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Assessment of the effect of effluent discharge from coffee refineries on the quality of river water in South-western Ethiopia

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The ecohydrological quality of water resource of Ethiopia is declining at an alarming rate, resulting in severe environmental degradation. This study finds out the effects of effluent discharge from intensive coffee refineries on river water quality based on physicochemical parameters and benthos assemblages as biological indicators. The experiment was done using complete randomized design (CRD) with three composite replicates in each refinery and on 24 river water sampling sites selected from four rivers in Limu Kosa District. A total of 72 water samples were collected from six sites: (upstream site (UPS), influent (INF), effluent (EFF), entry point (ENP), downstream one (DS_1) and downstream two (DS_2) in four rivers. Data analysis was performed by analysis of variance (ANOVA) using statistical analysis software (SAS). Spearman's median rank correlation among physicochemical and benthos assemblages as biological indicators of ecohydrological river water quality was characterized. Results reveal that there is a highly negatively significant difference in effect between the four rivers and 24 sites at p<0.05 and 0.01. The benthos assemblage communities of DS_2 and UPS of the ecohydrological rivers were more influenced by the effluents. Quality of DS_2 was more adversely affected compared to UPS. The alteration in river water quality parameters was more pronounced during the peak of coffee refineries. The impact of private refineries on receiving water was more significant than that of government refineries. Therefore, urgent attention should be given to the coffee refinery for effluent management options to avoid further damage to the ecohydrological river water quality using well-designed treatment technologies.

Key words: Biological indicators, benthos, ecohydrolological integrity, upstream downstream.

INTRODUCTION

Water is an essential and inevitable commodity for human growth and development than any other resource for life's sustenance. Although, the water resource of Ethiopia is declining at an alarming and accelerating rate,

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resulting in severe environmental degradation (Beyene et al., 2011; Dejen et al., 2015). South-western Ethiopia is a major and famous coffee growing region in Ethiopia; it has a number of coffee refineries situated along the bank of rivers and/or streams with a varying degree of hydraulic gradients. Wet coffee requires considerable amount of water during processing to receive the cherries, transport them hydraulically through the pulping machine, remove the pulp, and sort and re-pass any cherries with residual pulp adhering to them. The rise in the number of wet coffee refineries has therefore resulted in the generation of enormous disposal of these wastes which are discharged unwisely into nearby natural water way that flows into rivers and/or infiltrates ground water, becoming main threat to surface and ground water qualities as reported by Dejen et al. (2015). With intensification of wet coffee refineries and rampant waste discharges into ecohydrological integrity of river water, an increased pressure on fauna and flora of ecohydrological integrity of river water bodies becomes evident. Water bodies are the primary dump sites for disposal of effluents from coffee refineries containing wide varieties of synthetic and organic wastes that are near them (Haddis and Devi, 2008; Beyene et al., 2011; Dejen et al., 2015). Water pollution is an acute problem in all water bodies, and major river water quality is the gloomy setback for development in coffee producing zone, especially in South-western Ethiopia. According to rough estimates, effluent from 1000 kg of parchment coffee is generated by wet-processing method compared to the human waste that can be generated by 3000-5600 people per day (Beyene et al. 2011). Alarmingly increasing rampant wet coffee refineries contribute to dwindling surface water quality in South-western Ethiopia to a greater extent. As a consequence, there is a risk to ecosystems structures and their functions which allow for regulation of ecosystem processes, and risk to local community health and welfare as they might take in pollutants through consumption of crops such as onion, tomato, potatoes and maize and using of this river for domestic purposes (Kassahun et al. 2010; Dejen et al. 2015).

This has often gradually rendered the ecohydrological quality of rivers of the Limu Kosa District unsuitable for various beneficial purposes as well as their maintenance and restoration. Benthos assemblages within ecological water quality are interrelated and excellent indicators of water quality; they easily respond to organic and inorganic pollution load from human interferences (Kassahun et al., 2010; Beyene et al., 2011). Few, if any, studies have investigated this issue in Ethiopia to assess the effect and extent of the problem and to suggest solutions and recommendations accordingly. Virtually, no studies have specifically addressed the spatial variation of different ecohydrological integrity of river water quality based on the physico-chemical parameters and benthos assemblages as biological indicators of receiving water bodies of South-west Ethiopia. The objective of this study is to determine the effect and extent of effluents generated from coffee refineries on ecohydrological integrity of river water quality based on the physicochemical parameters and benthos assemblages as biological indicators of river water quality in Limu Kosa District (Figure 1).

MATERIALS AND METHODS

Descriptions of the study area

The study was conducted in Limu Kosa District of Jimma Zone (Figure 1). Limu Kosa District is located 420 km southwest of Addis Ababa, the capital city of Ethiopia, lying between Latitude of 7°50 and 8°36′ North and Longitude of 36°44′ and 37° 29′ East. The altitude of district ranges from 1200 to 3020 m above sea level. It has an area of 2770.5 km^2. Several perennial rivers (Gibe, Awetu, Kebena, Ketalenca, Bonke and Dembi), intermittent streams, springs and notable landmarks including Cheleleki Lake and Bolo Caves were found in the Limu Kosa District (data from the Limu Kosa District Agricultural and Rural Development Office). The availability and quality of river water not only impact human health and wellbeing, but also the functioning of essential ecosystems, including rivers, wetlands, lakes and coastal ecosystems. Without sound ecohydrological of river basin management, human activities can upset the delicate balance between ecohydrological integrity and environmental sustainability. As might be expected, water quality in Limu Kosa District rivers and wetlands ranges from absolutely pristine to dangerously poor.

Methods

Study period

A cross sectional study was conducted to assess the impact of wastewater discharge on ecohydrological river water quality by coffee refineries in Limu Kosa District from August 2011 to December 2013. During the whole study period, the primary data (three days of a week from the chosen sampling points) were collected through direct measurement of river water quality parameters of the selected study sites *in-situ* and under laboratory condition.

Experimental design of the study and selection of sampling sites

The experiment was conducted using complete randomized design (CRD) with three composite replicates to minimize the variation of all sample collected from the same sample site. In order to assess the ramification of coffee refineries effluent being discharged, physico-chemical samples were taken from the 24 ecohydrological river water sites (12 among each private and government refineries). Six sampling sites were selected for physico-chemical samples along each ecohydrological river. These sites were upstream site (UPS), influent (INF), effluent (EFF), entry point (ENP), downstream one (DS_1) and downstream two (DS_2). In order to understand the influence of effluent discharge by coffee refineries on ecohydrological river water quality, benthos assemblages as biological indicators of river water quality samples were also taken from the upstream (UPS) and downstream two

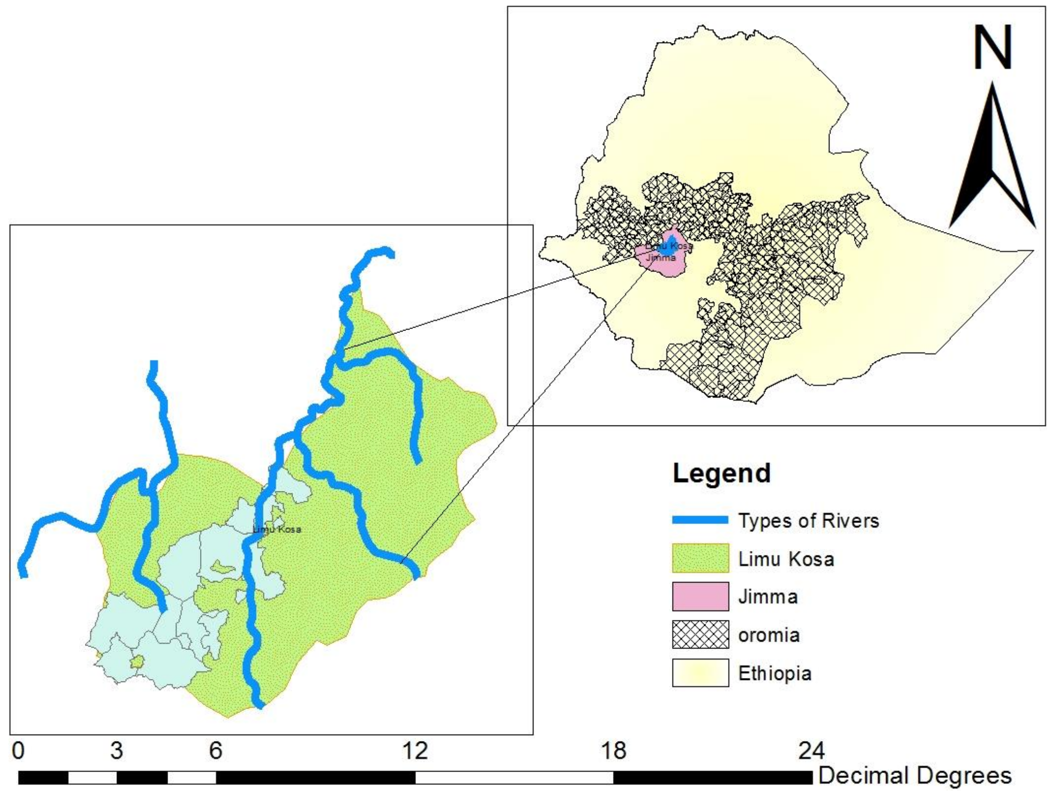

Figure 1. Map of Kosa District indicating sampling sites.

(DS_2) of the discharge points of ecohydrological rivers. UPS was the control sites without any effects from the effluent because of their sites. Influent (INF) was the point at which waste water enters the treatment plants; in this case lagoon. Effluent (EFF) is wastewater leaving the lagoon before it enters the river water. Entry point (ENP) is highly impacted; it is located after the EFF and the point at which lagoon effluent enters the river. Downstream one (DS_1) is located 500 meters below ENP. Downstream two (DS_2) is located 500 meters below DS_1. The aim of taking samples at different sites of the downstream is to analyze spatial variations and determine the rivers' recovery potential. At each sampling point, three samples were taken cross sectionally (corners and center) and three similar sampling campaigns were conducted. This makes the total analyzed samples 180. The distance between UPS, ENP, DS_1 and DS_2 was set at an interval of 500 m. Also, samples were taken from INF and EFF. No actual distance was determined because it depends on the coffee refineries designed. Specially, these wastewater samples were collected at the peak hours of coffee refineries three days in a week from the chosen sampling points (Figure 2) (Kobingi et al., 2009; Kassahun et al. 2010; Akali et al., 2011; Dejen et al. 2015).

Sampling procedure of physicochemical parameters data

Samples were collected in sterilized plastic BOD and glass bottles to maintain accuracy or minimize contamination of physicochemical changes that can occur between time of collection and analysis as indicated in APHA standard method (APHA) (2005). The water samples were collected by inserting the plastic and glass bottles to the opposite direction of the river flow and capped tightly immediately after filling to the tip of the mouth of this bottle by using depth-integrated sampling technique. Determinations of pH, EC, temperature, turbidity and DO fixing were carried out *in-situ* as APHA (2005). These samples were properly and carefully labeled, sealed and transported to the laboratory of the Department of Environmental Health Sciences and Technology, Jimma University. Cold storage was maintained throughout the process till analysis.

Sampling method of macro-invertebrates (benthos) from river water sites

A triangular D-frame Dip-Net (mesh size = 500 µm, sampled area = 0.9 m^2) was used to collect benthos by kick sampling method. In this method, the river bed was disturbed for a distance of about 100 m for 3-5 min. Benthos sample was conducted three times from each riffle and run sample site. These samples were properly and carefully labeled, sealed and transported to the laboratory of the Department of Environmental Health Sciences and Technology, Jimma University, Jimma, Ethiopia. Cold storage was maintained throughout the process till analysis. Identification to a family level was done using a compound light microscope and assisted by a standard identification key (Bouchard 2004; Kobingi et al., 2009).

Statistical analysis

The data were subjected to different statistical analysis such as analysis of variance (ANOVA) using SAS version 9.2, Minitab

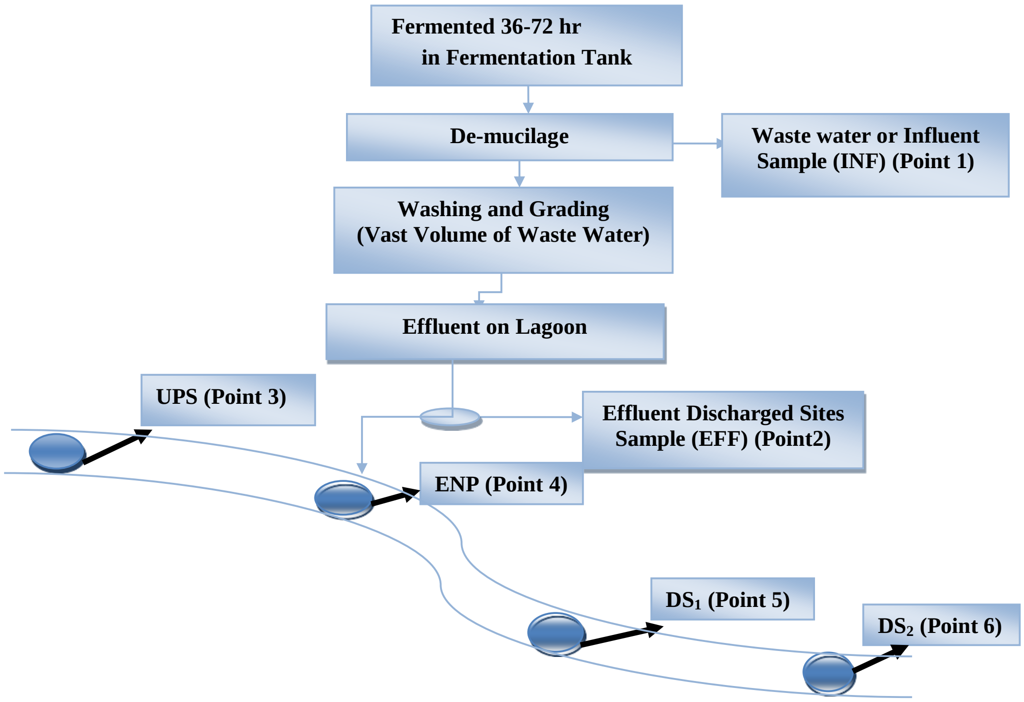

Figure 2. Map indicating general flow diagram of coffee refinery and effluent sampling points.

Version 16.0 software and MS Excel. When significant interaction effects were observed among the four rivers with river water and sites using a two-way ANOVA, One-way ANOVA was computed to see significant difference between each sample site for the physico-chemical parameters and benthos assemblages as biological indicators. Mean separation of different sources of variation among each river water and site was done using Tukey's test at α = 0.05 level of minimum significance difference (MSD). Pearson correlation matrix analysis was used to reveal the magnitude and direction of relationship between different physic-chemical parameters within and among benthos assemblages as biological indicators of river water quality. Benthos assemblages as biological indicators of ecohydrological river water quality samples were determined by using benthos assemblages multimetric indices.

RESULTS

Physical parameters and their significance level in four river water of the study sites

The average mean values of river water temperature ranged between 12.11±0.78-43.09±0.78˚C at Kebena UPS and Awetu EFF respectively. This result showed that there was highly significant difference in all sampling sites, but very high 43.96°C in the Awetu EFF, indicating much stress from the coffee refineries disposal at $p<0.05$ and 0.01. There was highly significant difference in the concentration of EC among the four river water and sites at $p<0.05$ and 0.01. The average mean values of EC ranged from 167.65±15.38-1187.26±15.38µS/cm among all sites. DS_1 to DS_2 exhibited non- significant variation of EC and TDS in contrast to other sites. The EC alarmingly increased with increase in TDS and water temperature (Tables 1 and 2).

The observed turbidity mean values ranged from 3.3±11.05-1363.67±11.05 NTU at Bonke UPS and Kebena INF respectively. The maximum average mean value obtained from the polluted sites (1397NTU) was higher than 2.86NTU recorded at UPS. The turbidity mean concentration at DS_1 to DS_2 was 114.10±11.05 - 980.58±11.05NTU which significantly exceeded the allowable limit set by WHO and EPA (10 mg/L). Consequently, various analytical mean values of TSS and TDS fluctuated between 756.35 ± 15.31 - 1063.35 ± 15.31 mg/L to 394.14 ± 15.31 - 342.09 ± 15.31 mg/L and 1095.64 ± 53.71 - 1197.37 ± 53.71 mg/L to 435.26 ± 53.71 - 481.92 ± 53.71 mg/L amongst the polluted sites of Kebena and Ketalenca DS_1 to DS_2, respectively. These mean values of TSS and TDS obtained from the polluted sites were higher than 16.79 ± 15.31 - 10.02 ± 15.31 mg/L to 302.96 ± 53.71 - 235.04 ± 53.71 mg/L recorded at Kebena and Ketalenca UPS, respectively. There were highly significant differences ($p<0.05$ and 0.01) in the values of TSS among the different sampling sites across the river water course. These results show significant increased values from DS_1 to DS_2 sites of the river water in TSS, but non- significant differences from DS_1 to

Table 1. Physico-chemical parameters selected for the study site and techniques used for methods of analysis.

Physico-chemical parameters	Abbreviation	Methods of analysis	Unit
Water temperature	WT	Probes multi parameter methods	°C
Turbidity	TURB	Turbidity meter	NTU
Electrical conductivity	EC	Probes multi parameter methods (EC meter)	µS/cm
pH	pH	Probes multi parameter methods (pH meter)	-
Total dissolved solids	TDS	Gravimetric Method, dried at 180°C	mg/L
Total suspended solid	TSS	Gravimetric Method, dried at 103-105°C	mg/L
Total solid (TS)	TS	Gravimetric Method, dried at 103-105°C	mg/L
Dissolved oxygen (DO)	DO	Probes multi parameter methods (DO meter)	mg/L
Biological oxygen demand	BOD_5	The Azide Modification of the Winkler Method	mg/L
Chemical oxygen demand	COD	Kit (Hachlange cuvette test, LCk 614 &114)	mg/L
Nitrate-nitrogen	NO_3-N_2	Phenoldisulfonic Acid Method	mg/L
Ammonia-nitrogen	NH_3-N_2	Direct Nesslerization Method	mg/L
Total nitrogen	TN	Kit (Hachlange cuvette test, LCK 138 & 338)	mg/L
Orthophosphate	Orth-P	Stannous Chloride Method	mg/L

Source: APHA, 2005.

DS_2 in TDS (Table 2).

Chemical parameters and their significance level in four river water of the study sites

The average mean values of pH in all six sites of river water were acidic and ranged between 3.12 ± 0.10-7.67 ± 0.10 at Kebena EFF and Awetu UPS respectively. The lowest values obtained from the EFF (2.9) were very lower than 7.93 recorded at UPS. Acidity was found to be potent at ENP than DS_1 which in turn was stronger than DS_2 (Table 3). The pH has shown significant differences among DS_1 and DS_2 river water at $p< 0.05$ and 0.01.

The average mean values of DO were fluctuated between 0.00±0.10 to 8.04±0.10 mg/L in river water samples collected among the four river water with river water and sites. Kebena EFF and INF showed the lowest value of DO as 0.00±0.10 mg/L. These variations may be attributed to oxygen consumption by aerobic organisms due to increase in oxygen demanding wastes. Level of DO in the river water was almost normal in the UPS. DO concentrations below 5 mg/L may also adversely affect the functioning and survival of biological communities and hence all pollution-sensitive taxa failed to retrieve (Table 3). There were highly significant inconsistencies of interaction effect of BOD and COD among all river waters at ($p<0.05$ and 0.01). The maximum average mean values of BOD and COD were recorded (2972.67±30.27 to 2576.05±30.37 mg/L) at Kebena EFF and INF;h minimum values were recorded (2.36 ± 30.27 to 3.99 ± 30.37 mg/L) at Ketalenca and Bonke UPS. BOD and COD showed alarming increment from 1773 ± 30.27-1719.83 ± 30.37 mg/L to 1797.89 ± 30.27-1836.40 ± 30.37 mg/L at Kebena DS_1 and $DS_{2;}$ then decreased slowly towards the rest of the Ketalenca and Bonke of DS_1 and DS_2 respectively.

TN concentration analysis revealed that there was highly significant difference in interaction effect among the four rivers but not at Kebena River of ENP, DS_1, DS_2 and Bonke ENP as well as EFF and PUS of all river water at $p \leq 0.05$ and 0.01. This is due to highly mobility or fixation of TN concentration among each river water site. The concentrations of NO_3-N and NH_3-N_2 in the river water were found to be statistically highly significant and the average mean values ranged from 2.43±0.03 to 4.99±0.07 mg/L. They were higher concentrations in all INF and alarmingly increment from DS_1 to DS_2 due to high coffee refineries' activities that ultimately discharge almost untreated effluent to the river (Table 3). The average mean values of orthophosphate (Orth-P) showed significant difference in all river water, but not DS_1 and DS_2 in all river water (Table 3).

Benthos assemblages as biological indicators of river water quality

UPS and DS_2 benthos assemblages of fauna from 8 taxonomic orders were collected from Limu Kosa District rivers. A total of 30 families fewer than 8 orders representing classes and comprising 1293 individuals were collected from the eight sampling sites. A total number of individuals found in the DS_2 were 387 compared to 906 individuals collected from the UPS. The pollution sensitive taxa of Ephemeroptera, Hemispheres, Trichoptera, Plecoptera and Coleoptera were present in greater number in the UPS. On the other hand, pollution

Table 2. Interaction effects of effluent discharges by coffee refineries on physical characteristics between the all river waters and among sites of river water.

River	Mean separation of physical parameters						
	Site	TSS	TDS	TS	EC	TURB	WT
Kebena	EFF	1800.35^{A}	2239.30^{B}	4039.64^{BA}	1045.80^{B}	1335.23^{A}	28.12^{EF}
	INF	1527.23^{B}	2681.23^{A}	4208.46^{A}	1160.68^{A}	1363.67^{A}	37.267^{B}
	ENP	1460.03^{CB}	2052.26^{B}	3512.29^{ED}	858.65^{C}	1190.48^{B}	24.27^{FIHG}
	DS_2	1063.35^{D}	1197.37^{E}	2260.72^{HG}	661.09^{D}	980.58^{C}	19.60^{JK}
	DS_1	756.35^{E}	1095.64^{E}	1851.98^{JI}	616.73^{D}	972.10^{C}	18.67^{K}
	UPS	16.79^{I}	302.96^{GH}	319.75^{M}	188.65^{H}	3.99^{H}	12.11^{L}
Awetu	EFF	1778.87^{A}	1508.64^{DC}	3287.51^{EF}	1035.56^{B}	1195.25^{B}	43.09^{A}
	INF	1126.52^{D}	2773.59^{A}	3900.1^{BAC}	1187.26^{A}	1188.10^{B}	36.75^{B}
	ENP	586.98^{F}	1537.99^{C}	2124.97^{HI}	844.00^{C}	675.94^{D}	34.97^{CB}
	DS_2	431.65^{G}	762.07^{F}	1193.72^{K}	505.65^{E}	514.38^{E}	25.40^{FHG}
	DS_1	434.23^{G}	753.82^{F}	1188.05^{K}	513.28^{E}	514.56^{E}	29.747^{ED}
	UPS	33.24^{I}	335.24^{GH}	368.48^{M}	197.94^{H}	6.99^{H}	20.08^{JIK}
Bonke	EFF	757.29^{E}	2298.43^{B}	3055.72^{F}	890.99^{C}	1316.66^{A}	37.82^{B}
	INF	1382.24^{C}	2202.67^{B}	3584.9^{EDC}	1151.17^{A}	1202.01^{B}	37.27^{B}
	ENP	578.45^{F}	1227.24^{DE}	1805.68^{J}	582.78^{ED}	520.62^{E}	36.86^{B}
	DS_2	543.76^{F}	577.02^{F}	1120.78^{LK}	395.69^{F}	128.70^{G}	23.64^{JIHG}
	DS_1	584.03^{F}	569.84^{GF}	1153.87^{K}	393.62^{F}	128.39^{G}	35.77^{B}
	UPS	28.07^{I}	230.00^{H}	258.07^{M}	167.65^{H}	3.30^{H}	27.32^{FEG}
Ketalenca	EFF	1381.05^{C}	1177.33^{E}	2558.38^{G}	1015.70^{B}	1352.37^{A}	31.29^{CED}
	INF	1051.68^{D}	2746.18^{A}	3797.86^{BDC}	1179.37^{A}	1237.58^{B}	33.95^{CBD}
	ENP	419.74^{HG}	753.73^{F}	1173.47^{K}	318.35^{GF}	334.88^{F}	30.10^{ED}
	DS_2	342.09^{H}	481.92^{GFH}	824.02^{L}	240.14^{GH}	122.30^{G}	21.36^{JIHK}
	DS_1	394.14^{HG}	435.26^{GH}	829.39^{L}	226.71^{H}	114.10^{G}	19.60^{JK}
	UPS	10.02^{I}	235.04^{H}	245.06^{M}	169.10^{H}	5.12^{H}	14.28^{L}
	Mean	770.34	1257	2028	647.77	683.64	28.31
	Max	1812	2816	4302	1227.16	1397	43.96
	Min	9.70	222.27	236.84	165.43	2.86	11.70
	WHO	500	1000	500	1000	10	-
	CV (%)	3.44	7.39	4.98	4.11	2.80	4.78
	MSD	83.45	292.79	318.08	83.85	60.24	4.26
	SEM(±)	15.31	53.71	58.35	15.38	11.05	0.78
	River	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	River*Site	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

CV, Coefficient of variation in percent; MSD, minimum significance difference at 5 and1%; SEM, standard error mean. Mean with different letters in the same column were significantly different (withTukey's test at 5 and 1% level of probability) as established by MSD test. Except EC (µS/cm), TURB (NTU) and WT (°C) the others parameters were expressed in mg/L. These six river sites were averages among each site. Awetu and Kebena river water from private and the other two were from the government refineries. Significant interactions and main effects were explored by Tukey's test, using the GLM procedure at P<0.05 and 0.01as established by MSD test.

tolerant species of families Chironomidae, Simuliidae and Leeches present in greater number in the DS_2 sections throughout the experimental period reflected the coffee refineries' stresses of the ecological status of rivers in its DS_2 sections (Appendix Table 1).

Analysis of the results of benthos assemblages as

Table 3. Interaction effects of effluent discharges by coffee refineries on chemical water quality between the all ecohydrological river waters and among sites of river water.

River	Mean separation of chemical parameters								
	Site	pH	BOD	COD	DO	TN	NO_3-N	NH_3-N	Ort-P
Kebena	EFF	3.12^{I}	2972.67^{A}	2735.50^{A}	0.00^{H}	98.40^{A}	3.36^{C}	7.04^{C}	13.18^{E}
	INF	3.33^{HI}	2689.67^{B}	2576.05^{A}	0.01^{H}	92.60^{BA}	3.86^{A}	8.11^{A}	22.90^{A}
	ENP	3.36^{HI}	2478.88^{C}	1940.57^{B}	0.02^{H}	78.61^{DE}	3.08^{D}	6.92^{DCE}	10.87^{F}
	DS_2	4.06^{DGEF}	1797.89^{E}	1836.40^{CB}	0.05^{H}	76.22^{DE}	2.81^{E}	6.83^{DCE}	10.83^{F}
	DS_1	4.28^{D}	1773.00^{FE}	1719.83^{C}	0.07^{H}	76.66^{DE}	2.74^{FE}	6.65^{DE}	10.34^{F}
	UPS	7.43^{A}	6.70^{I}	4.57^{G}	8.04^{A}	0.31^{K}	0.03^{J}	0.07^{K}	0.34^{I}
Awetu	EFF	3.59^{HGIF}	2254.95^{D}	1850.27^{CB}	0.11^{H}	88.72^{BC}	3.09^{D}	7.00^{DC}	11.47^{F}
	INF	3.31^{HI}	2205.32^{D}	1982.94^{B}	0.12^{H}	94.57^{BA}	3.60^{B}	7.49^{B}	20.37^{B}
	ENP	3.71^{HGEF}	1868.24^{E}	1525.88^{D}	1.49^{E}	82.56^{DC}	2.67^{FE}	6.93^{DCE}	11.00^{F}
	DS_2	4.12^{DEF}	1010.05^{HG}	1020.21^{FE}	3.16^{C}	35.14^{H}	2.64^{F}	6.63^{FE}	10.82^{F}
	DS_1	4.20^{DE}	989.30^{HG}	1035.08^{FE}	3.33^{C}	21.10^{J}	2.64^{F}	6.63^{GF}	10.40^{F}
	UPS	7.67^{A}	9.75^{I}	8.96^{G}	6.64^{B}	5.44^{K}	0.66I	0.06^{K}	0.91^{I}
Bonke	EFF	4.15^{DEF}	1849.67^{E}	1451.67^{D}	1.23^{FE}	96.02^{A}	2.98^{D}	5.40^{H}	15.40^{D}
	INF	3.55^{HGI}	2201.63^{D}	1835.09^{CB}	0.14^{H}	72.47^{FE}	3.97^{A}	6.01^{G}	17.56^{C}
	ENP	4.96^{C}	1129.35^{G}	1163.20^{E}	2.15^{D}	77.62^{DE}	2.78^{FE}	6.14^{G}	13.79^{E}
	DS_2	5.69^{B}	1030.60^{HG}	928.69^{F}	3.40^{C}	13.06^{I}	1.35^{H}	3.83^{J}	8.28^{G}
	DS_1	5.57^{B}	992.55^{HG}	961.88^{F}	3.55^{C}	41.52^{H}	1.95^{G}	3.81^{J}	8.19^{G}
	UPS	7.52^{A}	4.34^{I}	3.99^{G}	6.14^{B}	4.47^{K}	0.66^{I}	0.07^{K}	0.13^{I}
Ketalenca	EFF	3.48^{HI}	1618.17^{F}	1488.03^{D}	0.73^{FG}	95.29^{A}	3.09^{D}	5.12^{H}	8.25^{G}
	INF	4.55^{DC}	1717.18^{FE}	1551.15^{D}	0.25^{HG}	66.36^{F}	3.60^{B}	6.29^{FE}	10.60^{F}
	ENP	4.60^{DC}	1109.83^{G}	1014.92^{FE}	2.19^{D}	50.09^{G}	2.64^{F}	4.62^{I}	8.84^{G}
	DS_2	5.90^{B}	902.88^{H}	874.23^{F}	3.64^{C}	19.88^{I}	1.51^{H}	3.83^{J}	4.86^{H}
	DS_1	5.66^{B}	1009.38^{HG}	912.93^{F}	3.27^{C}	35.31^{H}	1.96^{G}	4.26^{I}	5.84^{H}
	UPS	7.52^{A}	2.36^{I}	9.74^{G}	8.01^{A}	5.87^{K}	0.66^{I}	0.05^{K}	0.34^{I}
	Mean	4.80	1401	1268	2.40778	55.35	2.43	4.99	9.81
	Max	7.93	2993	2867	8.31	99.23	3.99	8.37	23.31
	Min	2.90	2.03	3.19	0.00	0.30	0.03	0.05	0.13
	WHO	65-8.5	10	40	6	-	10-45	0.2-5	5
	CV (%)	6.03	6.74	8.16	5.80	3.71	2.17	2.30	3.97
	MSD	0.56	165.01	165.57	0.52	6.48	0.17	0.36	1.23
	SEM(±)	0.10	30.27	30.37	0.10	1.19	0.03	0.07	0.23
	River	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	River*Site	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

CV, Coefficient of variation in percent; MSD, minimum significance difference at 5 and 1%, SEM, Standard error mean. Mean with different letters in the same column were significantly different (with Tukey's test at 5 and 1% level of probability) as established by MSD test. Except pH, the others parameters were expressed in mg/L. These six river sites were averages among each site. Awetu and Kebena river water from private and the other two were from the government refineries. Significant interactions and main effects were explored by Tukey's test, using the GLM procedure at P<0.05 and 0.01 as established by MSD test.

biological indicators illustrated a highly significant difference between rivers and all sites at p<0.05 and 0.01. These benthos assemblages would indicate the environmental effects of coffee refinery activities on the ecohydrological river water quality and its vicinity. The analysis of the average species diversity of benthos assemblages as biological indicators (Shannon, equitability and Simpson) was much reduced in the DS_2

Table 4. Summary of benthos assemblages diversity indices and taxa richness among ecohydrological rivers.

River	F		S		D		H'		E		Min		Max	
	UPS	DS_2	UPS	DS_2	UPS	DS_2	UPS	DS_2	UPS	DS_2	UPS	DS_2	UPS	DS_2
Awetu	9	11	266	157	0.88	0.85	2.15	2.09	0.98	0.89	0	0	42	42
Bonke	9	6	169	54	0.88	0.63	2.14	1.32	0.97	0.74	0	0	29	31
Ketalenca	15	8	266	127	0.92	0.58	2.62	1.31	0.97	0.63	0	0	41	80
Kebena	13	3	205	49	0.92	0.50	2.54	0.87	0.99	0.79	0	0	25	33
Total			906	387	0.90	0.64	2.36	1.40	0.98	0.76	0	0	35	47
Grand			1293		-	-	-	-	-	-	-	-	-	-
Average			647		0.77		1.88		0.87		0		41	

Table 5. Results of ANOVA for benthos assemblage composition, abundance and distribution among sites.

Site	Mean separation of diversity indices and taxa richness				
	F	S	H'	D	E
UPS	12^a	227^a	2.36^a	0.90^a	0.98^a
DS_2	7^b	97^b	1.40^b	0.64^b	0.76^b
CV (%)	29	7	19.35	11.42	6.17
MSD (0.05)	2.98	12.52	0.40	0.097	0.052
SEM (±)	0.95	4.02	0.13	0.03	0.02

F=Total number of Families, S=Total number of Richness, H'= Shannon- Wiener diversity index, D=, Simpson's diversity index E= Equitability or Evenness diversity indices. Means with different letters in the same column are significantly different (Tukey's test at $P<0.05$) as established by MSD test.

as against UPS, which was very high throughout the experimental period (Tables 4 and 5).

Pearson correlation matrix (r) among selected physicochemical parameters and benthos assemblages as biological indicators of river water quality

PH and DO exhibited that they are positively and highly significant correlated with benthos assemblages, while BOD and COD are negatively and highly correlated with benthos at $p<0.05$. Meanwhile, TN, NO_3-N and Orth-P had negative correlation with all diversity indices and taxa richness, except evenness at $p<0.05$. The richness and all diversity revealed that there is a highly significant dependence on pH and DO parameters. This suggests that a local increase in pH and DO was responsible for increase in the richness of benthos (Table 6).

DISCUSSION

The good ecohydrological status of sampling sites in the UPS of Limu Kosa District areas was indicated by high proportion of pollution sensitive benthos, whereas entry point segment received huge volume of effluents that acts as physical-chemical barrier, which restricts the movement of benthos from DS_2 to UPS and vice versa. The results showed that the physicochemical parameter of the effluent discharged from government coffee refineries into the river water (Bonke and Ketalenca river water) decreased slowly towards $DS_{2,}$ while physico-chemical parameter of the effluent discharged from private coffee refineries into the river water (Kebena and Awetu river water) alarmingly increased towards DS_2. Deterioration of the river water quality increases during the peak time of coffee refineries when rampant discharges are discharged into the river water. It could lead to reduction in volume of river water and also impede the free flow of the river water. The ecohydrological river water banks were disrupted by most processing.

High physicochemical and nutrient parameters concentration widely exceed assimilation capacity of ecohydrological integrity of river water quality and do not allow for aquatic life and complex effects on flowing river water and increased eutrophication concentration at $DS_{2.}$

Table 6. Spearman's median rank correlation among physico-chemical parameters with benthos assemblages as biological indicators of river water quality characteristics.

Parameter	pH	DO	BOD	COD	TN	NO_3-N	Orth-P	S	H'	D	E
pH	1.00										
DO	0.93**	1.00									
BOD	-0.94**	-0.97**	1.00								
COD	-0.95**	-0.95**	0.98**	1.00							
TN	-0.93**	-0.91**	0.91**	0.94*	1.00						
NO_3-N	-0.96**	-0.94**	0.89**	0.90**	0.90**	1.00					
Orth-P	-0.99**	-0.91**	0.94**	0.88**	0.81**	0.94**	1.00				
S	0.89**	0.86**	-0.86**	-0.80**	-0.65*	-0.65*	-0.78*	1.00			
H'	0.79**	0.91**	-0.88**	-0.85**	-0.72*	-0.69*	-0.72*	0.88**	1.00		
D	0.77**	0.87**	-0.88**	-0.85**	-0.71*	-0.65*	-0.69*	0.86**	0.97**	1.00	
E	0.86**	0.88**	-0.83**	-0.81**	-0.43	-0.53*	-0.60*	0.75**	0.84**	0.89**	1.00

**= Correlation are highly significant at $p < 0.05$ probability levels, *= Correlation are moderately significant at $p < 0.05$ probability levels and '-' indicate negative correlation. E = Equitability or evenness index, BOD = biological oxygen demand, COD = chemical oxygen demand, DO = dissolved oxygen, D= Simpson's diversity index, H' = Shannon-Wiener diversity index, Orth- P= orthophosphate, NO_3-N= nitrate nitrogen, S= specious richness taxa and TN= total nitrogen).

TN is not strongly adsorbed on effluent cation exchange complex. Low adsorption coefficients of waste stabilization pond lagoon and constructed wetlands effluent result in maintenance of high dissolved NH_3-Nconcentrations in the effluent river water quality (Akan et al., 2009; Akali et al., 2011).

This result indicates that the decline at an alarming and accelerating rate of ecohydrological river application benefits both watershed and their surrounding environment and society (health and welfare) deterioration. Due to drawdown river discharge (hypoxia or anoxia), increased temperatures and reduced water quality in peak time (mid-September to mid of December) of coffee refineries, the health of ecosystem is usually at stake in these months; so maintaining ecosystem health and improving biodiversity in such months is more important for water resources planners. This poses a health risk to several rural communities which rely on the receiving water bodies primarily as their sources of domestic water and for other purpose (Walakira and James, 2011). Biological indicators were strongly positive correlated with pH and DO while negative correlations were noticed in BOD and COD of river water quality. This showed that there was hypoxia or anoxia which affected taxa richness and all diversity indices (Aina, 2012a, 2012b).

Outfalls from private coffee refineries that are discharged into the river water column as well as into vicinity revealed highly significant variation of physico-chemical and nutrient characterization as compared to government site. Lagoons that were intended to serve as wastewater stabilization were neither properly constructed nor were they of the right dimension to accommodate the generated waste during peak time of refineries lead to overflow of raw effluents into natural river water column. There is need for the intervention of appropriate regulatory agencies to ensure production of high quality treated final effluents by wastewater treatment facilities in rural communities coffee refineries (Sharma and Samita 2011; Mary Joyce and Macrina, 2012).

Conclusion and recommendation

High proportion of pollution sensitive taxa of benthos assemblages (Ephemeroptera, Hemispheres, Trichoptera, Plecoptera and Coleoptera) in the UPS as against high pollution tolerant species of families Chironomidae, Simuliidae and Leeches DS_2 was recorded. Coffee refinery effluents having contaminants are intensively incorporated with river water regularly. This study clearly reveals that river water quality was found to be unfit for human consumption and other domestic purposes due to the exceeding level of physico-chemical parameters values recommended by WHO at DS_2 of Limu Kosa District. Thus the challenges to continuous physico-chemical parameters and biological indicators monitoring will be immense. Both planners, regulatory agencies & the scientific community should work together to establish sustainable coffee production that is economically viable, environmentally amendable and maintain ecological integrity of receiving water bodies. Therefore, urgent intervention in the area of coffee refinery for effluent management options should be dealt with top priority to avoid further needless damage to ecohydrological integrity, and the development of river water quality using well-designed treatment technologies (lagoons) for coffee waste treatment is highly recommended.

Conflict of Interest

The author has not declared any conflict of interests.

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Appendix Table 1. Total number (n) of macro-invertebrates caught at four river water in Limu Kosa District.

Taxa	Kebena				Awetu				Bonke				Ketalenca			
	UPS		DS		UPS		DS		UPS		DS		UPS		DS	
	N	%	N	%	N	%	n	%	N	%	N	%	n	%	N	%
Odonata	**37**	**18.05**	**0**	**0.00**	**91**	**34.21**	**41**	**26.11**	**67**	**39.64**	**6**	**11.11**	**74**	**27.82**	**6**	**4.72**
Coenagrionidae	10	4.88	0	0.00	37	13.91	9	5.73	23	13.61	4	7.41	22	8.27	0	0.00
Gonphidae	8	3.90	0	0.00	0	0.00	0	0.00	18	10.65	0	0.00	10	3.76	0	0.00
Libellulidae	19	9.27	0	0.00	27	10.15	13	8.28	26	15.38	2	3.70	11	4.14	6	4.72
Aeshnidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	31	11.65	0	0.00
Lestidae	0	0.00	0	0.00	0	0.00	11	7.01	0	0.00	0	0.00	0	0.00	0	0.00
Cordulegastridae	0	0.00	0	0.00	27	10.15	8	5.10	0	0.00	0	0.00	0	0.00	0	0.00
Hemiptera	**30**	**14.63**	**0**	**0.00**	**28**	**10.53**	**12**	**7.64**	**29**	**17.16**	**6**	**11.11**	**31**	**11.65**	**16**	**12.60**
Belostomatidae	14	6.83	0	0.00	28	10.53	12	7.64	0	0.00	0	0.00	13	4.89	5	3.94
Gerridae	16	7.80	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	18	6.77	0	0.00
Corixidae	0	0.00	0	0.00	0	0.00	0	0.00	29	17.16	6	11.11	0	0.00	11	8.66
Coleoptera	**42**	**20.49**	**0**	**0.00**	**36**	**13.53**	**0**	**0.00**	**30**	**17.75**	**0**	**0.00**	**9**	**3.38**	**1**	**0.79**
Gyrinidae	25	12.20	0	0.00	36	13.53	0	0.00	19	11.24	0	0.00	9	3.38	0	0.00
Dytiscidae	17	8.29	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.79
Elmidae	0	0.00	0	0.00	0	0.00	0	0.00	11	6.51	0	0.00	0	0.00	0	0.00
Trichoptera	**46**	**22.44**	**0**	**0.00**	**71**	**26.69**	**8**	**5.10**	**18**	**10.65**	**0**	**0.00**	**63**	**23.68**	**3**	**2.36**
Hydropsychidae	17	8.29	0	0.00	0	0.00	0	0.00	18	10.65	0	0.00	0	0.00	0	0.00
Hydroptilidae	11	5.37	0	0.00	29	10.90	0	0.00	0	0.00	0	0.00	16	6.02	0	0.00
Leptoceridae	18	8.78	0	0.00	42	15.79	0	0.00	0	0.00	0	0.00	17	6.39	0	0.00
Brachycentridae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	12	4.51	0	0.00
Polycentropodae	0	0.00	0	0.00	0	0.00	8	5.10	0	0.00	0	0.00	0	0.00	3	2.36
Psychomyiidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	18	6.77	0	0.00
Diptera	**13**	**6.34**	**40**	**81.63**	**0**	**0.00**	**92**	**58.60**	**13**	**7.69**	**39**	**72.22**	**19**	**7.14**	**101**	**79.53**
Ceratopeganidae	13	6.34	0	0.00	0	0.00	0	0.00	13	7.69	0	0.00	0	0.00	9	7.09
Chironomidae	0	0.00	33	67.35	0	0.00	42	26.75	0	0.00	31	57.41	0	0.00	80	62.99
Pschodidae	0	0.00	0	0.00	0	0.00	6	3.82	0	0.00	0	0.00	0	0.00	0	0.00
Simuliidae	0	0.00	7	14.29	0	0.00	38	24.20	0	0.00	8	14.81	0	0.00	12	9.45
Tipulidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	19	7.14	0	0.00
Syrphidae	0	0.00	0	0.00	0	0.00	6	3.82	0	0.00	0	0.00	0	0.00	0	0.00

Appendix Table 1. Cont.

Ephemeroptera	**20**	**9.76**	**0**	**0.00**	**26**	**9.77**	**0**	**0.00**	**12**	**7.10**	**0**	**0.00**	**70**	**26.32**	**0**	**0.00**
Baetidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	41	15.41	0	0.00
Ephemeridae	20	9.76	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	14	5.26	0	0.00
Heptageniidae	0	0.00	0	0.00	26	9.77	0	0.00	0	0.00	0	0.00	15	5.64	0	0.00
Caenidae	0	0.00	0	0.00	0	0.00	0	0.00	12	7.10	0	0.00	0	0.00	0	0.00
Plecoptera	**17**	**8.29**	**0**	**0.00**	**14**	**5.26**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**
Perlidae	17	8.29	0	0.00	14	5.26	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Hirudinea	**0**	**0.00**	**9**	**18.37**	**0**	**0.00**	**4**	**2.55**	**0**	**0.00**	**3**	**5.56**	**0**	**0.00**	**0**	**0.00**
Leeches	0	0.00	9	18.37	0	0.00	4	2.55	0	0.00	3	5.56	0	0.00	0	0.00
Total	205		49		266		157		169		54		266		127	

Total # of Taxonomic order= 8 and Total # of individuals = 1293 UPS=906 DS=387