. The lower pH for kebena rivers is due to the high input of raw sewage into the river water and solid wastes effluents coming from the drains. These results are in line with the finding of different scholars [18].

Electrical conductance (EC) is a direct measure of the dissolved ionic component in water and hence electrical characteristic. Higher the conductance more is the number of ions present and vice-versa. The ions include both anions and cations [19]. Hence, the lowest and highest observed EC for Ethiopia rivers were Gilgel Abay at 22 and great and little akaki rivers at 385.9 respectively. This indicates that there are more dissolved ions in the little akaki river. one of the reasons could be an inflow of urban waste as well as the discharge of untreated municipal waste resulted in the river containing heavy ionic concentrations. River water temperature values in the review area ranged from 13.6-31.3°C. These suggest that the Ethiopian river water temperature is generally ambient and good for the specific reason for water quality; since, **high temperature** negatively impacts water quality by enhancing the growth of micro-organisms which may increase taste, odor, color, and corrosion problems [19]

The level of TDS for Ethiopia rivers ranges from 10 to 600. The highest TDS value was observed for Kebena River and the lowest obtained to be Dabena River. In general, the TDS values reported by different scholars for Ethiopian rivers were ranged from small to moderate.

The high levels of TDS at the kebena river may be associated with compositions of complex particulate matter which is characteristic of such conditions [24]. This complex particulate matter consists of both inorganic and organic chemicals, as well as microbial entities [25]. Similar studies have shown that high rates of deposition of organic pollutants are responsible for high values of TDS and low DO surface water [26]. High concentrations of TDS can lower the water quality and cause water balance problems for individual organisms and aquatic life.

Turbidity is the Intensity of light scattered by the sample in specific conditions with the intensity of light scattered by standard reference suspension under the same condition. Turbidity levels ranged from 2.83 to > 1000 NTU for the Ethiopian rivers as shown in Table 1. Except for the Gilgel Abay River, the other rivers do not exceed the 5NTU recommended turbidity level stipulated by WHO [27].

The DO content of water Ethiopia rivers was recorded maximum at the upper awash river at 7.84 mg/land the minimum was recorded to be 0.05 mg/l at kebena river. Except for the value reported for the upper awash river; the values of doing other rivers were well within the limits of drinking water standards of 6 mg/l [28]. Total nitrogen for most of the rivers except included in this study was not reported by the scholars. But the ketar river showed the highest TN content 1558.4 and the lowest was reported to be at meki river at 500.1.

BOD is the measure of the extent of pollutants in the water body. The untreated discharge of municipal and domestic wastes in water bodies increases the amount of organic content. Therefore, the microbes present in water require more amount of oxygen for its degradation. BOD is a measure of organic material contamination in water, specified in mg/L.

Table 1: Status of water quality for some rivers of Ethiopia

River	pH	EC	Turb.	DO.	BOD	TDS	TN	TP	Temp	References
Great & Little Akaki	7.6 + 0.08	385.9	-	3.02	130	-	-	-	19.4	[20]
Ketar	-						1558.4	86.4		[17]
Meki							500.1	22.3		[17]
Upper Awash River	8.15-8.63	327.67-364.33		4.67-7.84			Nil-2000	4-56		[21]
Kebena	4.9-6.5	44.06-110.1	<5	0.05-4.29	0.6002-6.002	40.03- 600				[22]
GilgelAbay River	7.31-9.6	22-292	27.5->1000			14-189			13.6 -31.3	[18]
Gudeer	8.44	316.47	2.83			149.37				[19]
Muger River (Chancho bridge)	7.51	40				10				[23]
Didessa River (Gimbe bridge)	6.97	50				20				[23]
Dabena River (W. of bedele)	7.02	30				10				[23]

BOD is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials (e.g., iron, sulfites) [29]. The BOD values for the Ethiopia rivers were also not reported as much, the BOD of the Great and little akaki rivers was the highest of the two reported values which is followed by 0.6-6 for the kebena rivers. The reported values were higher than the WHO standard but the value reported for kebena river was within the desired range [27]. The pH values of Ethiopian lakes were reported by different scholars (Table 2). The highest and lowest pH values were observed to be at lakes Abijata and Tana respectively. Generally, the pH values of the lakes included in the review have neutral to slightly alkaline pH. Unlike the others, the pH values for the rift valley lakes Abijata and shala were higher. The pH values of the lakes of Ethiopia do not fall in permissible limits by WHO [27] which are 6.5-8.5 except for lake ziway and tana The EC value for the Ethiopia lakes included in the study ranged from 404 to 19200. The highest value of EC was observed at Lake Shala and the lowest observed to be at Lake Ziway. Generally, except for Lake Hayq, Hawassa, Ziway, and Abaya, the lakes of Ethiopia do not fall in permissible limits by WHO [27] which are 1500.

Table 2: Status of water quality for the lakes of Ethiopia

Lake	pH	EC	DO.	TDS	Temp	References
Ziway	8.1	404	5	107.7-423.8	23	[17]
Hawassa	8.66	846	5-7		23.5	[30]
Chamo	8.84	1910	5-9		26.3	[30]
Hayq	9	910	8.4		18.2	[31]
Tana	7.3-8.5	115.-148	5.9-7	151-174	20-27	[23, 32, 33]
Abaya	8.9	623				[33]
Langano	9.4	1810				[33]
Abijata	10.2	15800				[33]
Shala	9.9	19200				[33]

The DO value for Ethiopian water bodies ranged from 1-9. The highest observed for Lake Chamo and the lowest was observed to be at Lake Ziway. The values of DO for the lakes of Ethiopia do fall than the permissible limit set by WHO [27] in the range of 4.5-7.5 except form lakes chamo and Hayq. TDS refers to the sum of all the components dissolved in water. In natural waters mainly dissolved solids are composed of Na^{+}, K^{+}, Mg^{2}+, Ca2+, Cl^{-}, SO_4^{2-} PO_4^{3-} and HCO_3^{-}. Water that contains too much-dissolved matter is not suitable for common uses. The TDS values reported for Ethiopia lakes varied from 107.7 to 423.8 for lakes tana and ziway respectively. The TDS values reported fall in permissible limits by WHO [27] which is 1000mg/l. The temperature for different lakes of Ethiopia varies from 18.2 to 27.

The highest and lowest temperature was found to be at Lakes Tana and Haiq respectively. Most of the temperature of the reported water lay within the range of the Bangladesh standard for fisheries [27].

2.2.2. Level of Heavy Metals in Ethiopian water bodies

Pollution of aquatic environments by heavy metals is a growing problem worldwide and currently, it has reached an alarming rate. As heavy metals cannot be degraded, they are continuously being deposited and incorporated in water, thus causing heavy metal pollution in water bodies. The presence of heavy metals in the water may have a profound effect on the microalgae which constitute the main food source for bivalve mollusks in all their growth stages, zooplankton (rotifers, copepods, and brine shrimps) and for larval stages of some crustacean and fish species [34].

Moreover, bio-concentration and magnification could lead to the high toxicity of these metals in organisms, even when the exposure level is low. The bio-accumulated heavy metals can transfer into other animals through the food chain and would end in our tables. Under such conditions, the toxicity is the concern of the present review. It tries to show an overview of the heavy metal pollution status of the metals in lakes and rivers of Ethiopia. The total concentrations of heavy metals in lakes and rivers of Ethiopia are shown in Table 3 and Figure 2. The levels of investigated metals varied from not detected to 2.6 for Cd, 0.6 to 89.46for Ni, 0.028 to 13.53for Pb, and not detected to0.17for Hg, respectively.

Table 3: Level of Heavy metal contaminants in rivers and lakes of Ethiopia

Water Body	**As**	**Cr**	**Cu**	**Zn**	References
Lake Hawassa	0.63	2.6	2.8	14	[35, 36]
Lake Koka	2.8-3.0	1.6-4.2			[37]
Great & Little Akaki water	1.46	0.029	67.04	25.5	[38]
Kebena	0.59-1.24	0		0	[39]
Addis Ababa Average		11	2.3	14	[38]
Lake Ziway		3.9	5.8	93	[35]
Gudar River			0.29	0.63	[19]
Chamo Lake	10.3	12.6	1.2	16.1	[40]
Abaya Lake	6.6	5.9	4	11.8	[40]
Abijata lake	301.5	121.2	0.7	18	[40]
Langano Lake	17	20	1.5	3.2	[40]
Haiq Lake			0.260-1.940	0.150-0.160	[41]
Lake Tana	ND	0.011	0.011	0.002	[42]
Tendaho Reservior		0.15		2.51	[43]

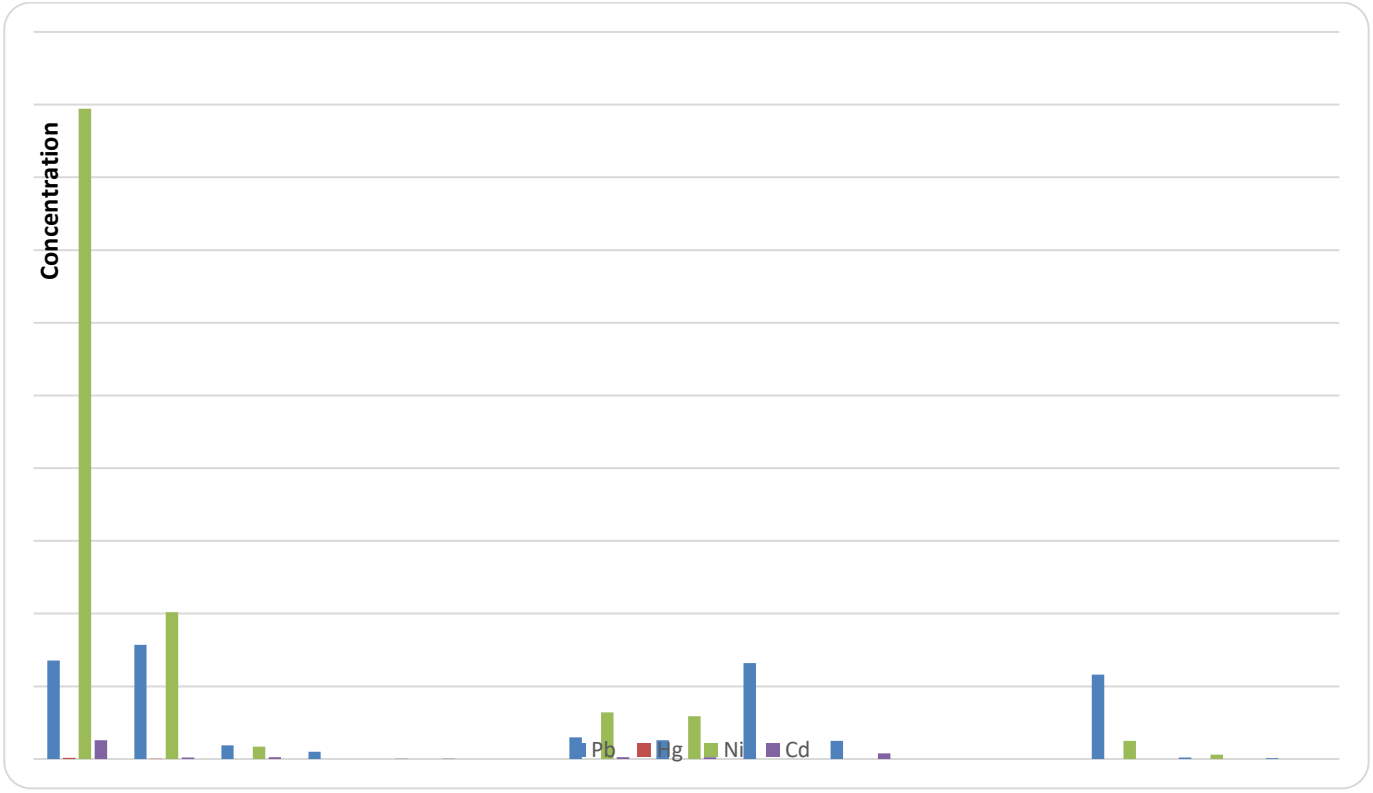

Figure 2 Fractionation of Cd, Ni, Pb, and Hg in water bodies of Ethiopia

Nickel has been considered to be an essential trace element for human and animal health. The maximum permissible limit for Ni in water is 0.2 mg/l [31]. The concentration of nickel in the rivers and lakes of Ethiopia exceeds the permissible limit. Cd is reported to be a component of pesticide and fertilizer. Volatilization of Cd from fertilized agricultural lands introduces significant amounts of Cd to the atmosphere which through runoff gets into the aquatic ecosystem [43]. The maximum permissible limit for Cd in water is 0.01mg/l [31]. The concentration of cadmium in the water bodies of Ethiopia is shown in Figure 2. In almost all the water bodies included in the review on the concentration of cadmium was recorded above the permissible limit.

According to WHO standards [27] permissible limit of lead in water is 0.05mg/l and in all the collected water bodies of Ethiopia concentration of lead was. In all the Ethiopia water bodies with the reported value of Pb concentrations samples concentration of above the permissible limit. Mercury concentrations in water bodies of Ethiopia included in this review ranged as shown in figure 1. Hg levels of water bodies of Ethiopia included in this review were above the World Health Organization (WHO) [27] permissible limit of 0.010 mg/L for drinking water (Figure 2).

Arsenic concentrations in the Ethiopia water bodies included in this review ranged from 0.59 to 301.5for Kebena river and Abijata lake respectively (Table 3). The reported values for arsenic the water bodies were higher than the WHO permissible limit of 0.010 mg/L for drinking water [27]. These water samples

were polluted with arsenic may be due to runoff from agricultural areas, where materials containing arsenic such as fertilizer and pesticides used. Cr is an essential micronutrient for animals and plants. It is considered as a relative biological and pollution significance element. Generally, the natural content of chromium in water is very low except for the regions with substantial chromium deposits. The concentration of Cr can result from industrial and mining processes [34]. The highest reported Cr value for is Ethiopia water bodies found to be at 121.2 at Abijata lake and the minimum at lake koka at 1.6. Generally, the reported values for Cr were recorded above the permissible limit set by the WHO [27].

Cu is an essential constituent of living systems and is widely distributed metal in nature. Cu can exist in the aquatic environment in three forms, namely soluble, colloidal, and particulate. Cu is a rare ingredient of natural waters. It is used in Cu pipes or does sink tanks with copper sulfate (II), which is used to prevent the growth of algae. It was proven that Cu is toxic to fish and other aquatic creatures, in those concentrations that do not pose a risk to man. It is known that the anion of Cu (II) is a mainly poisonous chemical element [44]. The reported values for copper concentration in Ethiopia water bodies are illustrated in Table3. Copper in waters from0.26–67., the smaller and greater concentration found in Haiq Lake and the Great & Little Akaki river. Though most of the levels of copper were above the permissible levels some waters were in safe limits from the permissible limit which is 1.0 mg/l [45].

Zn is found in natural waters in larger quantities compared with Cu, Pb, Cd, and Hg, so the industrial discharge waters containing high concentrations of it. Zn is an essential element for the life of animals and human beings. It is found in virtually all food and potable water in the form of salts or organic complexes [27]. The main sources of Zn pollution in the environment are zinc fertilizers, sewage sludge, and mining. Urban runoff, mine drainage, and municipal sewages are the more concentrated sources of zinc in water. The highest Zn concentration is known to be at Lake Ziway and the minimum reported was at Upper Awash River among the rivers included in the review. The zinc concentrations reported for waters were within the WHO [27] permissible limit of 3.0 mg/L for drinking water except for haiq and gudar lakes and upper awash rivers respectively.

Overall, the spatial variations of the concentrations of Cr, Zn, As, Cu, Cd, Hg, Ni, and Pb in Ethiopia rivers and lakes were more evident as can be seen from figure 1. The levels of the heavy metals Cd, Hg, Ni and Pb in Ethiopia rivers and lakes may have arisen from elevated nutrients due to geologic processes such as atmospheric deposition, rock weathering, and erosion as well as anthropogenic inputs such as urban waste industrial effluents and agricultural activities. However, the reported values are above the permissible limits for most of the heavy metals. A proper be management of source, the extent of the pollution, and mitigation measures have to be carried out seriously to overcome the potential eco-toxicity in Ethiopia water bodies.

Besides, to inorganic heavy metal pollutants, there have been reports that chlorinated pesticides like DDT and its metabolites were also reported to be found in Ethiopia lakes like Hawassa lake and tekeze reservoir [46, 47] beyond permissible limits. Though, the main sources of these organic pollutants in the water bodies are agricultural activities and surface runoffs.

2.3. Biological contaminants

Biological quality of water bodies is one of the major determinants of the water ecosystem functions and diversity of their biota [48]. Microbial pollution of lakes and rivers severely affects their use for domestic, agricultural, and industrial activities. Rivers and lakes can easily get pollution with pathogenic microbial agents from animal feces and sewerage systems discharged such water bodies (Table 4). Several microbial studies conducted in the lakes and rivers of Ethiopia clearly showed the water bodies are contaminated with pathogens of public health concern [35, 49-52].

Table 4. Rivers and lakes in Ethiopia contaminated with microorganisms.

Water Bodies	The sample was taken from	Detected indicator and pathogenic microorganisms	References
Lake Zeway	Surface water and sediments	*Salmonella*, *Shigella*, *Vibrio cholera*, *Vibrio* spp., *Escherichia. coli* O157:H7 (*E. coli*)	[35]
Meki and Quatar River	Surface water and sediments	*Salmonella*, *Shigella*, *Vibrio cholera*, *Vibrio* spp., *E. coli* O157:H7	[35]
Bahir Dar gulf of Lake Tana	Surface water	Total coliforms, fecal coliforms, *E. coli* and *Clostridium perfringens* (*C. perfringes*)	[53]
Lake Tana	Surface water and sediments	*Staphylococcus aureus (S. aureus), E. coli*	[49]
River Awash	Vegetables irrigated with river Awash water	Fecal coliforms	[54]
Tinke and Adella Lakes	Surface water and fishes	Helminthes, *E. coli, Salmonella, Yersinia and Klebsiella*	[51]
Lake Hawassa	Surface water	*E. coli, Klebsiella species, Citrobacter, Proteus species, Shigella , S. aureus , P. aeruginosa*	[52]
Akaki River	Surface water	*Etamoeba histolytica, T. trichuria* *Coliforms*	[55]
Drinking water in Eastern zone Tigrai	Surface water	*Escherichia coli , Legionella species, and Shigella species*	[56]
shankila river	Surface water	*E. coli*	[57]

Besides microbial pollution of water bodies with public health concerns, invasive plant species are major concerns of Ethiopian lakes, One and major biological pollutants to the Ethiopian lakes is water hyacinth (*Eichhornia crassipes*) [53, 58-60]. Water hyacinth is one of the world's most invasive aquatic plants and is known to cause significant ecological and socio-economic effects. Water hyacinth can alter water clarity and decrease phytoplankton production, dissolved oxygen, nitrogen, phosphorous, heavy metals, and concentrations of other contaminants. The effects of water hyacinth on ecological communities appear to be largely nonlinear. The impact of *Eichhornia crassipes* on the physicochemical characteristics of the water, in general, declines in temperature, pH, biological oxygen demand (organic load), and nutrient levels. Water hyacinth has spread throughout Africa causing widespread problems to millions of users of water bodies and water resources [61]. Water hyacinth also affects the amount of fish, affects the water quality, and brings many other side effects. These effects were also evident in Ethiopian lakes mainly in lake Tana and Rift Valley lakes ([58,59]). According to reports by different scholars, the distribution and abundance of water hyacinth increase rapidly in Ethiopian lakes and strongly affect both water quality and intensity of aquatic biodiversity especially in Lake Tana [41,62]. Proper weed management should be incorporated to overcome the potential effect of weed on the fauna and flora of the lake.

Conclusion

This review article aimed to overview the present state of the extent of pollution in the Ethiopia water bodies. The water bodies are overviewed concerning the physical, chemical, and biological water quality attributes. Numerous researches conducted researches on, physic-chemical analysis, heavy metal, pesticide, and biological pollution of different Ethiopia water bodies. Most of the Physico-chemical parameters reported for the lakes and rivers of Ethiopia were also beyond the permissible limit. Moreover, the concentration of heavy metals in these selected rivers and lakes exceeded the permissible concentrations, which penetrate the stream, through straight discharges of municipal, industrial, and mining effluents and natural routes. It may be concluded from the study that the Ethiopia water bodies included in the review contained high amounts of As, Zn, Cr, Cu, Hg, Pb, Cd, and Ni where their concentrations were also beyond the WHO permissible limits. The toxic metals are not only badly affecting water quality but also the human health treats as they can cause severe diseases but also creating an imbalance of the aquatic ecosystem of rivers. They also bio-accumulate and affect many animals in the food chain.

Besides, invasive weeds species like water hyacinth and pesticide pollution are the other major problems for the water bodies of Ethiopia. In general, most of the water bodies of Ethiopia included were heavily polluted. Common threats to water quality will lead to common and interrelated impacts that may be

cyclical and complex. So, proper management of sources of the pollution has to be put in place to sustainably use the waters of Ethiopia. Routine research work with wide public awareness, government participation, and government regulations can save the water of lakes and rivers of Ethiopia from deteriorating water qualities, and thus a safe and sound water environment can be made for future generations.

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