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An Overview of COD Load Removal at Glen Valley Reactivated Sludge Wastewater Treatment Plant

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Abstract: The objectives of this study were to assess the Chemical Oxygen Demand (COD) load removal at the conventional aerobic and the anaerobic routes of the Gaborone City Council, Glen Valley wastewater treatment plant and to assess the efficiency of the various sections of the treatment process in COD load removal. The Gaborone City Council Wastewater Treatment Plant at Glen Valley combines both the conventional and the anaerobic systems of waste water treatment. The reactors have a total volume of 301874 m^3 with anaerobic reactor volume of 189000 m^3 inclusive. A total of 1711 tonnes of COD was removed monthly and 56.3 daily over a five month study period at the conventional aeration process unit whilst the Secondary Digester removed monthly 1.02 tons and 34 kg daily. Both reactors therefore removed 1712 tons of COD monthly and 57.2 tons daily. The performance of the anaerobic digesters in COD load removal was poor (3.5%) due to unfavourable pH, temperature and high volatile acid to total alkalinity ratios (poor buffering capacity) during the study period. For efficient performance from the digesters, the temperature, pH and the volatile acid to total alkalinity ratios must be rigidly monitored to generate the required environment for micro flora activity.

Key words: COD, digesters, Glen Valley, organics, treatment, reactor, activated sludge

INTRODUCTION

Chemical Oxygen Demand (COD) was defined as the measured amount of oxygen needed to chemically oxidise the organics present in wastewater[1]. The less polluted the wastewater is, the less oxygen needed to chemically oxidise the organics present hence the less or smaller the COD value. This definition also implies that an efficient wastewater reactor would turn out effluent with very low COD values compared to what it receives. Indeed high COD load removal by anaerobic reactors have been used as criteria for wastewater treatment plants efficiency in China, India, Philipines, Taiwan, Thailand, Brazil and Mexico[2].

The Gaborone City Council Wastewater Treatment Plant was commissioned in 1997 to treat about 40000 m^3 of effluent daily from Gaborone and its enclaves with a population of about 250000 people. Presently, an average of 30000 m^3, is received daily. This comes from domestic households, chemical industries, Brewery, Slaughter houses (abattoirs), schools and health facilities.

In Gaborone, the major sources of COD loads are the Breweries, Chemicals and Paints, food and beverage industries[3].

The treatment plant combines both the conventional aerobic reactor with anaerobic reactors which are known for high COD load removal efficiency.

The total volume of the reactor components add up to 301874 m^3 comprising two Primary Settling Tanks (PST), Ten Aeration Tanks (AT) (eight axic zones and two anoxic zones), Four Secondary Settling Tanks (SST), Three anaerobic Primary Digesters (PD) and One Secondary Digester (SD).

Incoming township effluent mixes with vacuum tanker discharges into the Inlet Well (IW) where the combined effluent is sieved to remove coarse particles and grits. It is then aerated and channelled into Primary Settling Tanks (PST) where primary sludge is removed. From here, the effluent enters the Aeration Tank (AT) proper where, COD nutrients removal as well as denitrification take place. The primary treatment the effluent receives at the Inlet well and the PST reduces its COD load as primary sludge is removed. The initial aeration also continues the processes of organic matter breakdown. From the AT, the effluent enters the SST where clear supernatant effluent is continuously overflowed into channels to the polishing ponds. Old sludge is continuously wasted into the sludge thickening tanks to remove more water from it before it is pumped into the Primary Digesters (PD) and then into the secondary digester (PD).

The objective of this study was to ascertain the COD load removal by Gaborone City Council wastewater treatment plant monthly and daily and also the efficiency

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of the various treatment points in COD removal over a period of five months, August to December, 2003.

MATERIALS AND METHODS

Sampling of test samples was carried out in line with the Treatment Plant's general sampling method[4] with BOBS ISO 5666:1999 (Botswana Bureau of Standards) procedures.

Daily effluent inflow was monitored on SCADA equipment in the main control Process Room and logged every 2 h on 24 h basis. The monthly total was used to determine daily average effluent.

COD loads were determined at the IW, PST effluent and the SST effluent twice a week. Along the anaerobic line changes in the Volatile suspended solids loads of the Primary and the secondary digesters effluents were used to determine the COD load removal.

The closed reflux method of sample digestion and titrimetric method as outlined in[5] was used to determine the COD loads of the test samples. 2 mL of distilled water (blank) and test samples were pipetted into 16x100 mm borosilicate culture tubes containing 2 mL of digestion solution of normality 0.125 N Potassium dichromate ($K_2Cr_2O_7$) prepared by accurately weighing on a Precisa XT 220A, 6.129 g of a previously dried Potassium dichromate at 140 0C for 2 h and 20 g of Mercuric sulphate ($HgSO_4$) and dissolved in 500 mL of distilled water. 100 mL of concentrated sulphuric acid (98%) was added by continuously stirring with a magnetic stirrer. The solution was cooled to laboratory temperature and then transferred to 1 L volumetric flask and diluted to volume with distilled water and stirred continuously by magnetic stirrer. Next, 3.5 mL of catalyst solution prepared by the addition of 20 g of Silver sulphate ($AgSO_4$) to 2.5 L of concentrated sulphuric acid (98%) and allowed to stand overnight after a period of stirring with magnetic stirrer, was added slowly down the side of the culture tube to form a clear layer at the bottom of the tube. The cap was replaced and the tube tightly closed and the reagents mixed thoroughly by shaking. After cooling to laboratory temperature, reaction tube was placed in COD reaction block digester preheated to 150°C and then refluxed for 2 h. The tubes were cooled to room temperature. The contents were then transferred into a 250 mL conical flasks, 15 mL distilled water was added and in addition, two drops of Ferroin indicator prepared by adding 0.98 g of ferrous ammonium sulphate hexa-hydrate (FAS) to 80 mL of distilled water and then adding 1:10 Phenonthroline monohydrate stirred to dissolve.

This solution was then diluted to 100 mL with distilled water and then stored in a dropper bottle. The final solution was then titrated with 0.025 N FAS solution standardized with 0.025 N $K_2Cr_2O_7$ solution. In preparing the FAS solution, 9.8 g of FAS was weighed into a conical flask containing 80 mL of distilled water. 25 mL of concentrated sulphuric acid was added and the solution quantitatively transferred into a one litre volumetric flask and diluted to volume with distilled water. This solution was prepared prior to the analysis so as not to lose strength.

RESULTS AND DISCUSSION

Table 1 shows that an average of 952577400 L of effluent was received monthly during the study period containing an average load of 1950.3 COD mg L^{-1} of effluent received. This gives an average load of 1840598.1 and 1840.6 kg and ton COD/month, respectively as shown in Table 2. In Table 3, an average COD load removal of 93.6% was calculated for the five months under study period given a monthly average COD load removal of 1711 tons and daily average removal of 56.3 tons at the aerobic end.

Table 1: Total monthly effluent received m^3 L^{-1} and average monthly COD load (L^{-1} mg^{-1})

Months	Total effluent received (m^3)	Total effluent received (L/M)	Average monthly load COD (mg L^{-1})
August	1022922.0	1022922000	1645.5
September	783140.0	783140000	2658.1
October	1083896.0	1083896000	2188.2
November	986665.0	986665000	1768.4
December	886264.0	886264000	1491.1
Mean	952577.4	952577400	1950.3

Table 2: COD loads in kg/month and tones/month inflow for each month under study (Aerobic line)

Months	Load COD (kg/month)	Load (ton COD/month)
August	1683218.151	1683.2
September	2081664.434	2081.7
October	2371781.227	2371.8
November	1744818.386	1744.8
December	1321508.250	1321.5
Mean	1840598.100	1840.6

Table 3: COD load removal efficiency between the inlet works and the secondary settling tank in percentages used to calculate the total COD removal loads monthly and daily (Aerobic)

Months	Average monthly % COD removal; Inlet works: secondary settling tank	Total COD load removal (ton COD/month)	Daily load removal (ton COD/day)
August	98.7	1661.3	55.4
September	97.3	2025.5	67.5
October	85.2	2020.8	65.2
November	90.1	1572.1	52.4
December	96.5	1275.2	41.1
Mean	93.6	1711.0	56.3

Table 4: Performance of the anaerobic digesters in COD load removal and average monthly acid-alkalinity ratios, pH and average monthly temperature as monitored during the study period

Months	Average % monthly COD load removal	Total COD load (ton COD/months removal at full capacity	Average monthly VAA/TA ratio (expected: ≤0.3)	Average pH (6.8-7.2)	Average monthly Temp. (°C) (expected:35-38)
August	16.6	3.8	0.2	6.8	24.5
September	0.5	1.0	0.2	7.0	24.1
October	0.0	0.0	2.5	6.8	24.5
November	0.0	0.0	5.4	6.8	27.9
December	0.3	0.3	0.5	7.5	22.0
Mean	3.5	1.02	1.8	7.0	24.8

Table 5: COD load removal efficiency (%) monitored per treatment point along the aeration line

Months	Inlet well and primary settling tank effluent	primary and secondary settling tank effluent	inlet well and secondary settling tank effluent
August	4.1	98.6	98.7
September	39.4	95.6	97.3
October	44.8	64.1	85.2
November	35.8 (increase in load)	93.7	90.1
December	19.6	95.7	96.5
Mean	27.0	89.5	93.6

Table 6: Total COD load removals, monthly and daily by treatment plant (Both the Aerobic and the Anaerobic lines)

Months	Total COD load removal (ton COD/Month) A + AN	Daily COD load removal (ton COD/day)
August	1665.1	55.5
September	2026.5	67.6
October	2020.8	65.2
November	1572.1	52.4
December	1275.5	45.5
Mean	1712.0	57.2

A: Aerobic; AN: Anaerobic

Within the various sections of the aerobic treatment line, IW and PST effluent, PST effluent and SST effluent, COD load removal efficiencies of 27 and 89.5% averages, respectively over the study period (Table 5). The efficiencies at the IW and the PST were generally low and indeed in November there was an increase in COD load rather than removal. This was because sludge was wasted into the PST influent instead of the Thickening Tank sump because of faulty equipment at the sump, which therefore was out of use hence the increase in load over the IW load. For general COD load removal, not much was expected within this part along the treatment line since only a brief aeration and grit, primary sludge removal takes place. This might necessarily not lead to high COD load removal. At the Primary and secondary settling thank effluent; this is where much change is expected in COD load removal. Here, COD is removed in the aeration tank through the breakdown of organic matter aerobically by microbes. So as the AT operates efficiently denitrification as well as nutrients removal takes place in addition to COD removal which cumulatively lead to breakdown of organic matter to the elements of N_2, C as Co_2, P as Po_4 etc.

During the study period, the AT operated at maximum efficiency and full capacity hence the high level of COD load removal.

The contribution from the anaerobic line to the total COD load removal (Daily and Monthly) was non-significant (Table 4 and 6).

The total COD load anaerobically removed was 1.02 tons/Month (Table 4) and this gives a daily load removal of 0.034 tons COD/day compared to the 56.3 COD/day at the Aerobic end (Table 3). The months of October and November were very poor since no removal was noticed. The only significant contribution was in the month of August where 16.6% removal was observed given 3.8 tons COD. The very low temperatures monitored for the Digesters; 24.5 to 27.9°C instead of the expected range of 35 to 38°C could be responsible for this poor performance by rather very high efficiency reactors as, microbes were handicapped in terms of adequate heat.

Also, apart from the first two months (August and September) and the last month (December), the volatile acids to alkalinity ratios were too high for the efficient functioning of the reactors. This was initially thought to be responsible for the below average performance of the digesters as a result of lack of adequate carbonates to neutralise the volatile organic acids being produced to create the necessary pH conditions. However from Table 4, it was only in December that the pH was above the range at 7.5. Hence the actual lacking parameter might be adequate temperature (heat) but not pH. A study was done on a total of 338 anaerobic wastewater reactors in 26 sub-tropical countries[6]. Out of this number, 4 were African countries. Total COD removal, ton COD/day for the 338 reactors was 7476.1 given an average of 22.1Ton COD/day.

In South Africa Republic, 3 reactors were mentioned with 41.0 COD removal ton COD/day given an average of 13.7 ton COD/day. In Malawi, 1 reactor discharged 1.1 ton COD/day whilst in Kenya, a higher figure of 100.8 ton COD/day was given although the volume of the reactor was not mentioned. In Mauritius, a lower figure of 0.8 ton COD/day was recorded. Comparatively, the anaerobic line in Glen Valley wastewater treatment plant was performing below expectation at 34 kg COD/day during the study period considering its total volume.

In India, studies undertaken in 1996 on 96 Industrial cum municipal wastewater treatment plants gave a total of 3674 tons of COD/day, an average of 37.1 ton COD/day[6]. The Glen Valley Treatment Plant also treats effluent from both Industrial and Municipal sources.

In addition, a combination of 274 reactors in Brazil, India, China, Mexico, Philippines, Taiwan and Thailand were known to remove cumulatively 6418 ton COD/day an average of 23.4 ton COD/day[2].

Chemical Oxygen Demand (COD) is a very important pollution indicator in wastewater quality assessment as it gives an idea about the totality of effluent pollution indices. Significant reduction in initial loads after wastewater stabilisation is important if wastewater discharges into environment guidelines are to be met. Discharge of effluent of high COD load into the environment or water courses could lead to the reduction in dissolved oxygen to aquatic flora and fauna. This could negatively affect fish stock as some types of fish can not survive in very low dissolved oxygen environment. It is documented that when water is polluted (high COD load) with an effluent, there is usually a fall in the total number of species of organisms, change in the type of species present and a change in the number of individuals of each species in the water[7]. The result is consequent destabilisation of the aquatic food chain which can be harmful to the existing water course ecology.

The anaerobic line at Glen valley results in the discharge of secondary sludge. Because of the low COD load removal observed during the study period, it is important that this sludge was properly disposed off in a manner not to contaminate the environment.

However, for total and dependable treatment efficiency, it is important that the anaerobic line is well monitored and all physical and chemical parameters such as temperature, pH, acidity and alkalinity well controlled. The poor performance of the anaerobic line was as a result of below average performance by all these parameters in the Digesters. The volatile acid forming and the methane forming bacteria are very sensitive to these parameters and any slight changes in their optimum operational levels significantly affects their efficiency as revealed in the low COD removed in the digesters. The near 100% performance by the aeration line indicated the general efficiency of the aeration zone.

REFERENCES

1. Glynn, H.J. and W.H. Gary, 1996.Environmental Science and Engineering. Prentice-Hall International Inc. New Jessey, pp: 424-425.
2. Fang, H.H.P. and Y. Liu, 2001. Anaerobic Wastewater Treatment in (Sub-) Tropical Regions. In: Advances in Water and Wastewater Treatment Technology. Matsuo, T.K. Hanaki, S. Takizawa, H. Satoh and E. Armsterdam, pp: 285-293.
3. Emongor, V., E. Nkegbe, B. Kealotswe, I. Koorapetse and S. Sankwasa, 2005. Pollution indicators in gaborone industrial effluent. J. Applied Sci., 5: 147-150.
4. Hammer, M.J. and M.J. Hammer, Jr., 1996.Water and Wastewater Technology. 3rd Edn., Prentice Hall International, USA, pp: 125-130.
5. APHA, AWWA, WPCF, 1995. Standard Methods for the Examination of Water and Wastewater. 19th Edn., Washington, D.C.
6. Matsuo, T., K. Hanaki, S. Takizawa and H. Satoh, 2001. Advances in Water and Wastewater Treatment Technology. Elsevier, Tokyo, pp: 285-295.
7. Horan, N.J., 1996. Bilogical Wastewater Treatment Systems. Theory and Operation. John Willey and Sons, New York, pp: 36-37.