Chemical Oxygen Demand
Flow Rate Effect on Total COD and the Particulate/Soluble COD Ratio

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Sustainability IRES

1. Abstract

A Decentralised Wastewater Treatment System (DEWATS) located in Durban, South Africa was designed and constructed for technical evaluation. As part of this evaluation, total chemical oxygen demand (COD) and soluble COD analysis were conducted using a titration method. Samples were taken from the first and last chambers of the anaerobic baffled reactor (ABR), effluent from the anaerobic filter, and horizontal flow planted gravel filter (PGF) by manual grab sampling. Samples (before and after centrifugation) were then digested with potassium dichromate and the excess was determined by titration with ferrous ammonium sulfate to calculate COD. A significant reduction of total COD was discovered throughout the ABR chambers of the DEWATS, and particulate COD decreased the most throughout the wetlands. COD indicates the oxygen demand of biodegradable and non-biodegradable pollutants and gives a general idea of water quality.

2. Introduction

Bremen Overseas Research and Development Association (BORDA) designed and implemented the DEWATS plant in Durban to treat wastewater from about 80 households to determine its technical limitations and operational procedures. It is already known that the system uses anaerobic digestion processes to reduce COD, and anaerobic filters to further reduce it. Part of the motivation of this project is to determine in the stream can be used for irrigation, as water with too much COD would deplete plants of oxygen. COD is a parameter that measures the organic matter in wastewater and indirectly determines an overall water quality. It is typically measured titrimetrically or using a spectrophotometer (Barker et al., 1999).

3. Methods

In order to conduct the experiment, wastewater samples were collected from the DEWATS system using manual grab sampling. Samples were taken from the influent and effluent of the ABRs, the effluent of the anaerobic filters for streets one and three, and the effluent of the horizontal planted gravel filter for street one only. The titrimetric method was used for COD. Total COD samples were diluted with deionized water by one milliliter of sample per five milliliters of total solution. Soluble COD was prepared by centrifuging the sample with no dilution. The sample, in duplicate, and the blanks are then digested for 1 hour and 45 minutes in the *Ethos One High Performance Microwave Digestions System* with potassium dichromate and sulfuric acid. Organic matter in the sample partially reduces the potassium dichromate, and excess is titrated with ferrous ammonium sulphate (FAS), and the COD value is calculated from the milliliters of titration and standards. Equations for the reduction of potassium dichromate are as follows (UKZN-PRG, 2013).

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3-} + 7H_2O$$

$$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 6Fe^{3+} + 7H_2O + 2Cr^{3+}$$

4. Results

COD analysis was conducted on street one 30 June through 8 July, and on street three 13 July through 15 July. COD values (Table 3.1 and Table 3.2) were obtained using the milliliters of titration in a calculation spreadsheet using the equation:

$$\text{COD (mg/L)} = \frac{\text{(Blank - Titration) x molarity of FAS x 8000}}{\text{Sample (ml)}}$$

Results show that COD in the whole system improved throughout the week and was relatively similar at each stage of the system (Figure 4.1). 9:00 most often had the lowest concentration (Figure 4.2). The highest COD concentrations occur at 11:00 and greatest COD reduction is observed between ABR 1 and 7 for street one (Figure 4.3). Particulate COD, which is the difference between the total COD and soluble COD lines, is most noticeably reduced throughout the wetlands (Figure 4.4). In street three, contrarily, total COD was more noticeably reduced in the anaerobic filter and no significant change was seen in particulate COD (Figures 4.5 and 4.6). When compared to flow rate data that was collected on 13 July, as flow rate increases, COD concentrations increase as well (Figure 4.7). For total COD, samples were measured in duplicate. The values were graphed as a mean, maximum, and minimum, shown by the high-low bars. The size of the bars suggest the analysis had high precision.

Table 4.1 Street One COD

		30 June		2 July		6 July		8 July	
		COD	CODs	COD	CODs	COD	CODs	COD	CODs
9:00	ABR 1 in	532.77	267.31	--	--	572.26	245.50	749.15	278.31
		570.82				539.80		376.60	
	ABR 7	327.27	275.27	--	--	312.51	144.79	117.44	207.95
		296.83				312.51		214.62	
	AF2	220.72	170.25	--	--	190.76	196.72	117.43	123.52
		228.33				215.11		117.43	
	HPGF	76.11	108.20	--	--	117.70	103.87	12.15	87.56
		121.77				142.05		52.64	
11:00	ABR 1 in	627.91	313.46	540.99	259.67	894.94	407.61	441.39	243.91
		627.91		628.51		708.66		336.11	
	ABR 7	384.55	--	365.96	179.41	295.61	240.79	311.81	182.93
		361.52				263.22		328.01	
	AF2	262.58	117.74	445.52	132.20	157.93	152.65	174.13	118.83
		277.80		437.57		198.42		214.62	
	HPGF	140.80	81.15	159.12	97.57	141.73	127.47	93.14	70.36
		148.41		143.20		101.24		125.53	
13:00	ABR 1 in	642.29	318.23	--	--	688.41	299.02	328.34	198.57
		586.78				566.93		320.52	
	ABR 7	380.62	214.81	--	--	275.36	215.61	625.41	121.95
		428.19				259.17		211.07	
	AF 2	214.10	120.93	--	--	153.88	146.36	132.899	71.92
		229.95				153.88		171.99	
	HPGF	126.87	84.33	--	--	72.89	124.33	109.45	42.21
		158.59		--	--	121.48		85.99	

Table 4.2 Street Three COD

		13 July		15 July	
		COD	CODs	COD	CODs
9:00	ABR 1 in	536.25	306.92	448.38	--
		528.37		422.51	--
	ABR 4	370.65	220.77	431.14	--
		370.65		439.76	--
	AF2	252.35	137.69	189.72	--
		276.01		267.30	--
11:00	ABR 1 in	488.94	246.92	435.08	--
		504.71		381.18	--
	ABR 4	354.87	225.38	381.18	--
		386.42		350.37	--
	AF2	189.27	125.38	257.97	--
		165.61		227.16	--
13:00	ABR 1 in	557.69	348.46	508.23	--
		596.15		446.63	--
	ABR 4	465.38	254.62	408.13	--
		365.38		400.43	--
	AF 2	311.54	146.92	238.72	--
		303.85		277.22	--

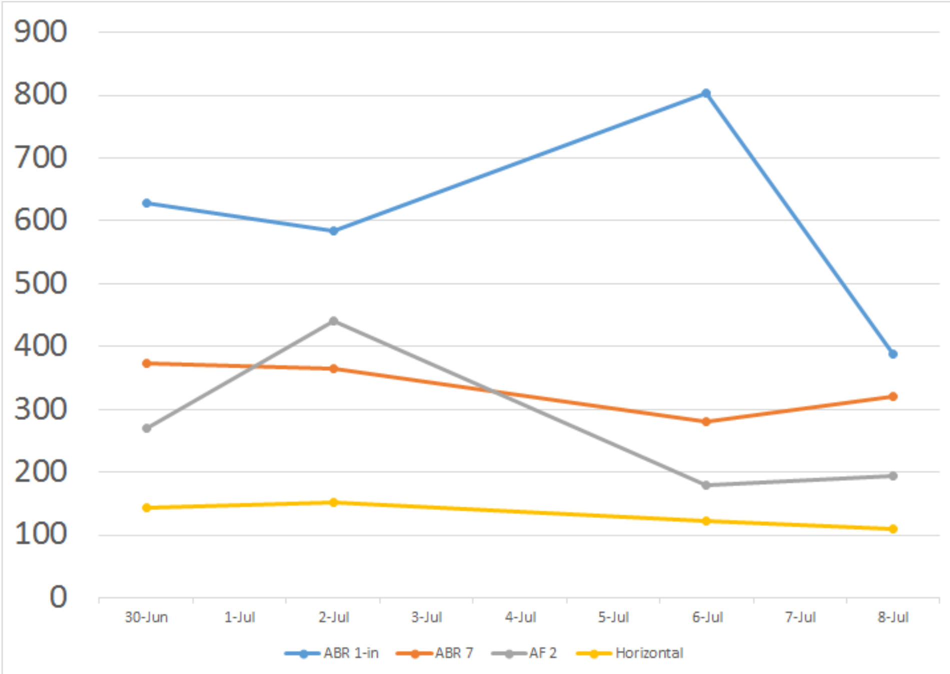


Figure 4.1- Chambers in street one over time

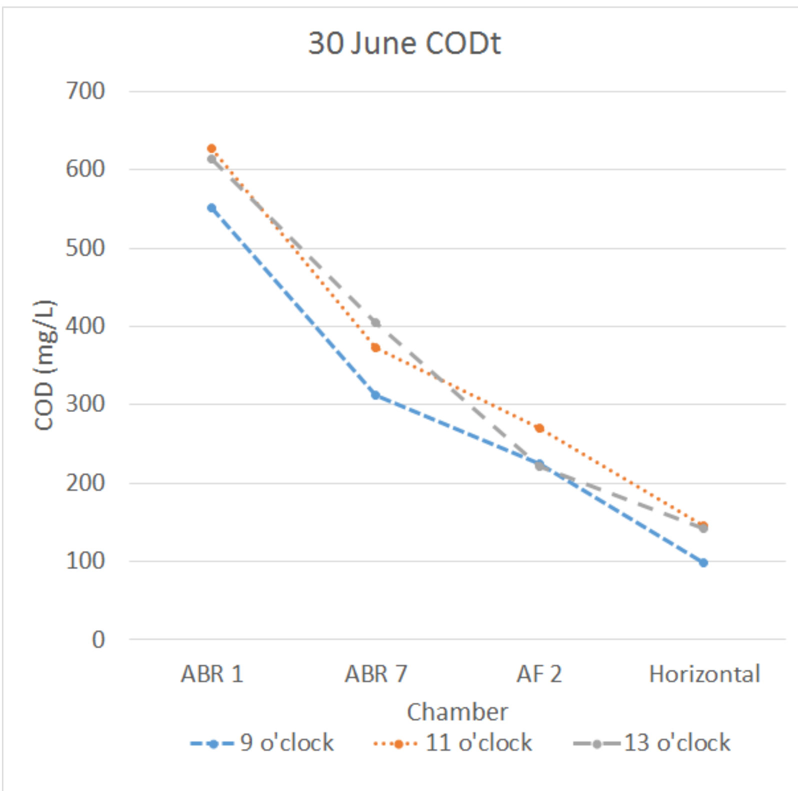
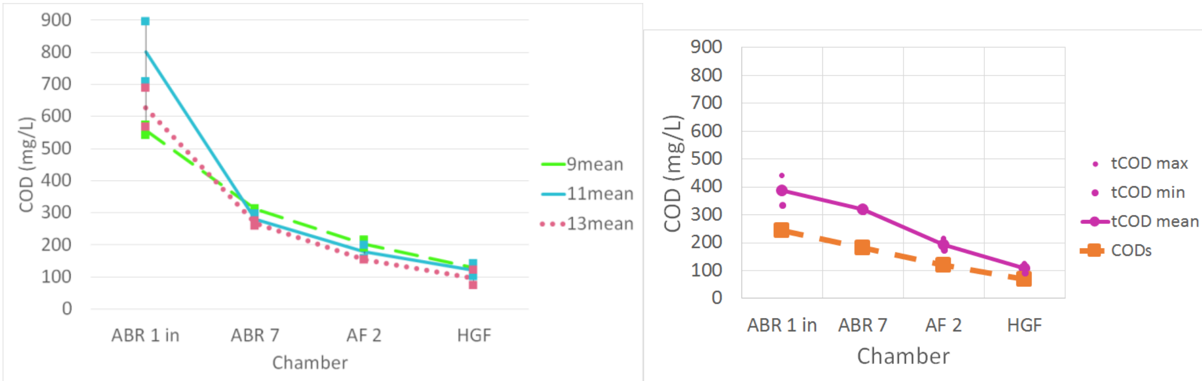
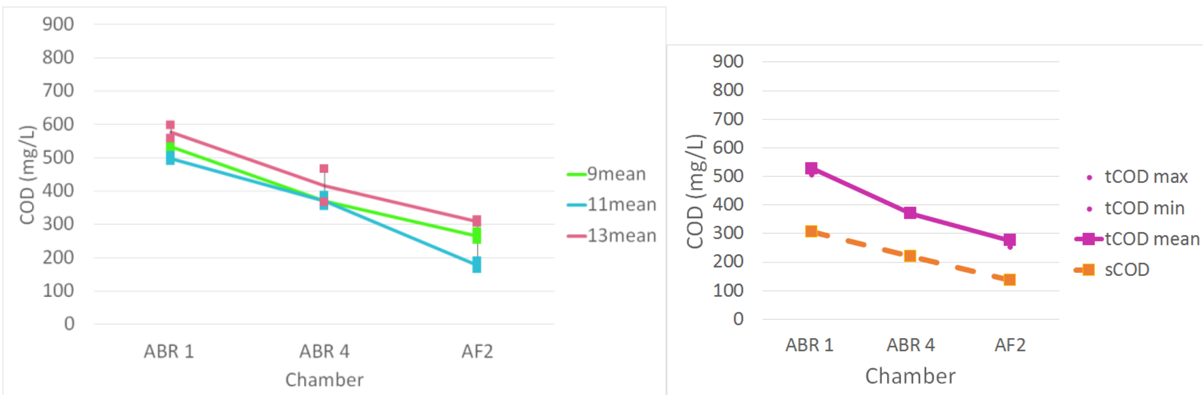


Figure 4.2- Chambers of street one throughout the day



Figures 4.3 and 4.4 - Results of street one, total COD and soluble COD



Figures 4.5 and 4.6 - Results of street three, total COD and soluble COD

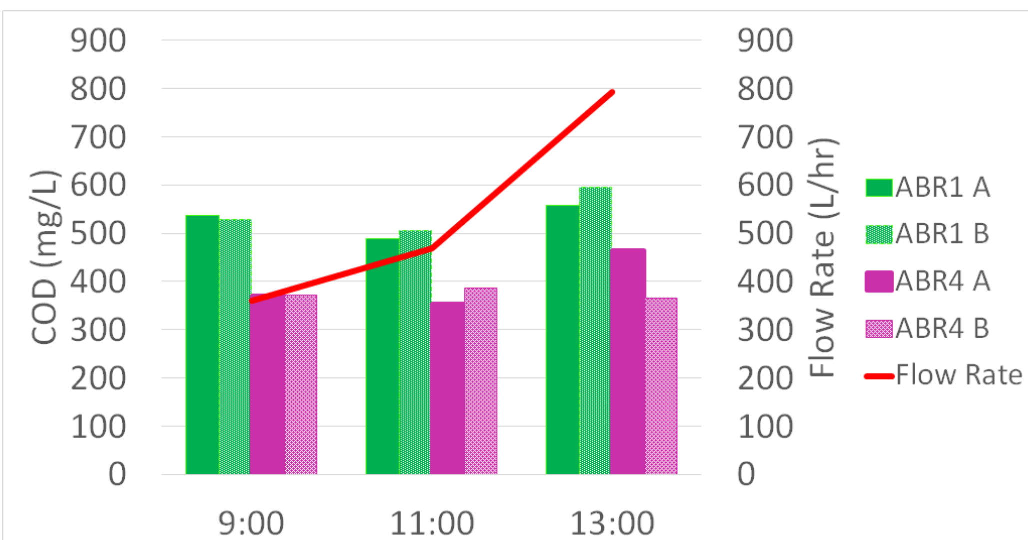


Figure 4.7 - Total COD, shown in duplicate, compared to the flow rate over time.

5. Discussion

In general for July, the flow rate peaked around 13:00 when COD values were the highest. Flow rate affects the retention time between the wastewater and the sludge layer, so the higher the flow rate, the shorter the contact time, which may account for a higher COD. The DEWATS system consistently reduced COD to about 400 mg/L in street one and street three, however, further reduction of both total and particulate COD through the anaerobic filters and the planted gravel filters are necessary. Street three's faster flow rate in July could account for the four ABR chambers being less efficient than street one's seven. According to another study conducted on COD in wastewater effluents, the general effluent limit is less than 75 mg/L, which, after anaerobic treatment, can usually only be obtained through post treatment (Barker et al., 1999). Total COD at this plant did not often drop below 100 mg/L. However, during the weeks of experimentation, the plant's effluent was not at its cleanest aesthetically, though it was improving. Additional recommended analysis would include sampling from street one and street three at the same times on the same day to give a better comparison of the two streets.

6. Conclusion

Flow rate affects total COD based on contact time. The higher the flow rate, the higher the concentrations of COD will be because the wastewater has less time in contact with the sludge layers. Additionally, in street one, significant reduction of total COD was seen throughout the ABR chambers, while most of the particulate COD was reduced in the filters. Street three was less efficient overall, but it had the highest flow rate during the study. The results of this study and future studies will evaluate the DEWATS system in meeting the water sanitation needs at a local level.

References

Barker, D.J., Mannucchi, G.A., Salvi, S.M.L., Stuckey, D.C. Characterisation of soluble residual chemical oxygen demand (COD) in anaerobic wastewater treatment effluents, *Water Research, 33(11), 2499-2520,* 1999.

Standard Operation Procedure - Chemical Oxygen Demand Closed Reflux, Titrimetric Method. Pollution Research Group. 20 June 2013.

Appendix A - Field Sheets