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Evaluating Water Quality of Lower Omo River and the Ethiopian part of Lake Turkana, Southern Ethiopia

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ABSTRACT: The study's surface water bodies, which include the lower Omo River and Lake Turkana in Ethiopia, are the most significant supplies of water for human activities, but they are also severely stressed by environmental factors and are in danger due to human activity. The physicochemical parameters were determined using standard analytical procedures in the Laboratory. The mean BOD_5 values obtained in this study were 16.268± 1.47 mg/l and 16.28 ±1.133 mg/l in the upstream and in the downstream respectively. The COD value was higher in the River(upstream) (mean 376.06 ±130.45mg/L) than in the Lake (downstream) (mean 136.00± 41.52 mg/L).The mean fluoride ion level in the River were 0.89 ±0.0135 while that of the Lake was 2.026±0.064mg/l. The mean concentration of total nitrogen were 8.938±1.327mg/L) and 17.84 ± 4.0083mg/L) in River and Lake respectively .The value for PO_4^{-3} was 1.866 ± 0.625mg/L in the River (LOR) while in Lake (ELT) , the concentration was 5.108±0.975mg/L . Mean concentrations for NH_3 were 0.54 ±0.361and 1.354 ± 0.655 in the river and lake respectively. The finding of Water quality index (WQI) revealed that the water quality status was very poor and unsuitable for drinking in the lower Omo River and Omo Delta. Hence monitoring the effluent standards from the upstream industries, managing the waste disposal system in the towns along the river side are vital to protect the freshwater from further pollution.

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Fresh water is a major issue for humanity because it is directly tied to human interests. Surface water bodies are the primary sources of water for human activities, but miserably, they are suffering from serious. In Ethiopia, river monitoring is not sufficiently extensive to give the data required for managing the quality of the water and sediment (Zinabu *et al*., 2019). The Omo-Turkana Basin extends over a sizable area in southwestern Ethiopia and Northern Kenya (Feibel, 2011; Velpuri *et al*., 2012. The 760 km long river flows south before reaching Lake Turkana in the lowlands at an altitude of 365 meters (CSA, 2017, Wakjira and Getahun, 2017).It typically receives up to 2,000 mm of precipitation per year (FAO, 2003, UNEP, 2010).Recently, the lower Omo basin has experienced a rapid development of industry, urbanization, and intensive agriculture (use of agrochemicals) in its upper stream part which drains in to the delta (UNEP, 2010; Wakjira and Getahun, 2017) have already resulted in changes to the environment of the River delta and the freshwater water chemistry (Ojwang *et al*., 2010; Avery, 2012**).**This could attribute to the pollution of fresh water ecosystem. However, river monitoring in Ethiopia is not far-reaching to endow with information for freshwater quality management (Zinabu *et al*.,

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2019). Hence, this paper aims to evaluate the water quality of the lower Omo River and the Ethiopian part of Lake Turkana, Southern Ethiopia.

MATERIALS AND METHODS

Description of the study area: The lower Omo River (LOR) and the Ethiopian part of Lake Turkan (ELT) are located in south Omo zone, DassenachWoreda in the southern part of Ethiopian rift valley. Within Ethiopia's borders, the Omo-Turkana Basin includes all of the Omo-Gibe River Basin on the lake's northern coast and a portion of the lake's northern end (Feibel, 2011). The lower section of the Omo-Gibe River and the Ethiopian portion of Lake Turkana are both located at a height of less than 400 meters above sea level (Feibel, 2011; Velpuri *et al*., 2012).Hence the surface and subsurface drainage from different industries and runoff from agricultural fields are towards the lower River basin.

Sample collection: Water samples were collected following the standard protocol by APHA (2017).Water samples were taken from the Ethiopian section of Lake Turkana (ELT) and the lower Omo River (LOR). Five sub sampling sites with three sampling points on each water body were taken having a total of 30 sampling points from upstream and downstream and composited to ten. A 2 L plastic vessel was used to collect each sample and it was filled to the brim 30 cm below the water's surface. The vessels were brought to the lab and wrapped firmly for examination (Beniah, 2020).

Sample Analysis: Water samples were collected and analyzed for fifteen (15) physicochemical parameters following the standard methods APHA (2017). Measurements of pH, DO, EC, TDS, temperature and Salinity were taken in situ from the selected sampling sites using a multiprobe water quality meter; multi HQ40d. The following standard methods were used to determine the parameters: hardness was determined by EDTA method;BOD_5 (mg/L) by Dometric method; COD (mg/L) by Open reflex method ; Cl^-(mg/L) by Argentometric method; F^-(mg/l) by SPANDS method; NO_3^{-2} (mg/L) by Phenol Disulphonic acid method; Nitrite using Colorimetric method by spectrophotometer; Ammonia by Nessler method and stannous chloride method were used to determine phosphate ($PO4^{-3}$) contents of the water samples.

Evaluation of water quality status: The Water Quality Index (WQI) was determined using the World Health Organization's (WHO, 2017) recommendations for safe drinking water. The weighted arithmetic water quality index approach classified the water quality according to the degree of purity using the most frequently measured water quality variables. The weighted arithmetic water quality index developed by Brown et al. (1972) was used to calculate the WQI using the following equations.

$$\mathrm{WQI} = \sum \frac{QnWn}{\sum Wn} \qquad (1)$$

Where n is the number of variables or parameters, Qn = Quality Rating

$$\mathrm{Wn} = \frac{\mathrm{K}}{Sn} (2)$$

$$\mathrm{Qn} = \frac{100(Vn - Vio)}{Sn - Vio} \qquad (3)$$

Where: Vn is the observed value for n^{th} water quality parameters of collected samples; Sn = Standard permissible value of the n^{th} water quality parameters; Vio: The n^{th} water quality parameter's ideal value in pure water (all other parameters have ideal values of zero except for pH and DO, which have values of 7 and 14.6, respectively).

According to (Otene and Alfred,2019; Okey*et al*. 2021), the unit weight(Wn) was obtained by calculating a value inversely proportional to the recommended standard value (Sn) of the corresponding parameter and K is the proportionality constant, Standard value for nth parameters is K = 1/(1/Sn), Sn= Standard value for nth parameters.

Data analysis: All data analysis was conducted using the IBM SPSS Statistics Version 25. An independent t- test was used to test the mean difference. A correlation analysis was also used to test the relation among the water quality parameters.

RESULTS AND DISCUSSION

The physical and chemical characteristics of water from lake and river are shown in Table 1.Mean temperatures measured in the sampling sites were within the range of 27.428±0.987 and 28.9± 0.845in the river and Lake respectively. PH values in the River ranged from 7.3 to 7.9 while those of the lake ranged from 8.7 to 8.9.Mean P_H values were7.62 ± 0.259 and 8.78± 0.08 in the River and Lake respectively. The results indicated that the lake water was relatively basic and it was above the permissible limit of Ethiopian standard agency (ESA, 2013) and WHO (2017) for drinking water. The present finding was similar with the study report of Okey *et al*. (2021).Conductivity is generally a very good predictor of total cations and salinity (Zinabu *et al*., 2002).The values of EC ranged from 533 µS/cmto549 µS/cm in the River and from 9580 µS/cm to 1019µS/cm in the

Lake with mean value of 541.4 ±6.19 and 9842.00 ±313.8 respectively. The EC value of this finding in the River water (533 µS/cm) was comparable with the previous study report (575µS/cm)by Maryam and Seyed (2022) from Zarrineh River in Iran. The mean EC value of the current finding both in River and Lake was higher than the study recorded in (Dirisu and Ezenwa, 2018). However, the previous study finding by Okey *et al*.(2021) reported higher mean value of EC(756.98 µS/cm) than the present finding in the River (541.4 µS/cm). The present study finding of the Lake was above the WHO (2017) standard. The higher EC value particularly from lake maybe due to higher salinity, TDS, Mg and Ca content in the Lake. Industrial waste, agricultural runoff and domestic discharges could also contribute to the rise of electrical conductivity in the freshwater (Okey *et al*., 2021). In all samples, turbidity levels were higher than maximum permissible limit set by WHO (2017). The study's River and Lake average turbidity levels were 115.2 and 161.2 NTU, respectively.

The Dissolved Oxygen (DO) in River and Lake was determined to be from 6.08 mg/L to 6.34 mg/L and from 5.22 mg/L to 5.93 mg/L respectively. Mean dissolved oxygen in the River was 6.182± 0. 1031mg/L while that of the Lake was 5.468±0. 2803mg/L.The DO value in this study of both River and Lake was comparable with the previous study report by Dirisu and Ezenwa (2018) from surface water. The DO value of current study both in the River and Lake Water was lower than the previous report (9.19 ±0.99) by Divya *et al*. (2016) from Tamiraparani River but higher than the WHO (2017) permissible limit. The BOD_5 values obtained in this study ranged from 15.2 to 18.8 (mean, 16.268 ± 1.47) mg/L (in the River and from 14.78 to 17.9 mg/L (mean, 16.28 ±1.133 mg/L) in the Lake. The mean BOD5values of the current finding both in River and Lake were higher than the study recorded (3.91mg/L) by Dirisu and Ezenwa (2018) from surface water and (2.43mg/L) by Divya *et al*. (2016) from River. The BOD_5 values recorded in this study both in the River and Lake were above the WHO (2017) permissible limits. The larger value of BOD_5 could attribute to higher degree of organic content in both water bodies .Values for COD were higher in the River (mean 376.06 ±130.45mg/L) than in Lake (mean 136.0 ± 41.52 mg/L). The COD indicates the toxic condition, the presence of biologically resistant organic substances and large amount of oxygen demanding chemicals (Okey *et al*., 2021). Total dissolved solids (TDS) affect freshwater organisms and lessens the solubility of gases like oxygen(Ogundele and Mekuleyi, 2018).The concentration of TDS in this study ranged from 250 to 256mg/L in the River (mean, 252.40 mg/L± 2.302mg/L) and from 504mg/L to 541 (mean, 519.60 ± 19.552mg/L) in the Lake (Table 1**)**. The mean TDS content of the River and Lake of this study was higher than the earlier reports (371.4 mg/L) by Okey*et al*. (2021)from Ogbor River in Aba, Nigeria and 83.45 mg/L by Dirisu and Ezenwa (2018) from surface water. The TDS values obtained in the downstream of this study (lake) was above WHO (2017) standard limits (500 mg/L) for drinking water. This might be complied with higher salinity content in the downstream water. High TDS values in the water body could be attributed to Surface runoffs, weathering of rocks, discharge of domestic waste and incursion of dissolved solutes from agricultural fields (Srivastava *et al*., 2007).

Table 1 physicochemical parameter of River and Lake Water

Parameters	**River water**	**Lake water**	**WHO,2017**	**ESA,2013**		
	Mean	**SD**	**Mean**	**SD**		
Temperature in ^{o}C	28.9	0.86	27.43	0.99	≤15	≤15
PH	7.62	0.26	8.78	0.08	6.5-8.5	6.5-8.5
EC(µS/cm)	541.4	6.19	9842.0	313.88	1000	1500
TDS (mg/l)	252.4	2.30	519.60	19.55	500	1000
DO) (mg/L)	6.18	0.10	5.47	0.28	5	5
BOD_5) (mg/L)	16.27	1.47	16.28	1.13	5	5
Salinity in percent	0.026	0.001	0.54	0.02	-	-
Total alkalinity(TA) in mg/l	92.0	9.08	904.8	101.56	120	200
Mg^{+2} (mg/l) in mg/L	8.64	1.73	10.73	2.01	30	50
Ca^{+2} ion in mg/L	10.20	2.04	11.44	2.32	75	75
Total hardness in mg/l	59.0	7.42	65	14.58	300	300
Cl^- (mg/l)	3.06	1.08	220.12	5.11	150	250
Fluoride ion in mg/L	0.88	0.14	2.03	0.064	1.5	3
Turbidity(NTU)	94.4	5.01	162.4	0.037	5	7
NO_3^- (mg/l)	8.94	1.33	17.84	4.01	50	50
PO_4^{-3} (mg/l)	1.87	0.63	5.11	0.98	**5.5**	0.02
NH_3 (mg/l)	0.54	0.361	1.35	0.66	1.0	-
NO_2^- (mg/l)	1.69	0.97	0.54	0.56	0.1	0.02

Chloride: In the present study, the concentration of chloride ion in the River (LOR) ranged between 2.5 to 4.99 (mean, 3.058±)while that of the Lake(ELT) was from 212.13 to 224.61 mg /L (mean, 220.2± 5.11mg/L).The mean Cl^- content of the River water of this study was lower than the earlier report (5.84 mg/L) by Okey*et al*. (2021). However, the mean Cl^- content of the Lake(220.2± 5.11mg/L) was higher than the preceding reports (23.19 mg/L) by Dirisu and Ezenwa (2018).The result found was below the WHO recommended safe limits (250 mg/L).

Flouride*:*The concentration of fluoride ion in the River varied between0.623 to1.552 mg/L(mean, 0.89 ±0.0135)while that of the Lake was from 1.916 to 2.071mg/L(mean, 2.026±0.064mg/l).Its presence at concentrations below 0.5 mg/L has been associated with dental caries in children, whereas concentrations above 1.5 mg/L have been connected to non-fluorosis disorders such non-dental fluorosis and skeletal fluorosis (Rofhiwa *et al*., 2011).Fluorinated minerals are easily dissolved in an alkaline environment which may account for the lake's high fluoride levels (Feifei *et al*., 2021). This is a typical issue, particularly in the rift valley lakes of East African countries due to geological indicators (Adimasu, 2014; WHO, 2014). This finding was consistent with those study reports by Awomeso *et al*. (2019) in the Nairobi River, where the levels ranged from 2.0 to 3.34 mg/L, and Feifei *et al*. (2021) in China, where the levels were on average 0.6 mg/L. The sources of fluoride in the present study could be a natural weathering of mineral bed rocks and it is also a common problem mainly in the rift valley lake of East African countries due to geological indicator (Adimasu, 2014; WHO,2014).According to the study in Kenya by Avery (2010) on Lake Turkana which is beneath the present study, fluoride concentration was reported as 10 to 11mg/L .Nitrate (NO_3): The concentration of total nitrogen varied between 7.88 and 11.19mg/L in the River(mean, 8.938±1.327mg/L) and from 11.20 to 21.28mg/l (mean, 17.84 ± 4.0083mg/L) in Lake. The finding of the present study was lower than the study report by Oluyemi et al. (2010) which was (36.32 mg/L).However, nitrate concentration of our finding was higher than the previous study report (0.63±1.37) by Dirisu and Ezenwa (2017). The range of NO_2^- readings in the River water was between 0.30 and 2.54 mg/l (mean, 1.69 0.9672) and the range for the Lake water was between 0.17 and 1.48 mg/L (mean, 0.54 mg/l).Phosphate ($PO4^{-3}$): The values for PO_4 were in the limit of 1.31 to 2.84 in River (LOR) (mean 1.866 ±0.625mg/L) while in Lake(ELT) , the concentrations were in the range of 4.09 to 6.22 (mean 5.108±0.975mg/L). This observation is in conformity with the observations by Awomeso *et al*.(2019) in Nairobi River which ranged from 2.0 to 3.34 mg/L. The, values for PO_4^{-3} in the Lake (ELT) of this study were slightly above WHO limit for drinking water. The phosphate value found in this study was consistent with the findings of Okey *et al* (2021). Agricultural chemicals may drain into rivers, increasing phosphate level, or phosphate additions used in detergent may have leached into water bodies through home, industrial, or municipal waste waters (Olajire and Imeokparia, 2001).The intensive agriculture practiced along the river stream may be related to the quantities of nitrates and phosphates found in this study(Wei *et al*., 2019). The nitrate concentration obtained for both water bodies did not exceed the WHO limit (50mg/l). Pollution of the River by the nutrient may be due to the application of fertilizers, domestic effluents, and leachate from refuse dumps and run-off from these sources.TDS and EC have a good association (r = 0.995), indicating that they are both directly proportional to one another. There was also a strong correlation among: EC and Mg ion (r = 0.75); EC and MgH (magnesium hardness) (r = 0.826); pH and MH(r= 0.952); pH and TDS(r= 0.81);EC and salinity(r= 0.997).

Table 2 Statistical analysis on correlation result of River

Parameters	Tem	pH	EC	TDS	TSS	DO	BOD	COD	Salinity	TA	Mg	Ca	Ca.Har	Mg.Har
Tem	1													
PH	0.48	1												
EC in mili/cm	-0.148	-.0896*	1											
TDS in mg/l	-0.090	-0.814	0.951*	1										
TSS in mg//l	-0.177	-0.584	0.404	0.512	1									
DO in mg/l	0.491	0.589	-0.688	-0.70	0.032	1								
BOD in mg/l	-0.112	0.666	-0.840	-0.67	-0.004	0.451	1							
COD in mg/l	-0.498	-0.219	-0.088	-0.36	-0.148	0.170	-0.16	1						
Salinity in %	0.042	-0.410	0.400	0.614	0.890*	-0.103	0.058	-0.58	1					
TA in mg/l	-0.439	0.510	-0.818	-0.83	-0.229	0.395	0.805	0.430	-0.39	1				
Mg in mg/l	-0.093	-0.788	0.751	0.827	0.898*	-0.274	-0.39	-0.24	0.860	-0.61	1			
Ca in mg/l	0.710	0.193	0.000	0.217	0.468	0.364	0.153	-0.77	0.707	-0.41	0.43	1		
Ca.Hardness	0.710	0.193	0.000	0.217	0.468	0.364	0.153	-0.77	0.707	-0.41	0.432	1.000**	1	
Mg.Hardness	-0.486	-0.952*	0.826	0.833	0.764	-0.549	-0.46	0.028	0.645	-0.45	0.895*	0.000	0.000	1

The values for Correlation analysis are represented in (Table 2). Independent t-test showed that there's was significant difference in temperature, COD, NO_2, NH_3 , ($P<0.05$); pH, EC,TDS,TSS, DO, NO_3, PO_4, salinity, alkalinity, Chloride ion, contents between both river and lake at ($P<0.001$). However, no significant difference exists ($P<0.05$) for BOD, Mg ion, Ca ion, Calcium hardness, Magnesium hardness, total hardness and Fluoride ion when values from both areas of upstream and downstream are compared (Table 3).On the basis of WQI scores, five categories have been introduced; WQI = 0-25 "Excellent water quality"; WQI = 26-50 "good water quality"; WQI = 51-75", Poor water quality"; WQI =76-100 ", Very Poor water quality" and WQI > 100 "Unsuitable for drinking. The results revealed that the river water fell into the category of Very Poor water quality. Based on the results of the water quality index calculation, , it was determined that the lower Omo River area around Omorate Town's WQI value was 76.677, which was very poor as it fell within the range of 76 to 100 (Table 4). The Ethiopian portion of Lake Turkana's WQI value was found to be 142.47, which was much beyond the 100-point threshold for very poor water quality and Unsuitable for drinking.

Table 3 Independent T-test

Parameters	Water body	Mean	Std. Deviation	t	Sig
Dissolved oxygen in mg/l	River	6.182	0.103	5.346	0.001
	Lake	5.468	0.280		
Biological oxygen demand in mg/L	River	16.268	1.471	.014	0.989
	Lake	16.28	1.133		
Chemical oxygen demand in mg/L	River	376.06	130.456	3.921	0.004
	Lake	136.0	41.526		
Total alkalinity in mg/L	River	92.00	9.083	-	0.001
	Lake	904.80	101.564	17.824	
Total hardeness in mg/L	River	59.0	7.416	-0.820	0.436
	Lake	65.0	14.57		
Chloride ion in mg/L	River	3.058	1.084	-	0.001
	Lake	220.118	5.11	92.821	
Fluoride ion in mg/L	River	125.358	278.190	0.991	0.378
	Lake	2.026	0.063		
TNO_3mg/L	River	8.93	1.32	-4.716	0.002
	Lake	17.84	4.00836		
TPO_4 mg/L	River	1.86	0.625	-6.255	0.001
	Lake	5.108	0.975		
NH_3 mg/L	River	0.540	0.361	-2.432	0.041
	Lake	1.3540	0.65		
NO_2 mg/L	River	1.690	0.967	2.303	0.050
	Lake	0.540	0.55		

Table 4 Weighted Arithmetic Water Quality Index for River

Parameter	Experimental Value	Standar d values (sn) (WHO,2017)	Unit weights (wn)	Quality rating (Qn)	QnWn
pH	7.62	8.5	0.0672	41.4	2.783
Electrical conductivity(µs)	541.40	1000	0.00057	54.14	0.0031
Total Dissolved Solids (mg/l)	252.40	500	0.0012	50.48	0.0606
Total alkalinity mg/l	92.00	120	0.0048	76.7	0.3682
Total hardness	59.00	200	0.0029	29.5	0.0856
Total suspended solids	502.40	500	0.00115	10.48	0.1264
Calcium mg/l	10.20	200	0.02472	5.1	0.1261
Magnesiummg/l	8.641	200	0.0029	4.32	0.01253
Chlorides mg/l	3.058	250	0.00229	1.23	0.002817
Nitrate mg/l	8.938	50	0.01142	17.876	0.20415
Phosphate(mg/l)	1.866	5.5	0.104	33.93	3.529
Dissolved oxygen (mg/l	6.182	5	0.1142	87.69	10.015
BOD	16.268	5	0.1142	325.36	37.156
Fluoride mg/l	0.8834	1.5	0.381	58.89	22.4371
Ammonia mg/l	0.54	1.0	0.571	54	30.834
Summation (∑)			**∑ Wn= 1.40355**	**Σqn=2739.096**	∑QnWn= 107.62

Conclusions: This research has provided baseline information on the physicochemical parameters of freshwater and the water quality status of lower Omo River basin. The downstream of the freshwater (ELT) was more polluted as compared to the upstream (LOR). The mean contents of DO, BOD, Turbidity, Phosphate, and Nitrite were above the maximum permissible limit set by WHO both in River and Lake water. The WQI showed that the quality of the lower Omo river could be regarded as very poor while the Ethiopian part of Lake Turkana were Unsuitable for drinking and need treatment before use.

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