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THE IMPACT OF URBAN AND RURAL LAND USE TYPES ON WATER QUALITY OF MEKI RIVER IN SODO WEREDA, GURAGE ZONE, SNNPRS, ETHIOPIA

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Abstract: Drinking water deterioration in most parts of Ethiopia is due to poor sanitation, uncontrolled land conversion and related human activities. Meki River is the only perennial river in Sodo district used for various water needs of the locality. Potentially significant impact on the water quality of Meki river due to urban and rural land use activities has not been receiving due attention. This study was aimed to distinguish the impacts of urban and rural land use activities on the surface water quality status of Meki river of Sodo Wereda. The data collection was conducted for three months period from December 2012 to February 2013. Preferred Physico chemical and bacteriological parameter analyses of the river water, collected from the four selected sites were conducted by using standardized laboratory methods to assess the quality of water and extent of pollution. Direct field observation and questionnaire survey were conducted to identify the probable land use activities that have been affecting the water quality in the locality and to know about the community perception on the issue. The study results revealed that the range of physico-chemical parameters including Biochemical oxygen demand (4.50±2.49 to 5.91±2.08 mg/l), Chemical oxygen demand (364.48-107.20 mg/l), Total suspended solids (33.33±12.58 to 204.67±5.03 mg/l), Turbidity (4.60±0.36 to8.97±0.47 NTU), Calcium (34.23±3.89 to 108±6.97mg/l), Phosphate (1.47±1.33 to 7.33±0.46 mg/l) and Nitrates (26.33±2.47 to 61±1.25 mg/l) were above the recommended limits of drinking water quality standards by WHO and Ethiopia. Result of bacterial analyses by MPN also exposed that the Total coli form and Fecal coli form count of Meki River were above WHO and Ethiopian standards for drinking water. Survey and field observation results pointed that the deteriorating water quality of Meki river has an unswerving relation with the urban domestic waste generation in the area and unsustainable agricultural practices in the nearby sites of the river. To sustain the ecological status of the river, effective land use management, proper sanitation and awareness programmes to the stakeholders should be followed.

Key words: Impacts, Land use, Meki River, Physico chemical parameters, Water quality

INTRODUCTION

All human beings require good quality water and sanitation facilities. However developing countries like Ethiopia, have suffered from lack of access to safe drinking water from managed sources and sufficient sanitation services (WHO, 2006). According to Meseret (2012), in Ethiopia majority of people are utilizing unprotected water sources such as rivers, streams, springs, ponds and hand dug wells. Hence, the sources are open; they are highly susceptible to contamination. In addition these sources are found near gullies where open field defecation is common and flood washed wastes affect the quality of water. Ethiopia is one of the countries with worst health status in relation to water quality (WHO, 2005). The causes behind this are the backward socio-economic development and lowest standard of living, poor environmental conditions and low level of social services. Land use and land use management practice affect the quality and quantity of runoff water that affect the quality of river water and biodiversity of aquatic organism in river water (Griffith *et al.,* 2002). Agricultural and Urban land use activities represent a large portion of the land use in the Meki River watershed. Runoff from these lands could have a major impact on the water quality of the River. The study area is situated in the most upstream of Ziway lake which is the principal source of commercial fishing in Ethiopia. Moreover, This River was selected in this study because this river runs

75 km in the Wereda and supplies water for many villages and two towns for drinking, bathing, cloth washing, cattle watering and irrigation purpose particularly during dry season. Thus this study tries to understand the different land use impacts on water quality of Meki River for identifying the suitability of river water for drinking purpose.

MATERIALS AND METHODS

Description of the study area: Sodo Woreda is located between 38p 37' and 13p 16' north longitudes and 38p 44.' and 39p 21' east latitudes. The study area, located in the Southern Nations Nationality and Peoples Regional State (SNNPRS) is possessed with a compact shape and an area of 88,553 km^2 (SWARDO, 2011). The topographic elevation ranges from 3600 -1600 meter above sea level (m.a.s.l). Temperature ranges between 10°C and 24°C. The mean annual rainfall of the wereda ranges between 801 mm and 1200 mm (SWARDO, 2011). It is estimated that about 134,634 people live in the woreda. The Meki River basin, which is part of the Ziway-Shalla basin, is located in the northern part of the Main Ethiopian Rift. The area extends from the Gurage Mountains, where the Meki River originates to the Ziway Lake where the river drains. The total length of Meki River in Sodo wereda is about 75 km. Preliminary survey was conducted in October, 2012 to gather general information on the physical characteristics of the study area such as land use and watershed features. Four sampling sites (MRS 1 - MRS 4) were selected based on the rate of human interference, agricultural and urban activities that have been taking place near the Meki River in Sodo District (Fig. 1). These four sampling points were taken purposively by which such points would confirm to show the relative water quality changes along the river (Table 1).

Questionnaire survey and field observation: To identify the types and status of land uses which contribute to the changes in water quality of the Meki River and perception of local community towards the water quality, questionnaire survey and direct field observation by the researcher were employed. The design of the survey questionnaire was based on Degroot (2006). The data was collected on a house-to-house basis. Moreover, the questionnaires sought to address the types and nature of land use activities, their implications on river body and the status of conservation activities if any. The final version of the questionnaire was translated into Amharic.

Sample size determination: To draw out the data to meet the objectives of the research,

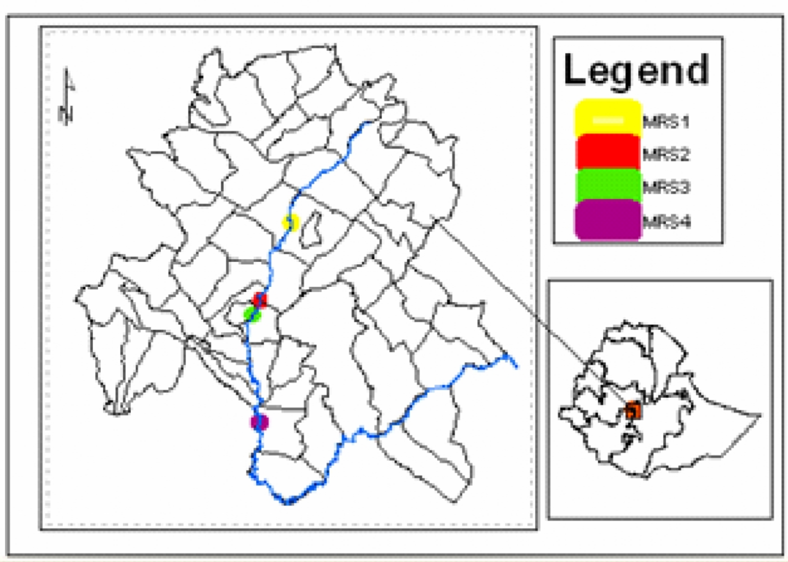

Fig. 1. The location of the study area with sampling sites (EMA, 2005)

Table 1. Morphometric details of the MRS1-4 from Upstream and Downstream

Station	Description	Latitude	Longitude	Elevation
MRS1	Forested, it is located at the upstream of Buee town effluent	$38^{o}32^{1}10^{11}$ & $38^{o}32^{1}12^{11}$	$8^{o}19^{1}46^{11}$ & 8^{o} $19^{1}52^{11}$	1978m
MRS2	Waste water generated by the Buee town and Cattle watering, Seedling production; agricultural runoff enter Meki river. Flour factory , Weldiya irrigation, 4 kilo meter downstream from MRS1	$38^{o}30^{1}36^{11}$ & $38^{o}30^{1}40^{11}$	$8^{o}15^{1}52^{11}$ & $8^{o}16^{1}6^{11}$	1897m
MRS3	Waste matter generated from Kela town and rural villages, Lime factory, agricultural runoff and raw materials of lime factory enter meki river 500 meters from MRS2	$38^{o}30^{1}12^{11}$ & $38^{o}30^{1}15^{11}$	$8^{o}15^{1}15^{11}$ & $8^{o}15^{1}18^{11}$	1886m
MRS4	Irrigation, golden poultry, Gogeti small scale irrigation run off enter Meki River. 8 km down from MRS3	$38^{o}30^{1}26^{11}$ &$38^{o}30^{1}40^{11}$	$8^{o}9^{1}44^{11}$ & $8^{o}9^{1}56^{11}$	1845m

households that lived in dwelling units situated within the Meki River basin were selected. A sample technique by Leslie (2010) was used and from sampling frame of 2718 households, 348 were selected for the data collection.

Water Sampling and parameters analyzed: Water sampling in each sites were conducted by grab sampling techniques. Sampling was done once in a month from December 2012 to February 2013. The study was carried out in the dry season to minimize confounding effects arising from surface runoff contamination of the water body during rain, since flooding might affect the spatial and temporal variation of water quality. Moreover the river water is used by the communities for drinking irrigation and livestock watering and other domestic purpose mainly during the dry season. Temporal variation of physical, chemical and bacteriological parameters of water quality was determined by the current study. The parameters measured were Dissolved oxygen (DO), pH, Temperature, Sodium, Potassium, Nitrates, Phosphate, Conductivity, Turbidity, Total suspended solids, Total dissolved solids, Total Solids, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Carbonate, Bicarbonate, Calcium, Total hardness, Chloride, Total alkalinity, Total coli form and Fecal coli form. Totally 12 water samples in four sampling points of Meki River were collected. Water sampling was conducted according to Hutton field water sampling techniques (Hutton, 1996). Onsite and laboratory analysis of the collected water samples were conducted by standard methods (APHA, 1989). WHO and Ethiopian water quality standards for drinking has been considered for comparison of surface water quality of Meki river of Sodo Wereda.

Statistical analysis and interpretation: The gathered data of physicochemical and bacteriological parameters were tabulated and analyzed using MS Excel and SPSS -15 version. Results of water analyses were compared against standards set by WHO and Federal Democratic Republic of Ethiopia, Ministry of Water Resource drinking water standards. Pearson's correlation analysis was adopted to compare relations between physico-chemical and bacteriological parameters and Analysis of variance (ANOVA) at 5% level of significance was used to compare the quality of water among all sites. The ANOVA table is presented in Table 8.

RESULTS AND DISCUSSION

Field observation and Questionnaire survey: The main land use related activities in the study sites observed by the researcher are shown in Table 1. Plate Number 1-4 confirms the observed and selected land use activities in relation with water quality in the study sites. Among the respondents, 54% were males and 46% were females.

Source of water used by the community: The residents of the river basin could obtain water from different sources, protected and unprotected. The main sources of water supply to the resident of Meki catchment in Sodo District is Meki River. Insufficient pipe water is supplied to residents of the river basin by the Buee water and sanitation service office. The respondents were asked about the source of water for house hold consumption in the catchments and responded that 64% would get water from Meki River (Table 2).This showed that Meki River is the source of water for domestic uses in Sodo Wereda, particularly in dry season. Mesert, (2012) reported that because of scarcity of potable pipe line water in dry season, people are forced to use unprotected river water for various house hold activities.

Status of cleanliness of the study area: Residents were asked about sanitation of the study area (Table 3). From the responses and direct observations by the researcher, it was confirmed that the study area was not clean. The sanitation facilities in the said areas were improper and moreover severe erosion into Meki River was occurring. It could increase the pollution load of the river.

Table 2. Source of water used by the communities

No.	Source of water	Frequency	Percentage
1	Hand pump	25	7.2
2	Natural spring	12	3.4
3	River	226	64.9
4	Pipe line	73	21.0
5	Other source	12	3.4
	Total	348	100.0

Table 3. The sanitation status of the study area

No.	Source of water	Frequency	Percentage
1	Not clean at all	217	62.2
2	Somewhat clean	35	10.1
3	Partially clean	61	17.6
4	Clean	35	10.1
	Total	348	100.0

Land use types in the study catchments: Based on prior land use and water quality studies, certain land uses have been associated with specific contaminants. Land use surveys also allow for a prediction of the risk of a pollutant entering the water (Tong and Chen, 2002). Based on this fact urban and rural land use data in selected sites of Meki River were collected by the researcher through administered questionnaires to the respondents in the locality. The identified land use types in the study sites are presented in Table 4. The study areas were not highly developed and industrialized; the major source of pollution was non point pollution (NP). NP sources of pollution generally consists of sediment, nutrients, organic and toxic pollutants originates from more diffuse pollution sources such as agriculture, urban storm water runoff or other land-uses (Davis and Hirji, 2003). Although NP source pollutants tend to occur in lower concentrations than point source pollutants, the environmental impact they cause can also be severe (EPA, 2002). Likewise urban and rural land use types may have an impact on Meki River water through non-point pollution. 114 (32.9%) of the respondents agreed the presence of the stated land use types in the study area. Land use conversion due to human activities might be in connection with some of the higher concentration of physico-chemical and bacteriological parameters in Meki River.

Soil erosion status, reasons and management practices: The respondents were asked to give information about the extent of erosion on their farm land and causes and measurement taken to prevent its impacts (Table 5). 213 (61.4%) responded high, 35 (10.1%) responded medium and 99 (28.5%) responded low rate of soil erosion in their farms. 120 (34.5%) respondents revealed the cause as deforestation, 39 (11.2%) agreed with plowing as the main cause, 127 (36.5%) commented sloppy area as the prime reason, 58 (16.7%) agreed with high rain fall and 4 (1.1%) in confirmation with other factors. From table 5 it was very clear that 192 (55.2%) of the respondents did not take any land management measures to protect their farm from erosion. This revealed that the farm land in the catchment was highly exposed to erosion due to land conversion by human activities and had direct impact on the alteration of water quality of Meki River.

Table 4. The land use practices identified in the study area

No	Land use practices identified in the locality	Frequency	Valid Percent
1	Irrigation	28	8.1
2	Agriculture	39	11.2
3	Forested	24	6.9
4	Residential	26	7.5
5	Market	18	5.2
6	Lime factory	32	9.2
7	Poultry production	27	7.8
8	Feed lots	16	4.6
9	Road and bridge	14	4.0
10	Traditional tannery	9	2.6
11	All of the above mentioned land use type	115	32.9
	Total	348	100.0

Table 5. Soil erosion status, reasons and management in the study area

Severity of erosion	Frequency	Percentage
High	213	61.4
Medium	35	10.1
Low	99	28.5
Total	347	100.0
The main reason for soil erosion		
Deforestation	120	34.5
Repeated plowing	39	11.2
Steep slopes	127	36.5
High rain fall	58	16.7
Other	4	1.1
Total	348	100.0
Measure taken to prevent soil erosion		
Terraces	41	11.8
Stone and soil bunds	20	5.7
Check dams	95	27.3
No measures taken	192	55.2
Total	348	100.0

Garbage disposal methods by households: Both urban and rural respondents in the locality were disposing garbage unscientifically in different places, which are hazardous for human health and environmental quality (Fig. 2). Majority of households 207 (59.7%), dispose waste materials in to open spaces.The garbage disposal means of the respondents were not safe and protected as a result it might be leaching directly to Meki River. Wastewater should be properly treated before discharging into river and maintaining sanctity of the river. The sewage either seeps into the soils or pollutes ground water or it flows through streams, rivers and pollutes surface water. The main causes of disposing refuse in unprotected open space was lack of proper disposing place particularly in urban place of Buee and Kela.

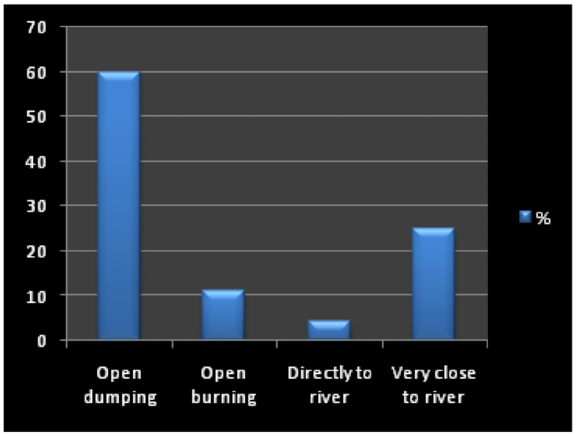

Fig. 2. Garbage disposal methods by the respondents

Sanitation facility: Among the respondents 78.7 % (274) had no latrine house and only 21.3 % (74) had their own toilet for execration (Table 6). This revealed that most of the residents in the catchment area did not have their own toilet. According to the respondents, the main reason for not having toilet were lack of space 93 (26.7%), shortage of fund 180 (51.7%), lack of awareness about the importance of latrine 71 (20.4%) and 4 (1.1%) other reasons, respectively. This study clearly showed that the majority of the communities in the catchments of Meki River was practicing open defecation. It was carried into the river by runoff and increases the pollutant load of the river and impaired the water quality.

Results of Physico chemical and bacteriological analysis

Table 7 shows the comparison of the studied water quality parameters (Mean ± SD) with WHO and EDWS water quality standards in dry months and Table 8 shows the results of ANOVA.

Table 6. Sanitation facilities in the locality

No.	esponse to sanitation facilities	Frequency	Percentage
1.	**Latrine facility**		
	Yes	74	21.3
	No	274	78.7
	Total	348	100.0
2.	**Reason for not having latrine**		
	Lack of space	93	26.7
	Shortage of fund	180	51.7
	Perception problem	71	20.4
	other	4	1.1
	Total	348	100.0
3.	**The place where communities defecate**		
	Public toilet	26	7.5
	Open field	220	63.2
	Own toilet	77	22.1
	other	25	7.2
	Total	348	100.0
4.	**Place of bath and cloth wash during dry seasons**		
	In Meki river	214	61.5
	Ponds	26	7.5
	Water from hand pump	27	7.8
	Pipeline water	80	23.0
	Spring water	1	.3
	Total	348	100.0
5.	**Use of more quantity of soap for washing**		
	Wet season	83	23.9
	Dry season	265	76.1
	Total	348	100.0

pH: The principal component regulating ion pH in natural waters is the carbonate, which comprises CO_2, CO_3 and HCO_3 (APHA, 1995). The pH values of Meki River were alkaline in all the three study sites and MRS1 was slightly acidic. One way ANOVA revealed there was significant difference in pH value in sampling sites. The mean standard deviation pH value at MRS3 (7.84±0.99) and MRS4 (8.11±0.27) significantly differed from MRS2 and MRS1. While pH value at MRS2 was greater than MRS1. The highest value of pH in MRS3 and MRS4 were probably due to domestic waste, lime stone and lime factory at the vicinity of the river. The value of pH in all four sites was within safe limit of drinking water quality as prescribed in WHO and EDWS (6.5-8.5). According to Tamiru *et al.* (2005) the pH value of Little Akaki River in Addis Ababa and that o f Beressa River in Deberberhan also showed parallel pH range with Meki river, because of the similarities of the land use activities in the localities.

BOD: Unpolluted, natural waters have a BOD of 5 mg/l or less. BOD directly affects the amount of dissolved oxygen in rivers and streams. The analytical value of BOD in Meki River ranged between 5.91±2.08 mg/l and 4.50±2.49 mg/l (Table 7). The overall average of BOD value in the three months of study was 5.32±1.88 mg/l. This indicated that the BOD value of Meki River falls above the recommended value of Ethiopia drinking water quality standard and WHO drinking water guideline (5 mg/l). ANOVA test showed that there was no significant difference in the value of BOD at the different study sites. The average BOD value of MRS1 was 4.50±2.49 mg/l which was lower than the other sites. This might be due to less human activities and organic pollutants at this particular site. MRS4 site had relatively high amount of BOD (5.91±2.08 mg/l), these could be due to urban and rural domestic waste and cattle watering at this sites. Biochemical oxygen demand (BOD) has been found to show significant positive correlation with COD, and had negative correlation with DO.

Chemical Oxygen Demand (COD): COD is an indicator of organic pollution and other chemical contamination in water (Faith, 2006). The maximum value of COD was 364.4±2.4 mg/L and the minimum value was 107.2±4 mg/L. The value of COD in all sites were extremely high

Table 7. Mean ± Standard deviation of water quality along with WHO & EDWS standard

Parameters	Units	MRS1	MRS2	MRS3	MRS4	WHO	EDWS
P^H	P^H unit	6.91±0.17	7.23±0.28	7.84±0.99	8.11±0.27	6.5-8.5	6.5-8.5
BOD	mg/l	4.50±2.49	5.82±1.64	5.05±2.03	5.91±2.08	0.8-5	5
COD	mg/L	128.64±4.2	364.48±2.4	107.20±4	128.64±2	<10	
DO	mg/L	10.16±1.20	4.87±0.59	7.47±1.80	5.47±1.16	7-14	
Temp	°C	19.40±0.44	24.60±1.39	24.90±0.78	24.50±1.3	30-35	-
EC	µS/cm	386.57±64.19	524±56.43	734.90±31.17	540.63±165	1000	
TDS	mg/L	207.10±5.03	328.53±5.68	361.90±9.55	368±7.19	600-1000	1000
TSS	mg/L	33.33±12.58	204.67±5.03	84.33±21.12	75±8.66	20	50
TS	mg/L	240.43±17.40	533.20±2.71	448.80±13.83	452.57±5.87	500	
Cl	mg/L	1.16±0.57	3.21±1.56	5.30±1.15	6.36±1.26	250	250
Ca	mg/L	34.23±3.89	53.07±2.57	108±6.97	108±4.50	75	75
TH	mg/L	170.67±73.93	260±4.0	461.33±78.14	486.67±42.06	300-500	392
TA	mg/L	259.33±9.02	250.67±10.07	328.67±18.90	318±27.50	120	200
CO_3	mg/L	191.77±9.76	206.17±55.16	247.23±16.28	219.03±28.25	N.S	
HCO_3	mg/L	20.40±1.04	19.10±0.98	26.77±1.72	26.17±2.65	N.S	
Turb	NTU	4.60±0.36	8.97±0.46	8.97±0.47	7.4±2.55	5	5
NO_3	mg/L	26.33±2.47	61±1.25	53.73±7.07	48.53±12.60	50	50
PO_4	mg/L	1.47±1.33	7.13±0.64	7.27±0.31	7.33±0.46	0.1-5	
Na	mg/L	87.33±1.15	93.33±1.15	97.33±1.15	94.67±1.15	200	
K	mg/L	6.47±1.36	7.10±1.34	7.57±0.96	7.80±0.35	20	
TC	MPN/100	330±329	18666±4618	2433±2289	12666±15044	10	0
FC	MPN/100	166±204	10333±2309	1340±1786.28	8000±12144	0	0

Table 8. ANOVA of physicochemical and bacteriological parameters in the four sites of Meki river

	Between group df=3				***Within group df=8***		***Total df=11***
	Sum of Sq.	**Mean sq**	**F**	**Sign**	**Sum sq**	**Mean Square**	
PH	2.721	.907	22.747	.000	.319	.040	3.039
BOD	4.045	1.348	.311	.817	34.636	4.329	38.681
COD	44588.339	14862.780	.	.	.000	14862.780	44588.339
DO	51.316	17.105	10.711	.004	12.776	1.597	64.092
Temp	62.670	20.890	18.905	.001	8.840	1.105	71.510
EC	184841.689	61613.896	6.942	.013	71004.433	8875.554	255846.122
TDS	50479.550	16826.517	335.518	.000	401.207	50.151	50880.757
TSS	48804.667	16268.222	92.302	.000	1410.000	176.250	50214.667
TS	140826.617	46942.206	350.526	.000	1071.353	133.919	141897.970
Cl	47.847	15.949	11.267	.003	11.324	1.416	59.172
Ca	201623.110	67207.703	36.264	.000	14826.515	1853.314	216449.625
TH	12954.809	4318.270	181.180	.000	190.673	23.834	13145.483
TA	14291.667	4763.889	14.703	.001	2592.000	324.000	16883.667
CO3	5005.983	1668.661	1.589	.267	8401.047	1050.131	13407.030
HCO3	138.416	46.139	15.333	.001	24.073	3.009	162.489
Turbidity	38.163	12.721	7.190	.012	14.153	1.769	52.317
NO3	2010.480	670.160	12.394	.002	432.560	54.070	2443.040
PO4	75.173	25.058	40.200	.000	4.987	.623	80.160
Na	161.000	53.667	40.250	.000	10.667	1.333	171.667
K	3.113	1.038	.882	.490	9.413	1.177	12.527
Tcoli	672819691.667	224273230.55	3.546	.068	50603660	63254575.000	1178856291.667
FColi	222584266.667	74194755.55	1.902	.208	312111733.333	39013966.667	534696000.000

and above the WHO, drinking water standard (<10 mg/L). The high value of COD was may be due to rain during sampling date and the extremely high value was noted in MRS2 in which urban and rural land effluent discharged into the sampling sites by runoff increased the concentration of oxygen demanding pollutants. Correlation analysis showed that there was a significant positive correlation of COD with BOD, TSS, and had significant negative correlation with total alkalinity, carbonate and bicarbonate.

Dissolved Oxygen: DO value at MRS1, MRS3 were agree with standards of WHO, 2004 (7-14 mg/L) and at MRS2 and MRS4, the values were less than the minimum required for the drinking waters such as 4.87 mg/l and 5.47 mg/l respectively. ANOVA showed there was significant variation of dissolved oxygen between sites. DO measure the degree of pollution by organic matter, the level of temperature as well as the self purification capacity of the water body. The lower value of DO at MRS2 and MRS4 might be due to the microbial activities in these two sites where oxygen was consumed by bacteria in order to degrade the organic pollutant load. The areas were clear with lack of vegetation, but surrounded by degraded land and gullies. Open gullies are used as a place for open defecation in the vicinity. Mixing of irrigation water and urban waste from Kella and Buee towns were also common in the locality. The mean DO value of Meki River was 6.99 ± 2.41 mg/l, which was nearly within the permissible range of WHO guide line but shows threat for aquatic organism. Pearson correlation statistical analysis showed that DO had significant negative correlation with TDS, Turbidity, NO_3, Na and showed strong inverse relationship with temperature (r= 0.781), and TSS (r= 0.856).

Temperature: The temperature of the water has an influence on chemical and biological characteristics of water. The rate of chemical and biological reaction varies with temperature. Water quality varies with temperature due to the fact that different species survive in different temperature ranges. The reason for comparatively low temperature at site MRS1 could be the high altitude. The higher temperature value at the rest of the sites was probably due to different land use practices (deforestation, agriculture, waste disposal, grazing) at the vicinity of the river. The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (Ahipathi and Puttaiah, 2006).

Conductivity: The high value of electrical conductivity at MRS2 was in relation to the release of urban waste of Buee into Meki River at this site. The results of the electrical conductivity value in all sites of Meki River falls within the recommended value of WHO and Ethiopian drinking water quality standards.

Total dissolved solids: The TDS analysis results indicated that the TDS value along Meki river shows spatial and temporal variability. It was lowest in MRS1 (207.10±5.03 mg/l) and increasing trend from upstream to downstream and maximum value with MRS4 (368±7.19 mg/l), like that of electrical conductivity of water due to different land use impact in the catchments. Kataria *et al.* (1996) reported that increase in value of TDS indicated pollution by extraneous sources. The average total dissolved solids of Meki River (316.38 ±68.01 mg/l) agreed with WHO and EDWS standards *i.e.,* 500 mg/l.

Total suspended solids (TSS): The value of TSS at MRS2 (204.67±5.03 mg/l) was extremely higher compared to the other three sites. This might be due to impacts of different unsustainable land use type existing in the area including deforestation, presence of bare gullies and the site was pressured by cattle watering and wind erosion. Generally, TSS in Meki River was above WHO and EDWS standards. MRS1 was less disturbed due to less human interference and surrounded by plants. Soil erosion is commonly considered a diffuse source of water pollution because it can occurs throughout the catchment of a watercourse, although stream bank erosion is a major contributor. The degree of erosion depends on the soil type, topography, intensity of rainfall, the land use, and management practices adopted. The TSS value which is above WHO and EDWS ultimately has an effect on other qualities of drinking water like taste, odor, hardness and corrosion (Chapman, 1996). This focused that the water was polluted and should not use for drinking and domestic purposes without prior and proper treatments. The Pearson's correlation analysis shows that TSS has a strong positive correlation (r= 0.810) with TS and had negative significant correlation with DO (r=-0.737).

Turbidity: Turbidity in Meki River water sample varied 4.60±0.36 NTU at MRS1 to 8.97±0.47 NTU in MRS3. The average value of turbidity in Meki River of Sodo district was 7.48±2.18 NTU which was above the desirable limits of WHO and EDWS standards. But MRS1 was fall within the standard limits. The ANOVA indicted that there was significant variation of turbidity between sites. The mean turbidity value of MRS1 (4.60±0.36 NTU) was less than the downstream sites of the river. Similar trends of high turbidity value in down streams of Awash River due to wind and water erosion observed and reported by Bedelu (2005). Turbidity can also rise sharply during dry weather if earth-disturbing activities are occurring in or near a stream without erosion control practices (APHA, 1992).

Chloride: Chloride is one of the important anions which determine the salinity of water. The average value of chloride (4±2.32 mg/l) in Meki River was within the permissible limit for drinking water agreed by WHO and EDWS. The trend of chloride concentration showed an increase from upstream to downstream due to increasing different land use and urban and rural domestic wastes. The high value of chloride at MRS3 and MRS4 is due to animal urine during watering and urine and waste matter of human entered at these sites during rainy season by runoff. Chlorides are troublesome in irrigation water and also harmful to aquatic life if it exceeds the allowable standards (Rajkumar, 2004).

Total hardness: Hardness is caused by multivalent metallic cations and with certain anions present in the water. Lehr (1980) reported five types of hard water such as soft, slightly hard, moderately hard, hard and very hard based on the quantity of $CaCO_3$/liter of water.

The analytical result of total hardness of Meki River indicated that the mean range varied from 170 ±73.93 mg/l at MRS1 to 486.67±42.06 mg/l at MRS4. The high value of hardness at MRS3 and MRS4 were in association with the lime factory waste and its raw materials and urban waste in the vicinity of these sites. The average value of total hardness for all sites was 344.67±142.82 mg/l. This result was probably due to addition of calcium and magnesium and decrease water volume by evaporation. Hujare (2008) reported total hardness was high during dry season than rainy season. However, the results falls within the permissible limits for drinking water of WHO (500 mg/L) and EDWS (392 mg/L).

Total alkalinity: The average value of TA in Meki River was 289.17±39.18 mg/l. Total alkalinity observed in the present study in all sites was above the agreed standards of WHO and EDWS for drinking water (120 mg/L). ANOVA results showed that there was a significant difference in total alkalinity between the sites. The more alkalinity value at the water sample taken at MRS3 and MRS4 could be due to soap, detergent for washing cloth, the lime factory and urban waste mixing to the river water, the discharge of domestic waste from Kella town and/or the run off limestone containing soils to the river in these sites. The slight alkalinity could possibly from calcium bedrock weathering or may reflect the importance of dissolution of limestone and dolomites in the watershed and it is in confirmation of an earlier study of Melaku *et al.* (2007) on Tinishu Akaki River. The Pearson's correlation analysis showed as the total alkalinity of Meki River water had a positive significance correlation with pH, EC,TDS, Cl, Ca, Na, and had strong positive correlation with TH (r= 0.903) and HCO_3(r= 0.994).

Calcium: The average laboratory analysis value of calcium concentration of Meki river of Sodo district ranges between 34.23±3.89mg/l at MRS1to 108 ±6.97 mg/l at MRS3, and the mean value of calcium was 75.83±34.57mg/l which was above the allowable standard by WHO and EDWS (75 mg/L) guide line for drinking water standards. Statistical analysis of ANOVA revealed that the mean value of calcium at MRS3 and MRS4 was higher than MRS1 and MRS2. The low value at MRS1 might be due to less human interference at this site and the higher value at MRS3 and MRS4 are in relation with increased rate of evaporation, presence of the lime factory waste and urban domestic waste mix with these sites. Ermias (2007) reported that the mean calcium value of Beressa River ranges between 24.38 mg/l to 47.5 mg/l, which is very low as compared to Meki River calcium levels. The Pearson's correlation analysis showed a significant positive correlation of Calcium content with Temperature, EC, TS, TA, HCO_3, PO_4, Na and had strong positive correlation with P^H(r=0.936), TDS (r=0.902), TH (r=0.971) and Cl (r=0.930).

Carbonate and Bicarbonate: The carbonate concentration of the river was very high while the bicarbonate level of the water sample was low. ANOVA of carbonate concentration showed that there was no significant difference ($P<0.05$) among the four sites. The mean concentration of carbonate value from upstream site to downstream sites showed an increase. This increasing level of carbonate has a relation with the lime factory waste and urban waste mix with the river water in the downstream sites. Carbonate showed significant positive correlation with, Na, and K ($P< 0.05$).

The bicarbonate concentration of Meki River was low as compared to carbonate concentration. ANOVA of bicarbonate concentration among all sites showed a significant difference ($P<0.05$). Both carbonate and bicarbonate value of downstream was higher compared to upstream site, showing a strong relation with the lime factory at the vicinity of the river around Kella Town. The value of bicarbonate was low while carbonate of Meki River were high opposite to that of Beressa River. In Beressa River the carbonate was very less and bicarbonate (109 mg/l to 172 mg) were high (Ermias, 2007).The bicarbonate concentration of the river water had significant positive correlation with, pH, EC, TDS, Cl, Ca, Na ($P<0.05$) and had strong positive correlation with ($P<0.001$) TH (r= 0.899) and TA(r=0.994).

Nitrates**:** The concentration of nitrate (NO_3) in Meki River water of Sodo District ranges from 26.3±2.47 mg/L at MRS1 to 61 mg/Lat MRS2. The NO_3 were high at MRS2, MRS3 and MRS4. ANOVA showed similarity of nitrate concentration between MRS2, MRS3 and MRS4 sites and were extremely higher compared to MRS1. Increased nitrate concentration of three sites could be due to the leaching of fertilizers from agricultural fields and rural and urban domestic wastes from the nearby towns. The levels of nitrate at MRS2, MRS3, MRS4 were above the recommended level of WHO *i.e.,* 45 mg/L and the nitrate value at MRS2 and MRS3 were above 50mg/L of EDWS. Akan *et al.* (2010) reported that high concentration of nitrates in water bodies can cause eutrophication problem and the consumption of that water for drinking can create methaemoglobinemia in human beings. The study results indicated the urgent need of treatment of Meki River water because the concentration of nitrate in the downstream sites were above the standards. The nitrate concentration of Meki River in dry months were below the mean concentration of nitrate (189±319 mg/l) in little Akaki River (Ferezer, 2012). Paired correlation analysis of nitrate showed significant positive correlation with Temp, EC, TDS, TSS, TS, Turbidity, PO_4, and Na ($P<0.05$). It had a significant negative correlation with DO (r=-0.777).

Phosphate (PO4): Phosphate determinations are important in assessing the potential biological productivity of surface waters. Increasing concentration of phosphorus and nitrogen compounds in river water leads to eutrophication and associated effects. The current study showed the mean phosphate range value of 1.45±.05 mg/l at MRS1 site to 7.33±0.12 mg/l at MRS2 site. Downstream sites showed a higher phosphate concentration compared with the upstream site and the downstream site results were above the WHO drinking water standard for phosphate (5 mg/l). ANOVA of phosphate showed there were significant difference among all the sites ($P<0.05$). The high value of phosphate at three sites could be due to the disposal of phosphate from domestic waste, intensive rearing of live stock near the river, uses of soap and detergent for washing clothes in dry season and the use of phosphate containing fertilizers around river banks. The lower value of phosphate at MRS1 was due to less human interference in that site. The study results showed that the phosphate concentration at MRS1site only fulfills the WHO standard of drinking water. Tamiru *et al.* (2005) reported the severity of phosphate contamination in Addis Ababa Rivers in relation with the land use practices and human interferences in the banks of the rivers. Roy *et al.* (2003) also found nitrogen and phosphorus-containing compounds to be positively correlated with the percentage of urban areas in the sites, similar to the trends in the current study.

Sodium: ANOVA results showed that the concentration of sodium at MRS3 (97.33±1.15 mg l) showed higher concentration in contrast to MRS1 (87.33±1.15 mg/l), MRS4 (94.67±1.15 mg/l) and MRS2 (93.33±1.15 mg/l). This could be due to washing and bathing using soaps and detergents directly in river water. The mean value of sodium was 93.45±10.24 mg/l, which showed that the values are within the permissible limits of WHO (2000) and EDWS standards for drinking water. Sodium showed significant positive correlation with pH, Temp, EC, TS, Cl, Ca, TH, TA, CO_3, HCO3, Turbidity, NO_3, PO_4, and TDS and had significant negative correlation with dissolved oxygen. Ermias, (2007) reported the analysis results of sodium in Beressa river water in association with the human activities and it was lower compared to Meki river.

Potassium: Though found in small quantities (<20mg/L) Potassium plays a vital role in the metabolism (WHO, 2004). The analysis results of potassium ranges from 6.47±1.36 mg/l at MRS1 to 7.80±0.35 mg/l at MRS4. The mean value of sodium and potassium was 7.23±1.07 mg/l, which showed that the values are within the permissible limits of WHO (20 mg/l). ANOVA results showed that the concentration of Potassium in all sites were similar. The level of potassium in Meki River showed a significant positive correlation with, pH, CO_3, PO_4, and had no significant negative correlation with mentioned parameters. Meki River showed similar value of potassium with that of Beressa River (Ermias, 2007).

Total coli form and fecal coli form: The Most Probable Number- multiple tube technique was used for coliform details. Bacteria are normally present in water, but it is the species and concentration of bacteria represents the quality of that water for potential uses. Some bacteria cause intestinal diseases associated with drinking water. ANOVA results of the current study of total coli forms showed a significant difference of total coli form among the four sampling sites. The mean value of total coli form at MRS4 and MRS2 were higher than MRS3 and MRS1.The range of fecal coli form varied from 166.67±204.29 MPN/100 ml at MRS1 to 10333.33±2309.40 MPN/100 ml at MRS2 and the high population of bacteria (coli form) in the mentioned sites could be associated with the discharge of domestic waste containing fecal matter into the river, domestic animals urination and defecation while watering and open defecation by people along the sides of river banks and gullies nearby.

The ratio of fecal coliform to total coli form was 49.9%, which indicated that the source of Meki River pollution in respect to bacteria were fecal matter of warm blooded animals and non fecal coli form from the soil. The presence of fecal coliform bacteria in a river indicates the presence of human or animal excreta. The high coliform count obtained in the samples may be an indication that the water sources are fecally contaminated (EPA, 2003). All the analyzed samples show contaminated status for drinking water which is above the permissible limits by WHO and EDWS standards and use of river water for drinking purpose must be avoided without pretreatment. The WHO and Ethiopian drinking water guidelines require the absence of total coliform in public drinking water supplies**.** Pearson's analysis of total coli form count of Meki river in Sodo district showed a significant positive correlation with TSS, TS, and had a strong positive correlation with fecal coliform (r= 0.979) and had no significant negative correlation. Whereas fecal coliform showed significantly strong positive correlation with total coli form (r = 0.979). The results of Total coli form and fecal coli form of Meki River was similar with that of Yubdo –Legebatu River, East Shoa, with contamination level of total coliform 1447.47 /100 ml and the lowest 193.8 coli form/100 ml (Birhanu, 2008).

CONCLUSIONS

The water of the Meki River was subjected to physical, chemical and bacteriological analysis. The results showed that Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, Turbidity, Calcium, Nitrates, Phosphate and Total alkalinity of the river water was above the permissible limits by WHO drinking water standards as well as Ethiopian drinking water standard guidelines. The physical and chemical properties like pH, temperature, Dissolved Oxygen, Electrical Conductivity, Total Dissolved Solids, Total Solids, Chlorine, Sodium, Potassium, Total Hardness of Meki River water were within the desirable limits of WHO and Ethiopian drinking water standard guidelines. Total coli form and fecal coli forms were alarmingly high in the tested water of Meki River. The results of this study revealed that the water quality of Meki River and its biological systems were adversely affected and impaired due to various land use activities by humans. The current study exposed that the main source of water pollution in Meki River was the different land use activities in urban and rural areas of the river basin. There is a perception which is in agreement with field observation and secondary data that the main contributors of water pollution were; discharge of lime factory wastes, domestic wastes, grazing at the river banks, poultry farm wastes, roads and bridge across river, floor factory, regular livestock watering, market waste, traditional tannery and poor land management practices and poor sanitation. Despite the above scenario, the people of Sodo Wereda extensively use the water of Meki River for various purposes such as cattle watering, washing, bathing, irrigation and drinking particularly in dry season. The study revealed that the Meki River water is not in a position for direct use of drinking. Proper pretreatment of the river water should be necessary for drinking purpose. The study pointed out the need for proper planning and implementation of different pollution mitigation measures by the authorities for improvement of the river water quality.

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