Investigation of Wastewater Discharges from Wet Coffee Processing Plant (WCPP) by using Aeration with Typha-latifolia Plant Treatment Process

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Abstract

The research was carried out to investigate wastewater discharge's technical viability from wet coffee processing plant (WCPP) treatments with aeration and Typha- latifolia plant. The WCPP wastewater was conducted at various aeration days (5, 10, 15, 20 and 25 days) after being irrigated for 21 days in the constructed wetland with Typha-latifolia plant and without a plant. The highest value of total solids, chemical oxygen demand and biochemical oxygen demand increasing were 87.8%, 97.4% and, 98.1%, respectively, in 25 days aerated with Typha-latifolia plant wetland. The Typha-latifolia with 25 days aerated WCPWW reduced 94.2% and 98.1% of NO_3-N and PO_4^3, respectively. As a result, the aeration days were increased with the removal efficiency of pollutants discharged from wet coffee processing plant increased with a constructed wetland with Typha-latifolia. It shows that aeration with constructed wetland treatment method was a low-cost, affordable, technically viable and eco-friendly treatment option for the wet coffee processing plant wastewater.

Key Words: Aeration, Constructed wetland, Coffee processing wastewater, Removal capacity and Wastewater treatment.

1. Introduction

In Ethiopia, more than 1,249 wet coffee processing plants were constructed near water bodies because the industries need a lot of water to wash wet coffee bean, removing the pulp and the mucilage (Dadi et al. 2018). The wastewater discharges from the process of wet coffee plants are directly into nearby streams and rivers without treatment, and it is the cause of environmental pollution and human health (Beyene 2014). Due to the problems, it is essential to treat wastewater discharge from wet coffee processing plant by using aeration with constructed wetland treatment before effluent to an environment. The pollutant parameters were characterized from October 1, 2020, to February 30, 2021, at Jimma University, Environmental Health Science and Technology Laboratory, Ethiopia.

1.2. Objective of the study

The main objective of this study to investigate wet coffee processing plant wastewater discharges treatment using aeration with wetland technology.

2. Literature Review

Coffee is a popular beverage and highly cultivated crops worldwide, and it is the largest consumed and traded commodity globally (Murty and Nadu 2012; Zerihun et al 2018; Ghosh, 2008). About 80 countries worldwide were cultivated coffee plantation and contributed to the world business sector (Murty and Nadu 2012). More than 8.2 million tons of coffees are produced in 2010/2011 in the world (USDA 2011). Globally around 2250 million cups of coffee are drunk every day (USDA 2011). More than ninety percent (90%) of coffee production occurs in developing countries, whereas utilization is mostly in industrialized economies (Bui 2017; Ponte 2002). Ethiopia is the beginning of highland coffee which is internationally traded coffee (Schmitt 2006). Coffee plays a crucial role in the incomes of the country population directly or indirectly (LCM 2000).

3. Methods

3.1. Experimental design procedure

3.2.1Aeration

The mixed wastewater was aerated at the rate of 0.016 L S^{-1} for various days duration. T1=WCPWW with 5 days aeration; T2 = WCPWW with 10 days aeration; T3 = WCPWW with15 days aeration; T4= WCPWW with 20 days aeration; T5= WCPWW with 25 days aeration. The aerated wastewater effluents were characterized by each treatment before used for wetland experiments.

3.2.2 Constructed wetland

The experiment was carried out with a constructed wetland with a plastic box (i.e. 0.45 m length x 0.20 m width x 0.27 m height). Each box was filled with gravel at the bottom, sand at middle and top by soil; then, the box was seated on the construction concrete stage by randomized block design method for Typha-latifolia plant and without plant (control) under greenhouse. The inflow rates for irrigated experiments were 0.037 L min^{-1} for all treatments with Typha-latifolia plant and controls for 21 days. Characterize the effluents of each treatment according to standards procedure [8] and calculated residence time using Eq. (1) is given below (APHA 1992; Crites et al. 1994).

$$Residencetime = \frac{PlantbedvolumexPorosity}{Coffeewastewaterflow} \quad (1)$$

4. Data Collection

4.1. Sample collection

Typha-latifolia plant is abundantly growing in Ethiopia. The plants' nurseries collected from various wetland areas. The wastewater samples were collected in plastic containers (polyethene jerrican) of 20 L capacity from Mana, Goma, Gera and Limu-Kosa District in Jimma Zone, Oromia, Ethiopia. The collected wastewaters were mixed in equal proportion (1:1 ratio) in the 200L storage container.

4.2. Physco-chemical characterizations of wastewater

The physio-chemical characteristics of wastewater used for the experiments are shown in Table 1. The wastewater samples were analyzed in the laboratory of Department of Environmental Health Sciences, Jimma University, Ethiopia, from October 2020 to February 2021. The wastewater was characterized as per the Standard procedure (APHA 1992).Characterization of wet coffee processing wastewater was carried out through total solids, biological oxygen demand, chemical oxygen demand, pH, and nutrients.

4.3. Analysis

4.3.1. Data analysis

Organic load, nutrient and total solid removal efficiency of aerated with constructed wetland treatment were calculated using Eq. (2) is given below (Clara 2005; Zerihun et al. 2018).

$$RemovalEfficiency\ (\%) = \frac{(C_o - C_d)x\ 100}{C_d} \quad (2)$$

Where: C_o =Initial parameter of WCWW concentration (mg L^{-1}) and C_d = Final parameter of treated WCWW concentration (mg L^{-1})

4.3.2. X-Ray Diffraction analysis

The soil structure was studied using an X-ray diffractometer (XRD) (Model No. XRD-7000, Shangai Drawell Scientific Instrument Co Ltd, China).

5. Results and discussions

5.1 Description of the study area

The study was carried out in Mana, Goma, Gera and Limu-Kosa districts located in Jimma Zone, around 19 km south-west, 55 km south-west, 75 km to the south-west direction and 25 km to the west of Jimma town, respectively. Jimma town is located 352 km from A. A. in South-west Ethiopia. Greater than 250 wet coffee processing industries (WCPI) were established in these four districts. It is indicated that these four weredas cover greater than 75% WCPI from the Jimma zone. These wet coffee processing plants discharge their wastewater into near water bodies without treat by using eco-friendly technology. These four weredas (districts) and Jimma town are lying between Latitude $7^0$33'(Gera district) up to $8^0$26'(Limu-Kosa district) North and Longitude $35^0$91'(Gera district) up to$37^0$36' (Limu-Kosa district)east and with an elevation of 1643m (Mana district) up to 1967m (Gera district) above sea level. The mean minimum and maximum annual temperature range between 20^0C and 32^0C, respectively.

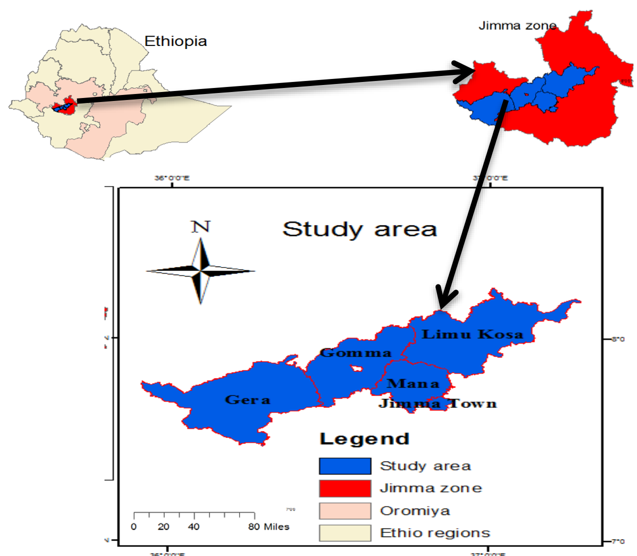


Figure.1. Location map of Gera, Gomma, Mana, Limu-Kosa districts and Jimma town

5.2. Characteristics of wastewater

Characteristics of raw wastewater (Table 1) were made in triplicate for each parameter. The instruments used for the analysis of parameter such as TDS and TSS by gravimetric method, BOD_5 by azide modification of the Winkler method, TN, TP and COD colourimetrically by DR 5000^{TM} UV-Vis spectrophotometer by using HACH instructions. Due to pectin and tannin's degradation results, the color of WCPWW was changed (Mendoza and Rivera 1998). The pH value was from 3.09 to 4.88 it indicates that the sugars changed to alcohol and CO_2. Then the alcohol is changed to acetic acid by the process of fermentation (Calvert 1997). The presences of total solids were high due to the biodegradable nature of wastewater. The BOD_5 value was from 3172 to 4432 mg L^{-1}, which shows that organic load amounts were high. Shanmukhappa et al. (1998) studied that BOD_5 amount 10,000–12,000 mg L^{-1} in CPWW. Due to the low degrading compound f COD amount (6070–7655 mg L^{-1}) in the WCPWW. Haddis and Devi (2008) in Ethiopia and Mburu et al.(1994) in Kenya, the finding of their study agreed with the result of this study.

Table 1. Physico-chemical analysis of wet coffee processing plant raw wastewater (WCPPRWW) and before aerated treatment

No.	Parameters	Raw CWW	The initial concentration of CWW before aeration treatment				
			T1	T2	T3	T4	T5
1	Colour (cu)	602±43	580±29	562±21	530±24	491±32	465±30
2	pH	3.50±41	3.83±0.15	4.14±0.67	4.08±0.76	4.13±0.61	4.15±0.73
3	EC (µs/cm)	735±50	1631±65	2047±63	2660±102	2730±68	2890±82
4	TSS (mg/L)	2907±68	2857±58	2566±79	2112±47	2015±38	2054±73
5	TDS (mg/L)	1940±69	1825±72	1805±47	1220±38	1025±43	925±54
6	TS (mg/L)	3820±69	3650±52	3290±76	3100±65	2900±98	2960±81
7	Turbidity(NTU)	729±21	511±68	793±14	801±26	577±58	188±79
8	DO (mg/L)	1.66±0.6	1.35±0.4	1.33±0.3	1.29±0.5	1.43±0.6	2.79±0.4
9	BOD5 (mg/L)	4322±110	4023±90	4244±62	4277±80	3484±64	3244±72
10	COD (mg/L)	7612±43	7224±49	7511±68	6554±110	6524±98	6174±104
11	BOD-COD ratio	0.57±0.01	0.56±0.01	0.57±0.01	0.65±0.01	0.53±0.01	0.53±0.01
12	NH4- N(mg/L)	10.78±0.32	7.12±0.43	7.04±0.64	8.9±0.86	9.74±0.62	9.3±0.81
13	NO3-N (mg/L)	260 ± 30	230±40	193±35	160±47	120±44	84±21
14	PO43 (mg/L)	10.48±0.4	8.15±0.9	7.15±0.8	5.3±0.8	4.33±0.8	3.19±0.9

5.3. Treatment of wet coffee processing wastewater

5.3.1. Treatment of Coffee Wastewater (CWW) using Constructed Wetland (CW)

The CW was processed at various hydraulic retention times of 5, 10, 15, 20 and 25 days in Table 2. The CW was irrigated with aerated CWW containing BOD_5 and COD amount from 3172 to 4357 and 6,070 to 7579 mg L^{-1}. The TS value from 2879 to 3702 mg L^{-1}. The pH range of 3.68–4.38. At 25days aeration with the Typha-latifolia plant after 21 days irrigated, the removal capacity for COD and BOD_5 was 97.4% and 98.1%, respectively. The highest removal capacity of TS by the Typha-latifolia Plant was achieved at 87.8%. The pH of treated effluent from Typha-latifolia ranged from 6.72 to 6.94.

Table 2 shows the efficiency of CW pollution amount decreased because of the aeration treatment of wastewater in various days' aeration. The CW treatment efficiency was increased both 25 and 20 days with Typha-latiolia plant wetland treatment and 25 days performed with higher efficiency than 20 days with Typha-latiolia plant. But, the amount of removal efficiency was different with days. For example, COD decreased by 18%, BOD_5 decreased by 15.2%, and TS decreased by 22.1% between 5 and 25 days of aeration. The difference in aeration days using Typha-latiolia plant with constructed wetland efficiency for the three parameters (COD, BOD_5 and TS) was the smallest amount, but the aeration days taken for pollutant decreasing were small five days compared with 25 days aerations. Aerobic treatment is good at 20 days aeration and 25 days aeration because COD of <250 mg L^{-1} according to the Central Pollution Control Board standards (Selvamurugan 2010).

Table 2: Removal capacity of Various Aeration days with constructed wetland

5.3.2. Aeration on CPWW

Aerated days with Typha latiolia plants (days)	COD (Raw CWW=7612mg/L)	BOD_5 (Raw CWW 4322 mg/L)	TS (Raw CWW 3820 mg/L)	NO_3-N (Raw CWW 260 mg/L)	PO_4 3 (Raw CWW 10.48 mg/L)
	Removal (%)	Removal (%)	Removal (%)	Removal (%)	Removal (%)
25	195 (97.4%)	82 (98.1%)	465 (87.8%)	15 (94.2%)	0.2 (98.1%)
20	235 (96.9%)	123 (96.9%)	760 (80.1%)	15 (94.8%)	0.2 (98..2%)
15	711 (90.7%)	363 (91.6%)	1023 (73.2%)	78 (70.0%)	1.1 (89.5%)
10	925 (87.8%)	486 (88.8%)	1268 (66.8%)	103 (60.3%)	1.7 (83.8%)
5	1564 (79.4%)	737 (82.9%)	1312 (65.7%)	147 (43.5%)	2.2 (79.0%)

The raw CPWW had contained; pH, EC, BOD_5, COD and TS of supply were 3.5, 735µs.cm^{-1}4322, 7612 and 3820 mg L^{-1}, respectively. The removal efficiency of BOD_5 and COD was 98.1% and 97.4%, respectively, after aeration treatments of 25 days and irrigated with 21 days. The maximum removal efficiency increase with increase aerations days increase due to additional supply of O_2 it is improved the degradation of organic matters. Vishnumurthi (2004), described that removed 98.98% BOD_5 from domestic wastewater due to the aeration process.

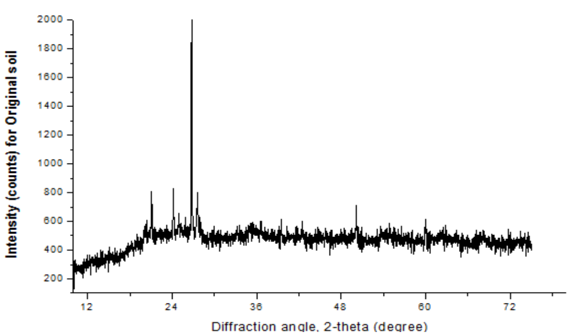
The removal efficiency of TS decreased with aeration days decreased by 87.8% for 25 days, 80.1% for 20 days, 73.2% for 15 days, 66.8% for ten days and 65.7% for five days. Choudhury et al. (1998), the removal capacity of TS was 54% wastewater from Kraft paper by batch aeration.

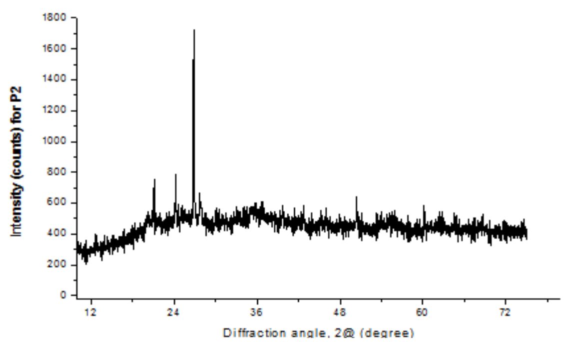
5.3.3. Constructed wetland treatment of WCPWW

The aerated CPWW with 5, 10, 15, 20 and 25 days were irrigated for Typha-latifolia and Control without plants for 21 days. The effluents result indicated that (in Table 4) from Typha-latifolia plants remove 98.1% of BOD_5 in aerated with 25 days WCPWW. A similar study indicated that the removal capacity of BOD_5 was 75% with the wetland process (Cooper 1993; Vymazal 2005). The TS removal efficiency of 87.8 % was shown in aerated 25 days CPWW treated with Typha-latifolia. The removal of total suspended solid shows in between75% to 89%. Sapkota and Bavor (1994), the removal capacity of total suspended solid in between 30% to 86% in gravel-based sub surface flow process.

5.4. X-Ray Diffraction (XRD) Analysis

The XRD analysis result is shown in Fig.2. The XRD analysis of the original soil before treatment and the sludge after treatment in constructed wetland shows that polymeric compounds present in the raw materials. All type of filling materials to constructed wetland system reveal diffuse peaks in the spectrum that peaks indicated the amorphous crystalline in nature and the soil contain metals (Ghosh et al 2008). A few small humps were described in the original soil's range and treated soil without plants (control that indicated an amorphous phase.





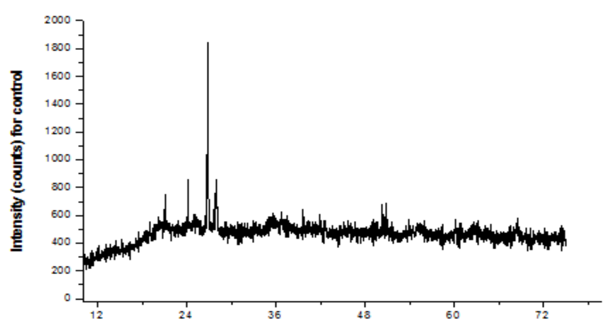


Figure 2. XRD analysis of before treated dried original soil, after treated dried soil from Typha-latifolia plant (P2) in CW, and without plant (control) in CW, respectively.

6. Conclusions

The above results may conclude that the wet coffee processing wastewater was appropriate for biological treatment. The discharged wastewater from WCPP followed by aeration and constructed wetland with Typha-latifolia plant were low-cost, affordable, technically viable and eco-friendly treatment technology.

Acknowledgements

The author would like to thank the Jimma University Institute of Technology, Ministry of Science and Higher Education, Ethiopia, and ExiST project (No. 51235, BMZ No. 201166305) funded by KfW (Germany) for their financial support. I am also thankful to the wet coffee processing industry owners Prof. A.Venkata Ramayya, Mrs. Saskia, Dr. Adnew, Mr. Zewudu and Mrs. Meskerem, for their assistance during Postdoctoral research.

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Biography

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