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Environmental Flows Risk Assessment of Effluent Outfalls from Conventional Wet Washed Coffee Refineries in Limu Kosa District of Southwestern Ethiopia

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Abstract: The objective of this study was to assess the effects of recurrent effluent outfall from conventional wet washed coffee refineries (CWCR) on environmental flows (Eflows) based on the physicochemical parameters & benthos assemblages as biological indicators. The experiment was done using complete randomized design (CRD) with 3 composite replicates at each 24 sampling sites of 4 river water basins. Six sampling sites were selected for physico-chemical & 2 sampling sites were selected for benthos assemblages samples along each 4 river basin. Data analyses were performed by different statistical analyses such as analysis of variance (ANOVA) using SAS 9.2 and Minitab 16.0 software. Results of physicochemical parameters with biological revealed that there is highly significant effect between 4 Eflows & among 24 sites at ($p<0.05$). Characteristics of effluent outfall from CWCR has a BOD of up to 2993 mg/L and a COD of up to 2867 mg/L as well as the acidity of pH below 3. These results can lead to depletion of DO and a decrease in pH (due to fermentation of organic matter) may hamper the sustainability of water bodies, which can kill off virtually all aquatic life. Except pH and DO, the other physico-chemical parameters exhibited that they were negative correlation with benthos assemblages. The results suggest that Eflows status of DS_2 were depredation by effluent outfall from the conventional wet coffee refineries as compared to UPS. Therefore, face urgent intervention in the area of coffee refinery for effluent management and well designed treatment technologies (lagoons) for coffee waste treatment is highly recommended.

Keywords: Assimilation Capacity, Benthos, Coffee Refinery, Lagoon, Pulp, Riverbank, Ecohydrological

1. Introduction

Southwestern Ethiopia is a major and famous coffee growing region in Ethiopia [1]. There are two ways, by which coffee can be processed: wet and dry coffee refineries. Waste products are generated from both methods. In the study, sites there were two types of wet coffee refineries. These are modern or advanced and conventional wet washed coffee refineries (CWCR). The modern or advanced are subjected to mechanical removal of the parchment layer from the bean and the CWCR are biological (anaerobic) which is simply dumping it into the river bank [1-2].

Most of the coffee producers of the Limu Kosa District of Southwestern Ethiopia have been reported to follow conventional wet washed method. Approximately 80% of coffee harvest from the southwestern part of Ethiopia is processed by the CWCR [1]. This method has been described as the cheapest of coffee refineries. Most of these CWCR are constructed along the river bank located nearby, because it uses large amount of water during various stages of coffee production and processing [3-4]. The quantity of water used and the volume of wastewater generated from each CWCR vary from one another depending upon the process adopted and technology applied. The volume of water required for CWCR has been reported as 3240 Liters per bags per 850 gallon per bags of green coffee [4]. The major problem is during the CWCR peak time, the quantity of water used is too great for the size of the tanks and overflow of effluents instantly discharge it into river water body nearby is a common occurrence. Consequently, the amount of wastewater generated is high. If 100% of coffee producers use this method it generates a 36 BM^3 of wastewater [5]. It has been estimated that more than 45 L of wastewater is produced per kilogram of coffee processed. This results in pollution equivalent to 45 kg COD or $273m^3$ of crude domestic sewage per day [6-7]. Obviously, CWCR requires a high degree of processing know-how and produces large amounts of effluents which have the potential to damage the Eflows [8]. Pollution of water resources can thus aggravate water scarcity [9]. These intensification of CWCR has therefore resulted in enormous volumes of rampant effluent discharges it into Eflows of households livelihood located nearby and become main threat to the surface and ground water qualities [3]. Although this fact is widely recognized, Eflows systems are the primary dump areas for disposal of effluents from coffee refineries containing wide varieties of synthetic and organic wastes. This variety of synthetic and organic wastes contains high acidic, nutrient, suspended and dissolved organic matter which makes it amenable to rapid biodegradation [3]. Due to this, river water body nearby these refineries is highly contaminated. Bad smell is common around the environment where CWCR existed. Currently, CWCR constitute a source of serious contamination. Therefore, there is a high risk to ecohydrological system services provision and household's livelihood (agricultural production, livestock, public health, and welfare). The disposal of effluent from conventional wet coffee refineries on pasture and agricultural land used to help as fertilizing the soil have been result in high acidification, water logging and anoxia. Due to this, different crops such as onion, tomato, potatoes, sorghum and maize had highly affected by quality and quantity [4, 10].

In spite of a generally good understanding of effect of effluent outfalls from CWCR, there is no innovation lab for effect of effluent generated from CWCR on the Eflows technology across the southwestern Ethiopia. Although, there is no consistent, reliable inventory, well studied and documented information with regarding to this area. Laboratory bioassays and chemical analysis of effluents policy is a new and only recently introduced and lacks in-depth studies. The intervention is not well supported by comprehensive research and thus there is gap of knowledge in the area. To fill the knowledge gap, the researcher tries to rigorously examine the problems and economic viability of effects of recurrent effluent outfall from CWCR towards livelihood improvement. Therefore, this research study aim was to assess the past, present & future trends of effects of recurrent effluent outfall from CWCR on Eflows of household's livelihood based on the physicochemical parameters and benthos assemblages as biological indicators in Limu Kosa district of southwestern Ethiopia. Consequently, the second objective of this research was to evaluate the capacity of coffee wastewater treatment performance of the conventional lagoon pond (traditionally waste stabilization ponds) before disposed into Eflows (socio-ecohydrological system services provision).

2. Materials and Methods

2.1. Descriptions of the Study Area

The study was conducted in Limu Kosa District of Jimma Zone, Southwestern Ethiopia (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°6′ North and Longitude of 36°44′ and 37°29′ East. The altitude of the District ranges from 1200m to 3020m above sea level. It has an area of 2770.5 km^2. Gibe, Awetu, Kebena, Ketalenca, Bonke and Dembi were found in the Limu Kosa District (data from the Limu Kosa District Agricultural and Rural Development Office).

2.2. Methods

2.2.1. Experimental Design of the Study and Selection of Sampling Sites

The experiment was done using complete randomized design (CRD) via 3 composite replicates at each 24 sampling sites of 4 river water basins to minimize their variations. From one river basin, six sampling sites were selected for physico-chemical and two sampling sites were selected for benthos assemblages. At each sampling site, 3 samples were collected cross sectionally (two corners and one center). These sites were upstream site (UPS), influent (INF), effluent (EFF), entry point (ENP), downstream one (DS_1) and downstream two (DS_2). UPS was used as control sites without any effects from the effluent because of their sites. Influent (INF) was the point at which wastewater enters the lagoons (treatment plants). Effluent (EFF) is wastewater leaving from the lagoon but before it enter the Eflows. Entry point (ENP) as highly impacted that was located after the EFF and it was the point at which lagoon effluent enters the Eflows. The distance between UPS, ENP, DS_1 and DS_2 was set at an interval of 500 m. Downstream one (DS_1) was located at 500 meters below of ENP. Downstream two (DS_2) was located 500 meters below of DS_1. In addition, samples were taken from INF and EFF, no actual distance determined because it depends on the coffee refineries designed. Specially, these wastewater samples were collected at the peak hour of coffee refineries for three days of a week from the chosen sampling points (figure 2) [3, 11, 12].

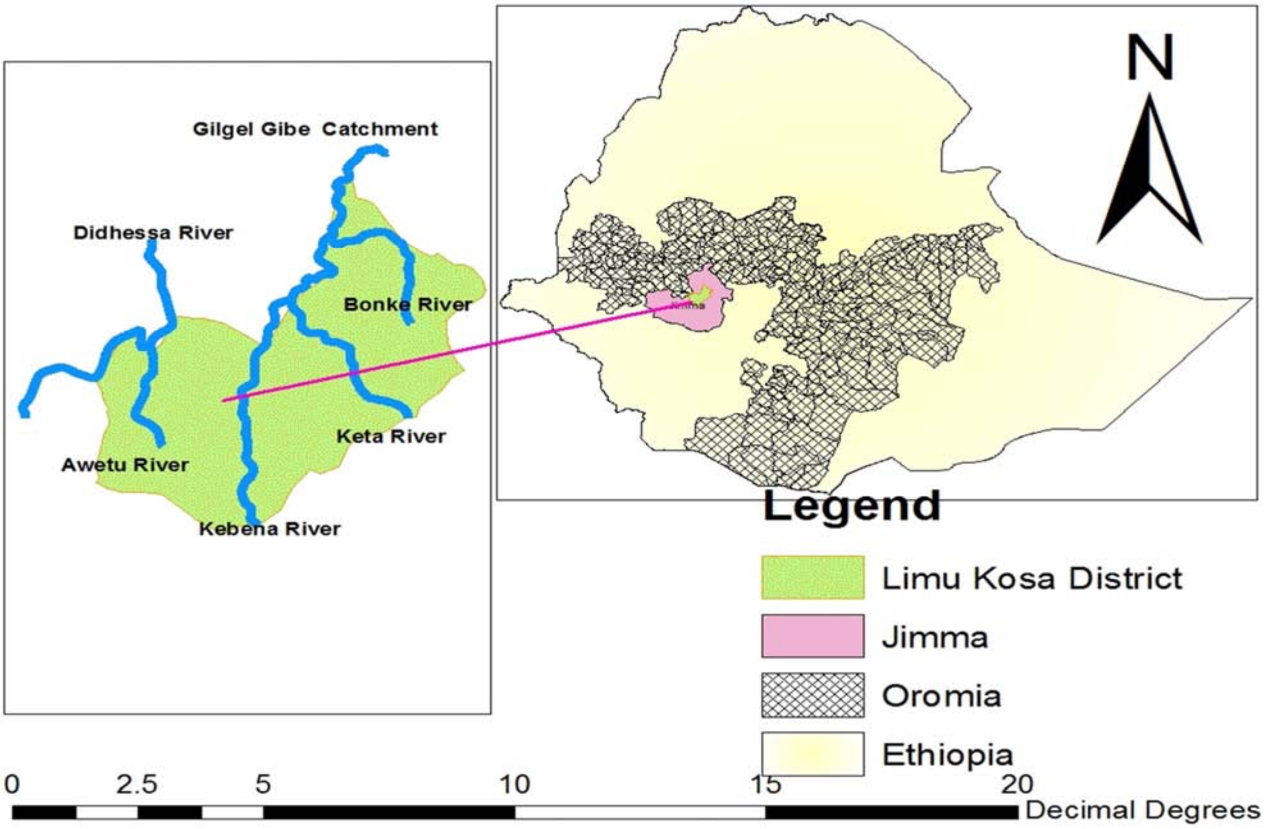

Figure 1. *Map of the study sample site area.*

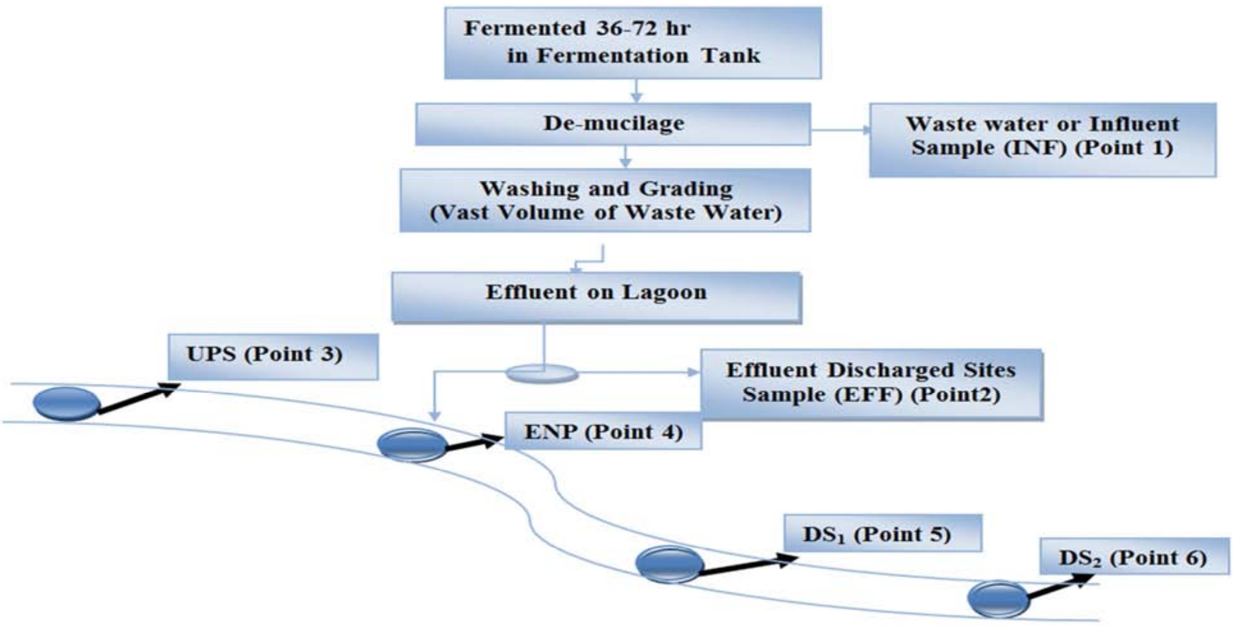

Figure 2. *Map indicating general flow diagram of coffee refinery and effluent sampling sites.*

2.2.2. Sampling Procedure of Physicochemical Parameters Data

Two liters of water samples were collected in sterilized plastic BOD bottles and glass bottles from each site, kept in a container with ice, and transported to the laboratory to maintain accuracy or minimize contamination of physicochemical changes that can occur between time of collection and analysis as indicated in America Public Health Association (APHA) standard method [13]. These 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. Water quality variables such as pH, water temperature, dissolved oxygen (DO), turbidity, and electrical conductivity (EC) were measured at in-situ using a HI 98290 multi parameter meter with a HI 7639829/10 probe (HANNA Instruments, Woonsocket, RI, USA). The probe was gently stirred in a 5-L bucket filled with river water for at least 40 seconds. The other water quality, chemical and biological samples were determined according to the APHA standard method [13] for the examination of water and wastewater as putted in the table below.

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

S.NO	Physico-chemical parameters	Abbreviations	Methods of sample analysis	Units
1	Water temperature	WT	Probes multi parameter methods	˚C
2	Turbidity	TURB	Turbidity meter	NTU
3	Electrical conductivity	EC	Probes multi parameter methods (EC meter)	µS/cm
4	pH	pH	Probes multi parameter methods (pH meter)	-
5	Total Dissolved Solids	TDS	Gravimetric Method, dried at 180°C	mg/L
6	Total Suspended solid	TSS	Gravimetric Method, dried at 103-105°C	mg/L
7	Total Solid (TS)	TS	Gravimetric Method, dried at 103-105°C	mg/L
8	Dissolved Oxygen (DO)	DO	Probes multi parameter methods (DO meter)	mg/L
9	Biological Oxygen Demand	BOD_5	The Azide Modification of the Winkler Method	mg/L
10	Chemical oxygen demand	COD	Kit (Hachlange cuvette test, LCk 614 &114)	mg/L
11	Nitrate-Nitrogen	NO_3-N	Phenoldisulfonic Acid Method	mg/L
12	Ammonia-Nitrogen	NH_3-N	Direct Nesslerization Method	mg/L
13	Total nitrogen	TN	Kit (Hachlange cuvette test, LCK 138 & 338)	mg/L
14	Orthophosphate	O-PO_4^{3-}	Stannous Chloride Method	mg/L

Source: APHA standard method [13].

2.2.3. Sampling Method of Benthos for Environmental Flows

Benthos community was sampled, identified, and quantified according to the method described, which is an internationally accepted kick-sampling procedure for benthos sampling. The sampling effort was equally divided into three (these three samples were taken cross sectionally: two corners and one center) over the different habitats per sampling site. Benthos sample was conducted three times from each riffle and runs sample sites. The sampling was realized via a 10-minute kick-sampling technique with a rectangular kicking net (20X30 cm) with a mesh size of 300 µm over a distance of 10 m Niels De Troyeret al. [14]. The organisms were sorted in the field and stored into labeled vials with an 80% ethanol solution. Afterwards, they were transferred to the lab for identification to family level using a stereomicroscope (10X and 20 X magnifications) and the identification keys of [15–17].

2.2.4. Data Quality Management

Certified standard methods were used for all procedure of the set of experiments. All reagents were of analytical grade and their expiry dates were checked. For each test, replicate sample analysis was made to maintain accuracy. Blank and control experiments were run. The results of all tests were honestly and cautiously recorded on a prepared data registration format APHA standard method [13].

2.2.5. Statistical Analysis

SAS version 9.2, Minitab Version 16.0 software and MS Excel, were used to analyses data. ANOVA were used to determine the significant difference of concentrations for various physic-chemical parameters and benthos assemblages. Benthos assemblages as biological indicators of Eflows were test by using benthos assemblage's multi metric indices. Mean separation of difference in concentration levels obtained for a given parameter along Eflows & sampling sites were considered as significant if calculated P-values were < 0.05. To evaluate its capacity of coffee wastewater (organic load) and nutrients treatment performance of the conventional lagoon pond (traditionally waste stabilization ponds) were calculated using following formula of [2].

$$\text{Removalefficiency } (\%) = \frac{(Cinf\text{-}Ceff)X100}{(Cinf)}$$

Where Cinf = initial parameter concentration and Ceff = final parameter concentration. Spearman rank correlations analysis was used to indicate the relationships between Eflows and benthos assemblage's variables to evaluate with among sampling site differences.

2.2.6. Ethical clearance

Ethical clearance was obtained from the Ethical Committee of the Jimma University, College of Agriculture & Veterinary Medicine (JUCAVM). The laboratory analysis was followed scientific procedures and the results were recorded honestly in data collection formats. In addition, authors of books and journals that are used were cited properly. Scholars, individuals, and organizations contributed for the successful completion of this study were also acknowledged.

3. Results

3.1. Significant Level of Physical Parameters Characteristics Between Eflows and Sampling Sites

The average mean values of water temperature were ranged between 12.11 ± 0.78-43.09 ± 0.78°C at Kebena UPS and Awetu EFF respectively. This result showed that highly significant difference in all sampling sites but very high 43.96°C in the Awetu EFF at ($p<0.05$ & 0.01). There were 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 not significant variation of EC & TDS in contrast to other sites. The EC was alarmingly increased with the increased in TDS & water temperature (Table 2). The observed turbidity mean values ranged from 3.3 ± 11.05-1363.67 ± 11.05 NTU at Bonke UPS & 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. Consequently, various analytical mean values of TSS & TDS were 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 & Ketalenca DS_1 to DS_2 respectively. These mean values of TSS & 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 & 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 bodies located nearby. These results showed that significantly increased values from DS_1 to DS_2 sites of the river water in TSS, but not significant differences from DS_1 to DS_2 in TDS (table 2).

Table 2. *Interaction effects of effluent discharges by conventional wet washed coffee refineries (CWCR) based on physical characteristics between Eflows and sampling sites.*

Mean separation of Physical parameters							
Rivers	**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	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	River*Site	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: 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 (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 0.01 as established by MSD test.

3.2. Significant Level of Chemical Parameters Characteristics Between Eflows and Sampling Sites

The average mean values of pH at 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 of obtained from the EFF (2.9) which was 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. The Kebena EFF and INF showed the lowest value of DO as 0.00 ± 0.10 mg/L. Level of DO in the river water was almost normal in the UPS (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 BOD and COD were recorded (2972.67 ± 30.27 to 2576.05 ± 30.37 mg/L) at Kebena EFF and INF with minimum values were recorded (2.36 ± 30.27 to 3.99 ± 30.37 mg/L) at Ketalenca and Bonke UPS. There was an increment of BOD and COD from (1773 ± 30.27- 1719.83 ± 30.37 mg/L) to (1797.89 ± 30.27 to 1836.40 ± 30.37 mg/L) at Kebena DS_1 and DS_2 then it decreased slowly towards the rest of the Ketalenca and Bonke of DS_1 and DS_2 respectively. TN concentration analysis revealed that 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 sites. The concentrations of NO_3-N and NH_3-N in the river water were found to be statistically highly significant and the average mean values were ranging from 2.43 ± 0.03 to 4.99 ± 0.07mg/L on the other hand it were higher concentration at all INF and showed that alarmingly increment from DS_1 to DS_2 due to high CWCR activities that ultimately discharge almost untreated effluent to the river (Table 3). The average mean values of O-PO_4^{3-} were showed that significant difference with all river water but not at DS_1 and DS_2 difference among all river water (table 3).

Table 3. *Interaction effects of effluent discharges by conventional wet washed coffee refineries (CWCR) based on chemical characteristics between Eflows quality and sampling sites*

Mean separation of Chemical parameters									
River	**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$^{H G I F}$	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$^{HG E F}$	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	2.41	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	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	River*Site	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Note: 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.

3.3. Capacity of Coffee Wastewater Treatment Performance of the Conventional Lagoon Pond

Capacity of conventional wet coffee wastewater treatment performance of the conventional lagoon pond (traditionally waste stabilization ponds) before disposed into environmental flows based on the physicochemical parameters during the sampling period were presented in table 4 below. The conventional lagoon pond (traditionally waste stabilization ponds) removal efficiency of organic load ranged between 20.89% to 10.52% and solids was 57.13% to -17.88%, and for nutrients, it was about 43.69 to 32.50%. Negative percentage recoveries showed that low adsorption level by efficiency of conventional lagoon pond (table 4).

Table 4. *Capacity of conventional wet coffee wastewater treatment performance of the conventional lagoon pond before disposed into environmental flows*

River	pH	BOD	COD	TN	Ort-P	TSS	TDS	TS	EC	TURB
Kebena	6.31	-10.52	-6.19	-6.26	42.45	-17.88	16.48	4.01	9.90	2.09
Awetu	-8.46	-2.25	6.69	6.19	43.69	-6.52	12.65	6.13	1.52	-0.07
Bonke	-16.90	15.99	20.89	-32.50	12.30	45.21	-4.35	14.76	22.60	-9.54
Ketalenca	23.52	5.77	4.07	-43.60	22.17	-31.32	57.13	32.64	13.88	-9.28

3.4. Spatial Distribution of Benthos Assemblages as Best Indicators of Bio-assessment of Environmental Flows

Species composition and distribution of benthos in four river water bodies nearby CWCR showed differences between them which based on the presence or absence of some specie. 1293 individuals belonging to 30 families in 8 taxonomic orders, were identified in the four major river water bodies nearby conventional wet coffee refineries during the survey. A total number of individuals found in the DS_2 were 387 as compared to 906 individuals collected from the UPS. The taxa of Ephemeroptera, Hemiptera, Trichoptera, Plecoptera, and Coleoptera were present in greater number in the UPS as compared to DS_2. On the other hand, pollution tolerant species of families Chironomidae, Simuliidae, and Leeches were present in greater number in the DS_2 sections throughout the experimental period (table 5).

Table 5. *Diversity indices of benthos in river water bodies nearby conventional wet coffee refineries.*

Rivers	F		S		D		H'		E	
	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
Bonke	9	6	169	54	0.88	0.63	2.14	1.32	0.97	0.74
Ketalenca	15	8	266	127	0.92	0.58	2.62	1.31	0.97	0.63
Kebena	13	3	205	49	0.92	0.50	2.54	0.87	0.99	0.79
Average					0.90	0.64	2.36	1.40	0.98	0.76

Analysis of the results of diversity indices of benthos in river water bodies nearby CWCR as biological indicators illustrated a highly significant difference between four rivers and all sites at ($p<0.05$ and 0.01).The analysis of the average species diversity indices of benthos as biological indicators (Shannon, equitability and Simpson) were much reduced in the DS_2 as against UPS very high were recorded throughout the experimental period (Tables 5 and 6). H' and D values decreased consistently from the UPS to the DS_2.

Table 6. *Results of ANOVA for diversity indices of benthos in river water bodies nearby conventional wet coffee refineries (CWCR).*

Mean separation of diversity indices of benthos					
Site	**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

Note: 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.

3.5. Pearson Correlation Matrix (r) Among Selected Physicochemical Parameters and Diversity Indices of Benthos as Biological Indicators of Environmental Flows

pH and DO exhibited that they are positively highly significant correlated with diversity indices of benthos, while BOD and COD have shown negative highly significant correlation with diversity indices of benthos at ($p<0.05$). Meanwhile, TN, NO_3-N and Orth-P has shown a 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 7. *Spearman rank correlations between environmental flow and biological variables determined at sampling sites.*

	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, NO3-N= Nitrate nitrogen, S= Specious richness taxa and TN= Total nitrogen).

4. Discussion

A good hydro-ecological integrity of river basin status of sampling sites in the UPS of Limu Kosa District areas were indicated by high proportion of pollution sensitive benthos, whereas, entry point segment receive huge volume of effluents that acts as physical-chemical barrier, which restrict the movement of benthos from DS_2 to UPS and vice versa. The results showed that the physicochemical parameter of the effluent discharged from conventional wet washed coffee refineries (CWCR) into the river water (Bonke and Ketalenca river water) decreased slowly toward DS_2, while into the river water (Kebena and Awetu river water) alarmingly increased towards DS_2. This deterioration of the ecohydrological integrity of freshwater systems river basin quality increases as soon as during the peak time of CWCR time alarmingly increasing rampant discharges into the river basin. The river water bodies located nearby were disrupted by most processing, because CWCR use large quantities of water for fermentation, receiving the cherries, transporting them hydraulically through the pulping machine, removing the pulp, and sorting and re-passing any cherries with residual pulp adhering to them as done by [2-3].

This result indicated that the declining at an alarming and accelerating rate of eco-hydrological system services provision based livelihoods of the people. Due to drawdown river discharge (hypoxia or anoxia) and increased temperatures and reduced water quality in peak time (mid September to mid of December) CWCR, 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 [18].

Benthos assemblages as biological indicators of Eflows were strong positive correlated with pH and DO, while negative correlations with BOD and COD showed that there was low oxygen levels river water bodies nearby CWCR [19]. They also found negative relationship of the mentioned benthos assemblages with variables associated to pollution (turbidity, conductivity, nutrients and total suspended solids) reflected a deterioration of the water quality nearby conventional we coffee refineries [20]. The results can lead to degradation of the level of oxygen in water, which can kill off virtually all aquatic life.

The level of assimilation and removal capacities efficiency of CWCR wastewater treatment systems (lagoon pond) that were intended to serve as effluent outfalls from CWCR from river ecosystem services were very poor. This result indicates that the coffee waste needs much more retention time to stabilize when compared to other organic wastes. This result revealed that conventional lagoon pond (traditionally waste stabilization ponds) is not an eco-friendly waste management option to treat the coffee wastewater effectively. Also the conventional wastewater treatment systems (lagoons) that were intended to serve as assimilation capacity and removal of effluent outfalls from CWCR were properly did not construct nor were they of the right dimension to accommodate the generated effluent during peak time of refineries [2]. Although this fact is widely recognized, lead to overflow of effluents into river water body nearby is a common occurrence. 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 CWCR [3].

5. Conclusion and recommendation

The effluents from CWCR are loaded with organic matter and are high in toxicity. The results can lead to degradation of the level of oxygen in river water, which can kill off virtually all aquatic life. High proportion of taxa of benthos assemblages (Ephemeroptera, Hemiptera, Trichoptera, Plecoptera, and Coleoptera) in the UPS as against high pollution tolerant species of families Chironomidae, Simuliidae, and Leeches DS_2 were recorded. CWCR effluents having contaminants are intensive incorporated with river water regularly. This study clearly revealed that Eflows were 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. Therefore, urgent intervention in the area of CWCR for effluent management options should be dealt with top priority to avoid further needless damage to the ecohydrological integrity and their development of river water quality using well designed treatment technologies (lagoons) for coffee waste treatment is highly recommended.

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