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Carbon Abatement in Wastewater Stabilization Ponds Case Study of Dandora Waste Water Stabilization Ponds in Kenya

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Abstract :*This research has attempted to estimate and compute the greenhouse gases, primarily methane, emissions from Dandora Sewage Treatment Plant (DSTP) in Nairobi Kenya using the Intergovernmental Panel in Climate Change (IPCC) Guidelines (1996) and IPCC Good Practice Guidance (2000).Operations data from year 2007 to year 2013 was obtained from Nairobi City Water and Sewerage Company (NCWSC), the operator at the plant and analysed to determine the average BOD loading rate and flows to the Plant as well as the BOD removal rate across the anaerobic ponds from which the amount of methane being generated by the DSTP was computed. The average BOD loading rate and effluent to and from the anaerobic ponds of DSTP was 454.11mg/l and 120.82 mg/l respectively between year 2007 and 2013.This was 88.7% of the design capacity of 512mg/l. The plant received an average of 83,648.30 m3/day which was 52.28% of the design capacity of 160,000m3/day from year 2007 to year 2013.This represented a BOD mass loading of 37,985.53kg/day against a designed capacity of 81,920kg/day which was 46.37%.Thus DSTP has been operating at about 50%.The plant generated an average of 11.29m3/day of methane from year 2007 to year 2013 at the current flows and can generate an average of 14.1m3/day of methane at a full capacity of 160,000m3/day at a BOD loading of 512mg/l. Methane generated from the anaerobic ponds at the plant can be collected using floating covers and be used to generate electricity that can be imported into the national grid at a feed in tariff ,be used in operations of the plant or be sued for carbon credits. This would increase revenue to the operator as well as prevent methane being released into the atmosphere as it is the case now.*

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I. Introduction

The solution to making decisions of controlling and reducing the rate at which Methane (CH_4) increases in the atmosphere is by recognizing and quantifying the sources, both natural and anthropogenic. [1].The United Nations Framework Convention on Climate Change (UNFCCC) is worldwide renowned source for common action on the lessening of greenhouse gas emissions [2]. One of the important requirements for participating countries under the UNFCCC is the assemblage of yearly greenhouse gas (GHG) register for the individual countries that covers four broad sectors of Energy and agriculture, Land Uses, industrial processes, and waste among others. Reports on Methane Emissions and nitrous oxide emission from wastewater treatment under the waste sector [2]. However, computations of GHG emissions is not normally done directly, but rather estimated through the usage and adoption linking emissions to data recoverable from activities linked to these emissions. Increases of GHGs concentrations in the atmosphere have led to further studies of GHGs estimation, sources and sinks. Wastewater treatment plants receive wastewater as influent and produces treated waste water for discharge by using different processes such as anaerobic treatment, aerobic treatment, and mix of the two types of treatment. On-site greenhouse gases emissions are generated by solids treatment processes, liquid treatment processes, and the burning of biogas and remnant fuels for energy production. Off-site greenhouse gases may also be produced because of solids dumping such as transportation and degradation away from site where solids are from [2].

1.1 Anaerobic Lagoons

One specific sub-set of ponds is anaerobic ponds, which are those ponds where anaerobic conditions exist throughout the water column, as well as in the sludge layer on the floor. Anaerobic treatment is achieved by obligate anaerobic bacteria and it is essentially the conversion, under anaerobic conditions, of organic matter to 'biogas' – that is methane and carbon dioxide [2]. Biogas is a valuable fuel which, at large plants (e.g. the modern waste stabilization ponds at Melbourne, can be profitably recovered to generate electricity. Anaerobic digestion proceeds in four stages .These stages are hydrolysis which breaks down complex wastewater organics into simple digestible sugars. This is followed by Acidogenesis which is the anaerobic oxidation of fatty acids and alcohols and the fermentation of amino acids and carbohydrates to volatile fatty acids and hydrogen gas. The next stage is Acetogenesis which is the conversion of butyrate and propionates from Acidogenesis stage to acetates which is finally followed by the Methanogenesis which is the final stage and converts acetates, hydrogen and carbon dioxide, to methane [3]. Many anaerobic and facultative bacterial species are responsible for Stage 1, such as Bacillus, Clostridium, Proteus, Micrococcus, Staphylococcus and Vibrio. As concerns about environmental impacts have increased in the last few decades, one of the issues which is receiving attention is that of the impact treatment plants are having on the environment, beyond that of discharge of treated effluent and the fate of sludge and other by-products .These impacts include direct Green House Gases (GHG) emissions from the process construction and operation as well as indirect effects such as GHG emissions from power generation. Based on operational experience, however, it is known that emissions from any given process will vary in response to factors such as flow, concentration of organics, pH, temperature and contamination. In addition, design of the process will also influence emissions. Determining a basis for more accurate estimation of gas generation rates will enable more effective assessment of GHG aspects of wastewater treatment.

II. Objective Of The Study

This study aims to establish the amount of Methane being produced by the anaerobic ponds at Dandora Sewage Treatment Plant (DSTP) in Nairobi Kenya using the Intergovernmental Panel in Climate Change (IPCC) Guidelines (1996) and IPCC Good Practice Guidance (2000).

III. Dandora Estate Wwtp

This plant is Located 30 km from East of Nairobi in Kenya, (DEWWTP) features the largest wastewater stabilisation pond in Africa, treating 80,000 m³/day of waste water generated in Nairobi currently. The plant consists of intake works of 160,000 m³/day consisting of Screens and Grit chambers for primary treatment before eight series of ponds comprising of Anaerobic, Facultative and Maturation ponds. The plant has a total of 23 anaerobic ponds with series one carrying two and the rest three ponds each as described in

Table III-1below [4].

Table III-1: Details of Anaerobic ponds at DEWWTP

Series	Number of Ponds	Size of Ponds	Arrangement
Series 1	2	70m by 35m	Parallel
Series 2	3	70m by 35m	Parallel
Series 3	3	65m by 65m	Parallel
Series 4 to 8	3	120m by 90m	Parallel

Each series has 1 fulcaultaive pond measuring 700m by 300m with 3 maturation ponds measuring 300m by 150m in parallel in series 3 to 8.Series 1 and 2 have each 3 maturation ponds in series measuring 300m by 300m as shown in Figure III-1 below. After treatment, this the effluent is discharged into Nairobi River.

Figure III-1: Pictorial Representation of DEWWTP

IV. Data Analysis

This study analysed the influent and effluent BOD_5 loading across the anaerobic ponds at DESWWTP from year 2007 to year 2013.The average BOD loading to DSTP was 454.11 mg/l for the periods between years 2007 to 2013.This represented 78% of the design capacity of 512mg/l. High loading were observed to occur in the months of January to March and July to October due to less rains which could have resulted into reduced volumetric loadings as depicted in Table IV-1 below .

Table IV-1:Daily BOD loading to DSTP from 2007-2013

YEAR/ MONTH	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
2007/2008	280	480	218	261	282	247	240	270	301	279	232	304
2008/2009	383	416	417	417	403	427	524	586	652	590	518	531
2009/2010	655	784	907	781	650	609	369	540	499	315	331	257
2010/2011	428	523	522	516	272	379	581	517	359	498	477	391
2011/2012	373	387	364	338	287	221	299	442	384	276	163	231
2012/2013	294	306	379	318	247	198						
AVERAGE	402	483	468	438	357	347	403	471	439	392	344	343

The BOD loadings were observed to have gone up in the year 2008/2009 and year 2009/2010 which could be attributed the improvement of the Plant that was carried out including Desludging of the Lagoons .The plant was also fitted with mechanised equipment at the Inlet works including programmable Logic System (PLC) which from the information gathered during the visits to the Plant later failed leading to shutting off of the fine Screens and Grit Chambers. The effluent BOD averaged at 79mg/l from year 2007-2013.The levels were on average 49% higher than the recommended standard of 30mg/l by National Environmental Management Authority (NEMA) of Kenya as shown in Table IV-2 .This could be attributed to the Failure of the programmable Logic system in year 2010 that led to the shutdown of the intermediate screens, the Fine (cup screens) and the grit chamber which had been automated in the year 2008 when the Inlet works were expanded from a capacity of 80,000m3/day to the current capacity of 160,000m3/day.

Table IV-2: BOD effluent standards (mg/l) from DSTP

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
2007/2008	98	81	55	32	46	62	40	67	57	54	97	79
2008/2009	96	106	117	117	89	101	132	100	110	112	113	118
2009/2010	109	129	158	113	108	83	77	67	79	63	73	59
2010/2011	111	136	150	116	146	51	75	86	62	94	64	86
2011/2012	75	60	64	60	61	34	28	54	50	53	35	29
2012/2013	36	37	51	47	48	35						
Average	88	91	99	81	83	61	70	75	71	76	76	74
% above NEMA Standard of 30mg/l	58%	61%	69%	51%	53%	31%	40%	45%	41%	46%	46%	44%

The observed BOD removal averaged at 67%.this compared well with the designed BOD removals of 52% at a temperature of 16^oC [5].At the mean temperature of 22^oc, which was the mean of the observed temperature at the plant, the designed BOD^5 removal would be 64%.However, the plant has been operating with three anaerobic ponds against the designed two anaerobic ponds and at an average temperature of 22^oC which is above the designed operating temperature of 16^oC. This has resulted into reduced volumetric loading to each anaerobic pond under loading the ponds and higher operating temperatures which attributes to the slightly increased efficiency by three percent.

V. Results And Discussion

During the study, data for these years was collected from the operator at Dandora Sewage Treatment Plant and analysed for the amount of methane that was being produced in that was being produced in this period. It was noted that the plant was operating at about 50% of its design capacity and organic loading in terms of BOD. The highest period in which the maximum biogas was produced was from December 2008 to June 2009 when the plant received the highest amount of flows. These flows could be attributed to the high amount of rainfall received in this period due to the Elnino phenomenon experienced at the time which could have swept organics accumulated in sewers to DSTP.This is as depicted in **Error! Reference source not found.** below.

Table V-1 daily methane generation from 2007-2013

Year	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
2007/2008	7.76	13.31	6.05	7.22	7.82	6.85	6.65	7.49	8.34	7.74	6.42	8.44
2008/2009	10.60	11.52	11.57	11.57	11.17	11.84	14.52	16.25	18.07	16.35	14.37	14.71
2009/2010	18.16	21.72	25.16	21.67	18.01	16.90	10.23	14.98	13.83	8.73	9.18	7.13
2010/2011	11.87	14.51	14.47	14.30	7.55	10.52	16.11	14.34	9.96	13.81	13.23	10.85
2011/2012	10.34	10.73	10.09	9.36	7.94	6.12	8.30	12.26	10.64	7.66	4.53	6.40
2012/2013	8.16	8.48	10.50	8.82	6.84	5.50						
Mean	11.15	13.38	12.97	12.16	9.89	9.62	11.16	13.06	12.17	10.86	9.55	9.51

VI. Conclusions

The plant is currently producing an approximately 8.3m3/day of methane at the current flow of 83,648m3/day The plant can generate an average of 14.12 m3/day of methane while operating at full capacity of 160,000m3/day. Biogases capture and reuse systems for anaerobic waste water treatment lagoons are the simplest and easiest ways of biogas operation. Instead of investing in a new centralized aerobic treatment plant to avoid anaerobic treatment at DSTP, covering the existing anaerobic lagoons with suitable covers and extracting the captured biogas is an economically feasible means to reduce methane emissions and utilising the gases for economic benefits. The DSTP can utilise the captured and recovered methane as a source of fuel to produce electric power by employing reciprocating engines and turbines. Power produced at the waste water treatment plant can be utilised on site thereby saving the plant operations from purchased power. DSTP can also treat and refine the captured biogas and sell it as liquefied pressurised gas (LPG) in LPGs cylinders to homesteads or industries to be used as cooking gas and thus generating revenue coupled with prevention of the emissions into the atmosphere. Through Methane capture and use at wastewater treatment facilities, DSTP can be able to realise the following benefits among others:

- Reduced GHGs and associated air pollutants.
- DSTP can provide an onsite source of energy to run the plant.
- DSTP can convert the emissions into a source of revenue.
- DSTP can create a renewable source of energy to replace power consumption at the plant.
- The capture and conversion of the methane gas at the plant can create jobs related to project construction and operation.

The capture and utilisation of the gas emissions will enhance the Operator's (NCWSC) image as innovative and Sustainable ways of managing waste water in the city.

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