Assessment of Industrial Effluent Pollution on Borkena River, Kombolcha, Ethiopia

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Abstract. In this study the effect of untreated and partially treated industrial wastewater on Borkena River was assessed. Six sampling sites were chosen spatially along the tributary of Borekena River and the River itself. The results indicated significant water quality deterioration, which characterized by Temperature, TSS, TDS, DO, BOD_5, COD and Phosphate with the mean concentration range from 45.27 ± 6.0 to 302.00 ± 10.56 °C, 571.67 ± 94.34 to 1633.33 ± 175.46, 450.00 ± 30 to 2422.33 ± 431.2, 6.40 ± 0.61 to 2.77 ± 0.35, 10 ± 0.50 to 190 ± 1.01, 34 ± 3.00 to 508 ± 4.00 and 12.93 ± 4.41_329.33 ± 43.03 mg/L respectively. The magnitude of these values were found above the permissible limits of ambient surface water quality stated by Ethiopia Environmental Protection Authority at all sampling sites, except upstream of Borkena River (SP_6). Significant increment of these parameters was evidenced at the downstream (SP_5) in comparison with the upstream (SP_6) of Borkena river ($P < 0.05$). The mean concentration of pH, EC, Sulphate, and Nitrate nitrogen were ranged from 6.84 ± 0.35 to 9.75 ± 0.43, 0.92 ± 0.27 to 9.07 ± 0.43, 7 ± 5.20 to 59.67 ± 11.52 and 3.57 ± 0.16 to 28.68 ± 4.91 mg/L were found under the permissible limits, except pH at sampling point 1 and 3. It was therefore concluded that Huaxu textile and BGI-brewery industry's effluents are polluted, from which Huaxu textile industry's effluent was contributed more for Borkena River contamination.

Keywords: Borkena River · Untreated wastewater · Partially treated wastewater

1 Introduction

Population growth, urbanization, and industrialization are adversely affect the quality of most of surface water globally (Walakira and Okot-okumu 2011; Owa 2013). This is due to extensive anthropogenic inputs of nutrients and sediments through unmonitored disposal of municipal-, institutional- and industrial solid and liquid wastes (Annalakshmi and Amsath 2012; Tessema et al. 2014). Rivers crossing urban and peri-urban areas of the developing countries are become the most polluted water source, since they are the

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formal and informal disposal sites of Treated, Partially-treated and Untreated municipal and industrial wastewater (Bernard 2010; Suthar et al. 2010; Ljee 2011). As the result, the rivers and streams are highly polluted and hardly satisfy environmental demands for aquatic life. Studies also show that people lives near to polluted rivers, which carrier toxic chemicals and pathogens are exposed to acute and chronic diseases.

Physicochemical water quality monitoring is essential to characterize the quality of the rivers/streams with time and space. It also helps to identify the point and source of contamination.

In Ethiopia, Most of Industries are located near to rivers/streams in order to easily dispose their untreated and partially treated wastewater in to them. Likewise, Loyal and Workie streams are receiving untreated industrial wastewater from Huaxu textile and BGI-brewery industries and municipal wastewater from surrounding community from Kombolcha town. These streams tribute in to Borekena river that is used for cleaning, construction of buildings, irrigation of vegetables, swimming by children, drinking by animals and birds. Currently people living in near and downstream of the industries disposal points are facing many health related problems such as asthma, bronchial disease, dysentery, cholera, typhus, skin ulcer and chronic disease. So it is necessary to evaluate the extent of pollution on the streams and Borkena river in order to discover the effect of untreated and partially treated wastewater. Therefore, this study is aimed to assess the quality of Huaxu textile's and BGI-brewery's wastewater effluent, sewage from the surrounding community and receiving water bodies and to assess the pollution magnitude with respect to the national wastewater discharge standards.

2 Methods and Material

2.1 Study Area Description

Kombolcha town is one of the industrial towns of Amhara region. It is situated 24 km of south-west of Dessie town and 380 km north of Addis Ababa, the capital city of Ethiopia. Kombolcha town is geographically located in the latitude of 11°5′ N and longitude of 39°44′ E with an elevation ranges from 1842 masl to 1945 masl. The average annual temperature is 23 °C. Borekena river crosses the town from east to west directions. Most of the industries are located very closely to the center of the town and along the streams and Borekena river. Untreated and partially treated industrial and domestic wastewater is discharged in to Borkena river through its tributaries: Workie and Loyal streams.

2.2 Data Collection

Sampling points and sampling time are selected by surveying the location where and when Industrial and domestic wastewaters are discharged to the streams and where the streams join the river. In addition, upstream and downstream of the Borkena River was sampled to evaluate the water quality variation before and after wastewaters are discharged, respectively. Based on these criteria, Six (6) sampling locations are selected on the streams and the river. Sample point 1 (SP_1) at the outlet canal of Huaxu textile industry's untreated wastewater; Sample point 2 (SP_2) is at the point where Huaxu

textile wastewater joined Loyal stream; Sample point 3 (SP_3) is at the point just before the loyal stream joined the Borekena river; Sample point 4 (SP_4) is at outlet canal of BGI-brewery industry partially treated wastewater to Workie stream, Sample point 5 (SP_5) is at the point after Loyal and Workie streams joined Borekena river and Sample point 6 (SP_6) is on the upstream of Borkena river before these industrial and domestic wastewater pollution (Fig. 1).

Grab sample was collected two times for each sampling point. Sample collection and handling procedure were performed according to American Public Health Associations recommended procedures (APHA 1999). The samples were collected by 2 L polystyrene bottle. The bottles were washed out thoroughly with the detergent, acid (1: 1 HNO_3 and H_2O by V/V), tap water, and then with distilled water before sampling. The actual samplings were done at midstream depth by dipping each sample bottle at approximately 5–10 cm below the water surface, projecting the mouth of the container against the flow direction.

The sample was taken twice (on March 24 and April 7/2018 at 6:00 AM) with three replicates to evaluate the effect of different wastewater effluent colors (i.e. Red and Grey color) from Huaxu textile industries. Samples were transported to the Bahir Dar Institute of technology water treatment laboratory in ice box within 8 hrs. The samples kept in the refrigerator at 4 °C till analyzed.

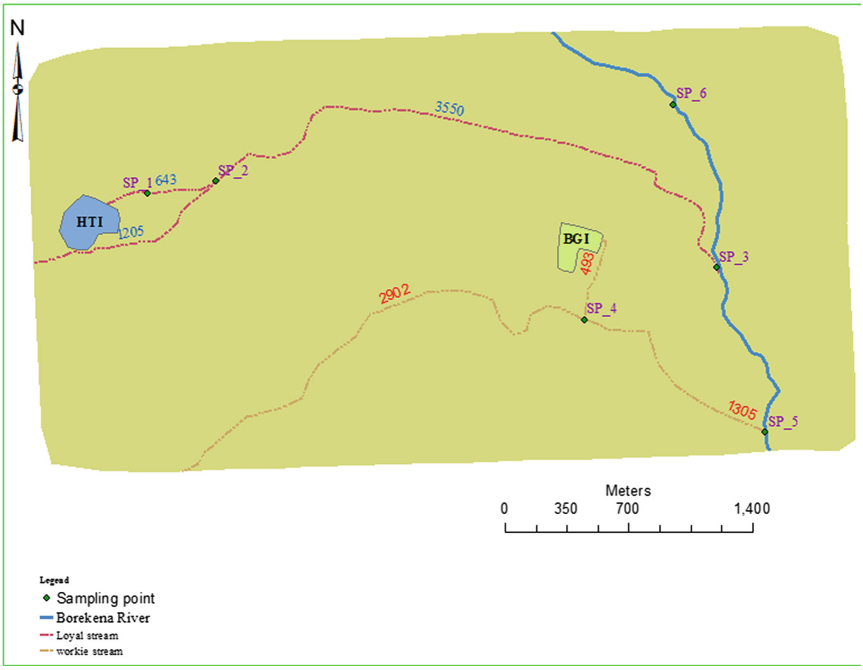

Fig. 1. Sampling location in the study area (length of stream segments in meter) (Color figure online)

2.3 Data Analysis

The water quality sample taken from each sampling points were tested at Bahir Dar Institute of Technology water treatment laboratory. The twelve (12) physicochemical water quality parameters were analyzed with descriptive statistics methods using SPSS-PC statistical package (SPSS 20 for Windows version). The mean value of each parameter was compared with Ethiopian Environmental Protection Authority ambient environment standards (EEPA 2003). ANOVA test was conducted to evaluate the significance of the water quality variation among sampling point with 95% confidence interval. Geographic Information System (GIS) software was used for data analysis and interpretation.

3 Result and Discussion

The Physicochemical water quality parameters analysis results revealed that the effluents discharged by Huaxu textile and BGI-brewery industries polluted the respective receiving streams and Borkena river in large. Domestic sewage discharged in to Loyal stream is also contributed to the pollution.

The mean temperature value were ranged from its highest value of 20.95 ± 0.94 °C at sampling location of SP_1 and lower value of 14.95 ± 1.39 °C at sampling location SP_6 (Fig. 2 and Table 1). The mean temperature values from Huaxu textile industry Effluent to loyal stream were recorded as 20.95 ± 0.94 °C, 18.93 ± 1.18 °C and 16.05 ± 0.39 °C at sampling locations SP_1, SP_2 and SP_3, respectively, which indicates that the value was decreasing along the stream because of the hot industrial wastewater is diluted with the natural stream water having lower temperature (14.95 ± 1.39 °C). The temperature of BGI-brewery industries effluent (19.20 ± 1.06 °C) is lower than Huaxu textile industry effluent (20.95 ± 0.94 °C), but still higher than the upstream river temperature.

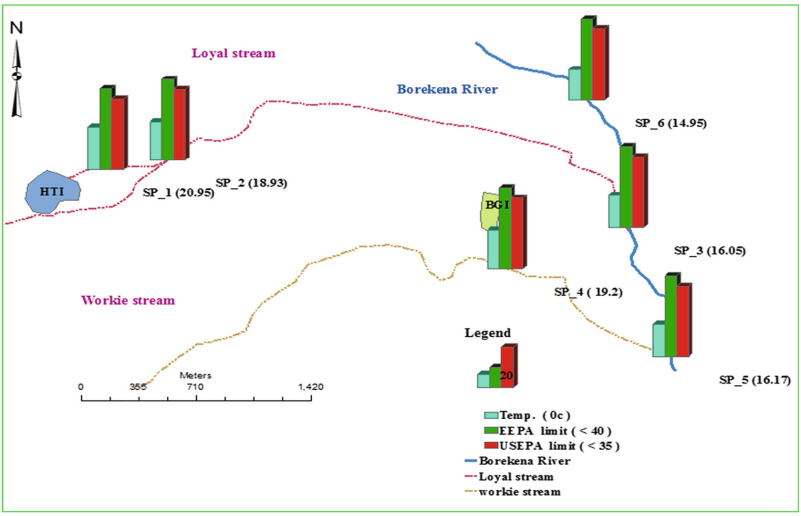

Fig. 2. Mean values of temperature (in °C) at different sampling point.

Table 1. Physicochemical and Biological water quality parameters (n is sample number, HTI: Huaxu Textile Industry, BGI: BGI-Brewery Industry, Upstream: Borkena river upstream and Downstream: Borkena river downstream)

Parameter	SP_1 (n = 6)- HTI effluent	SP_2 (n = 6)	SP_3 (n = 6)	SP_4 (n = 6) BGI effluent	SP_6 (n = 6) Upstream	SP_5 (n = 6)- Downstream	EEPA (2003) standard
Temp (°C)	20.95 ± 0.94	18.93 ± 1.18	16.05 ± 0.39	19.20 ± 1.06	14.95 ± 1.39	16.17 ± 1.04	≤(Upstream Tem ± 3 °C)
EC (µS/cm)	8.46 ± 5.49	7.47 ± 5.54	6.80 ± 1.09	9.07 ± 0.43	0.92 ± 0.27	4.02 ± 0.90	≤1000 @20 °C
pH (pH unit)	9.55 ± 0.44	8.98 ± 0.52	9.75 ± 0.43	7.43 ± 0.06	6.84 ± 0.35	8.22 ± 0.2	6–9
TSS	1633.33 ± 175.46	1474.17 ± 92.21	963.67 ± 155.64	1114.33 ± 182.97	571.67 ± 94.34	997 ± 23.30	≤25 & 50 Max value
TDS	2422.33 ± 431.2	1591.17 ± 211.65	1868.50 ± 158.28	1770 ± 26.46	450.00 ± 30	1383 ± 15.27	≤15% change from upstream
DO	3.19 ± 0.65	3.46 ± 0.42	2.87 ± 0.53	2.77 ± 0.35	6.40 ± 0.61	3.52 ± 0.50	50% Samples ≥9
BOD_5	109.83 ± 13.33	115.67 ± 15.92	136.00 ± 25.3	190 ± 1.01	10 ± 0.50	150 ± 2.50	≤5 mg/L O_2
COD	473.83 ± 66.32	453.67 ± 64.53	487.50 ± 20	155 ± 5.57	34 ± 3.00	508 ± 4.00	≤40 mg/L O_2*
NO_3^--N	13.23 ± 3.61	17.28 ± 6.56	28.68 ± 4.91	15 ± 5.25	3.57 ± 0.16	12.56 ± 0.07	≤ 50 NO_3^- (11.3 NO_3^--N)
PO_4^{-3}	329.33 ± 43.03	140.00 ± 45.64	165.50 ± 35.06	47.9 ± 3.97	12.93 ± 4.41	106.67 ± 46.09	≤25
SO_4^2	59.67 ± 11.52	40.67 ± 14.81	42.50 ± 31.97	14.86 ± 3.9	7.00 ± 5.2	18 ± 2.20	≤200
Hardness (of $CaCO_3$)	658.33 ± 24.22	202.93 ± 19.92	226.25 ± 7.5	54.17 ± 6.29	110 ± 2.5	298.83 ± 29.62	No limit is stated

Units in mg/L unless otherwise state

The analysis result revealed that a significant temperature variation between the point SP_2, where Huaxu textile industry effluent mixed with loyal stream (20.95 ± 0.94 °C) and the upstream of Borkena river (14.95 ± 1.39 °C) ($P = 0.035 < 0.05$). However, no significant temperature variation ($P = 0.29 > 0.05$) between upstream (14.95 ± 1.39 °C) and downstream of Borkena river (16.17 ± 1.04 °C), this is because of larger volume effect of Borkena than Loyal river. The temperature values at the Upstream and downstream of Borkena river and at SP_3 are under the permissible limit of EEPA (2003), such as below upstream temperature ±3 °C.

The maximum mean value of BOD_5 was recorded as 190 ± 1.01 mg/L at SP_4. This highest value is mainly attributed to the availability of large amount organic matter in the partially treated BGI wastewater. The result showed that a significant increment of BOD_5 value (Fig. 3 and Table 1) along the Loyal stream ($P = 0.04 < 0.05$), this is caused by the additional domestic sewage discharge in to Loyal river from the surrounding community. These leads to a significantly increment of BOD_5 ($P = 10^{-6} < 0.05$) at the downstream, SP_5 (150 ± 2.5 mg/L) in comparison with the upstream of the river, SP_6 (10.00 ± 0.5 mg/L).

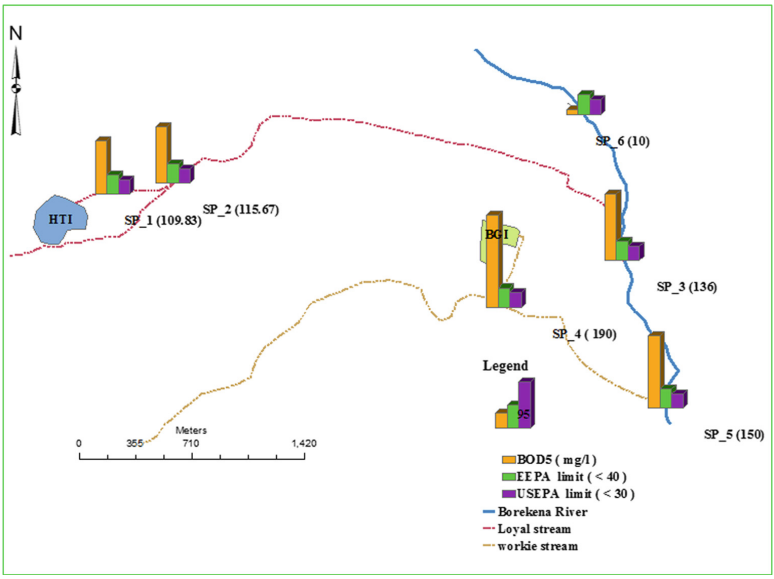

Fig. 3. Mean values of BOD_5 (in mg/L) at different sampling point.

All the measured values of BOD_5 except the value on the upstream location of Borkena River (SP_6) were found higher than EEPA (2003) permissible surface water BOD_5 limit (below 25). Higher BOD_5 concentration at the downstream of Borekena river is resulted primarily from an excess amount of biodegradable organic matter contents of partially treated BGI industrial wastewater (190 ± 2.01) than the untreated Huaxu textile industrial wastewater and sewage released from the surrounding community (136.00 ± 25.3). Large organic matter presence maximize the availability of decomposers, which

uses much amount of oxygen for their growth and deplete dissolved oxygen concentration (Table 1).

All the measured values of COD except the value at the upstream of Borkena river were found higher than EEPA (2003) permissible (below 40). There is a significant COD value increment between upstream and downstream sampling location of Borkena river ($P = 8 * 10^{-9} < 0.05$), which is because of much chemical waste release from Huaxu textile industry and considerable addition from BGI waste (Fig. 4 and Table 1). Desta (1997) and Mammo (2004) studies also confirmed the high magnitude of COD from Ethiopian textile factories effluent. The red and gray colour of Huaxu textile industry effluent and algae blooms downstream of loyal rives are reasoned out with the availability of large concentration of dissolved solid (2422.33 ± 431.2) and PO_4^{-3} (165.50 ± 35.06), respectively (Fig. 5). Maximum concentration of PO_4^{-3} was recorded at Huaxu textile industry effluent sample site (329.33 ± 43.03). This results significant increment of PO_4^{-3} concentration ($P = 0.024 < 0.05$) at the downstream of Borkena river (106.67 ± 46.09) from the upstream sampling site (12.93 ± 4.41). At all sampling site the PO_4^{-3} concentration is higher than the EEPA (2003) permissible limit (below 25 mg/L) except SP_6 Temperature, BOD5, COD and Phosphate.

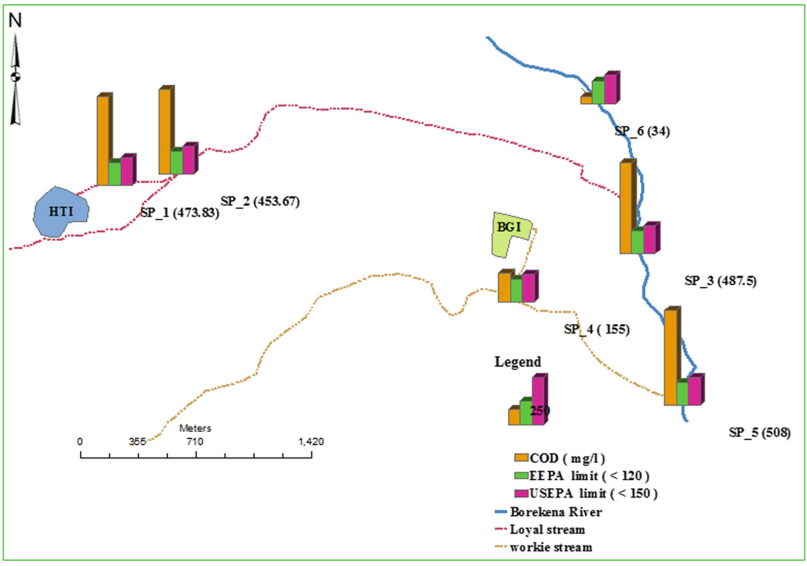

Fig. 4. Mean values of COD (in mg/L) at different sampling point.

The mean concentration magnitude of TSS, TDS, DO were found above the permissible limits of ambient surface water quality value stated by EEPA (2003) at all sampling sites, except at the upstream of Borkena river (SP_6). Significant increment of these parameters was identified at the downstream sampling point (SP_5) comparing with upstream sampling point (SP_6) of Borkena river ($P < 0.05$). The mean concentration of pH, EC, Sulphate, and Nitrate nitrogen were found within the permissible limits, except pH at SP_1 and SP_3.

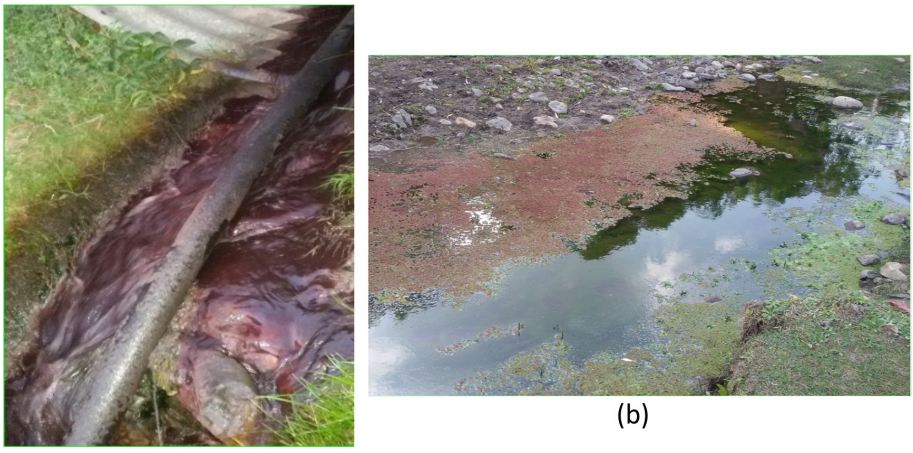

Fig. 5. (a) Red colour Huaxu textile industry effluent (b) Algae blooms at downstream of Loyal stream (Color figure online)

4 Conclusion and Recommendation

The physicochemical parameters analysis results confirmed that untreated Huaxu textile industry and partially treated BGI brewery industrial wastewater are hardly satisfied EEPA (2003) and US EPA (1994) discharging standard.

It was therefore concluded that Huaxu textile and BGI-brewery industry's effluents are polluted, in which Huaxu textile industry effluent was highly contaminated than BGI. As the consequence aquatic life and surrounding livelihood of Borkena River in large and respective tributary rivers (Loyal and Workie streams) were adversely affected.

In general, the result of this study give us insight about the high level of Borkena river contamination due to untreated and/or partially treated industrial and domestic effluent discharge from Kombolcha Industrial zone.

It is recommended to conduct Heavy metals concentrations in Huaxu textile industry effluent for future work so as to quantify types and strength of the pollution in detail, to predict its impact on the environment and target for pollution prevention. It is also important to make periodic quantity and quality measurement of the effluent, since the type, concentration and parameters load can differ with process type and production variation. Enforcement of environmental protection rules and periodic monitoring program is mandatory to decrease the industrial pollution level.

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