

Original Research Article

Mitigating Climate Change through energy recovery at Dandora Wastewater Treatment Plant, Nairobi County, Kenya

ABSTRACT

The world is experiencing an increase in the rate of greenhouse gases emissions accumulating in the atmosphere due to natural and anthropogenic causes. These gasses absorb and emits radiation within the thermal infrared range thus contributing to the Green House effect. The building up of greenhouse gasses beyond the natural acceptable levels can change the earth's climate thus contributing to climate change. To mitigate climate change, there is need to cease the increase of greenhouse gases either by not adding them into the air and or increasing the earths' ability to withdraw them out of air. This study looked into mitigating climate change through energy recovery at Dandora wastewater treatment plant in Nairobi. The study employed both primary and secondary data. Operational data on the raw sewer chemical oxygen demand and biological oxygen demand levels was collected from the plant between 2007 and 2013. MS excel was used to analyze the data in order to cipher the trends of biological oxygen demand & chemical oxygen demand loadings and removals and thus estimation of biogas and methane likely to be generated and energy recovery thereof. The relationship between these two variables were tested through a Correlation coefficient test. The two-level computations estimated the daily biogas generation at the treatment plant as 2738m³. The study estimates methane generated to be equivalent to 68398MJ/Day of energy. Considering the calorific value of LPG of 46MJ/kg, this is equivalent to 495 cylinders daily serving 2974 households daily. The findings indicate that recovery of energy from the Plant mitigates climate change through reduction of emissions by 16 tCO₂-e per day. The energy recovered had a positive correlation with the emission reduction at a high value of $r = 0.99$. The study concludes that energy recovery from wastewater treatment plant reduces emission thus mitigates climate change.

Keywords: Climate change; greenhouse gas, energy recovery, global warming

1. INTRODUCTION

The world is experiencing an elevated rate of greenhouse gases (GHGs) brought about by natural and anthropogenic causes. These greenhouse gases blanket the earth, trapping sun's heat in the atmosphere and increasing temperatures making it warm, a phenomenon referred to as the greenhouse effect. When the greenhouse gases build beyond the natural acceptable levels, they can alter the earth's climate thus having negative effects on natural ecosystems as well as on human health.

This study focuses on Methane as a greenhouse gas. The waste sector (Anaerobic waste treatment and main sewer) contributed approximately 9% of total global CH₄ emissions in 2006 (US EPA 2006). Furthermore, the Green House Gas emissions factsheet of 2017 by USAID estimated emissions from agricultural sector as 62.8%, energy sector as 31.2%, industrial processes sector as 4.6%, and lastly waste sector (1.4%) (USAID, 2017). Anaerobic wastewater treatment plant is the main human sources of methane gas which is the focus of my study.

The treatment and technology employed in a wastewater treatment plant dictates the type of greenhouse gas emitted therein. (Letting *et al*, 1999). Effluents from wastewater treatment plants generate methane (CH₄) when treated anaerobically. Biological decomposition of organic matter and pollutants is one of the well-developed methods of environmental conservation through remedial specialty in handling wastes and wastewater (J.H Reith *et al*, 2003). Biogas is the by-product of anaerobic digestion; biogas is a gaseous fuel that is made up of about 60% methane and 40% carbon dioxide (J.H Reith *et al*, 2003). Methane when purified, can serve as an alternative energy source (Lord and Gregory, 2010). These greenhouse gases if not collected and recycled will prevent the emission of heat from the earth back into the space. This results in increased temperatures on the Earth's surface and creating global warming. Due to multidimensional applicability of carbon footprints, there is a huge scope to apply it in the context of Wastewater Treatment Plants in terms of emission control, energy generation, and, credits for bio energy (Snip and Keesman, 2009).

This study focused on climate change mitigation through energy recovery from a wastewater treatment plant. Energy will be recovered through utilization of methane produced from the effluent waste. Methane produced can be utilized for domestic use as green energy instead of the other non-renewable energy sources; but most captivatingly, it will go a long way in ensuring that the greenhouse effect is kept to a minimal.

Sewage management or effluent waste management continues to be a big issue in Kenya, polluting environmental mediums like the air, land and water sources. For instance, given today's technological development, these effluents can be treated anaerobically and this yields biogas that creates energy (Alexander, 1998). In Kenya, the application of anaerobic digestion has been applied in treating sewage in major towns including the Dandora Waste Water Treatment Plant (DWWTP) in Nairobi. It is evident that DWWTP is one among the largest such treatment plants in Kenya

Specifically, due to high population density in Nairobi County, the increasing levels of urbanization, and the enormous amount of waste that is produced in both solid and liquid forms (Gebbie, 2013).

The total average industrial and domestic effluent waste inflow at the DWWTP may rise to about 250,000 m³ per day in the year 2025 (Gebbie, 2013). This rapid increase in the average effluent inflow at DWWTP is directly proportional to the overall increase in biogas production. Methane in biogas is one of the potent atmospheric pollutants and it's estimated that its global warming potential (GWP) is 21 times more than that of carbon dioxide (CO₂) (Waluszewski,2010). Biogas generated at this facility has not undergone any measurement and is released to the atmosphere without being harnessed leading to emission of greenhouse gases and air pollution. For this reason, this study aims to contribute towards the reduction of climate change impacts through energy recovery at DWWTP. The energy generated can be utilized at the community using it for heating as well as cooking purposes.

2. Literature review

2.1 Greenhouse gasses

There are fears born out of anthropogenic activities that have modified climate patterns globally. These major concerns include the release of gases such as GHG into the atmosphere. Data shows that in 2013 estimated 60.2 MtCO₂e (metric tonnes) of GHGs emissions were recorded in Kenya (GoK,2016). The emissions accounted for 0.13 percent of the total global GHG emissions. The emissions were generated by the following sectors: agricultural sector (62.8%) energy sector (31.2%), Industrial sector (4.6%), and waste sector which contributed 1.4% (Climate links, 2017). According to Parsons et al., (1996), methane gas is a significant global warming element causing climate change. In the last 300 years, atmospheric methane increased by about 150%, its average content has increased nearly threefold compared to preindustrial times (IPCC, 1997).

2.2 Impacts of climate change as a result of increase in greenhouse gasses

Some of the notable impacts of climate change include rising temperatures and heatwaves (Rayhan et al.,2023), melting icecaps and rising sea levels (Rayhan et al.,2023), altered precipitation patterns and extreme weather events (EPA, 2009), Destruction of ecosystem and biodiversity loss, migration and extinction of species (Droste, 1997), threat of food security and agriculture (Braber 1995), human health challenges, displacement and migrations, treats to water resources among others. The main challenges experienced in Kenya include extreme weather patterns and threat to food security (GoK,2016).

2.3 Environmental benefits of capturing biogas

Kenya joined the international community in addressing climate change challenges by signing and ratifying the United Nations Framework Convention on Climate Change (UNFCCC) on 30th August of 1994 Kenya. The key objective of the Convention is to limit greenhouse gas concentration in the atmosphere to a level which would avoid dangerous manmade interference with climatic systems. The UNFCCC is the accepted international standard for worldwide cooperation in controlling anthropogenic GHG emissions. The UNFCCC requires every signatory country to produce an annual national inventory of GHG emissions for the previous year, divided into four general categories (energy; industrial processes; agriculture, deforestation and other land use; waste). So far, 90 countries have submitted plans to the UNFCCC proclaiming intentions of cutting emissions by 2020. This includes 48 developing countries (UNFCCC, 2004).

Kenya is a signatory of both the UNFCCC and has ratified Kyoto Protocol, meaning it has an obligation to participate in international climate change events such as annual Conference of The Parties (COP) on Climate Change. In 2006 the UNFCCC held its 12th Conference of Parties (COP) in Kenya. The Nairobi framework is the most significant product and aims to assist developing countries, particularly those in Sub-Saharan Africa, in getting involved with the CDM (NEMA, 2015)

Kyoto Protocol 1997 defines three variable approaches to help parties listed in Annex I meet targets set by COP 2 of UNFCCC:

- Clean Development Mechanism by which a certain amount of Certified Emission Reduction (CERs) can be generated by investing in non-annex 1 parties.
- Joint Implementation (JI) refers to the generation of credits for investments in emission reductions between Annex I countries.
- National portion of emitters International Emission Trading (IET), lets a country sold to one that has failed to meet its target.

This study on the generation of renewable energy from wastewater can pass as a Clean Development Mechanism and be accorded premium as per the CDM National Clearing House (NCH). One of its objectives is to quantify the level of emission reduction that can be achieved by converting methane to energy rather than it being released freely into the atmosphere. This is because this project can be taken up by Annex 1 countries as a means to reduce their emission targets. Since CC is a global matter then both sides will have benefitted from such investments Kenya being able to minimize emissions as well as eradicate poverty by providing alternative cheap energy for cooking.

2.4 Research Gap

According to the Energy Regulation Commission, there are eight thousand plants producing biogas in Kenya. The plants utilize various raw materials-such as agricultural waste, slaughterhouse or municipal wastes etc. There is however a challenge in accounting for all biogas produced in Kenya because there is no verified concrete data making it difficult to assess biogas potential in Kenya (Otieno, 1998).

This study aims at giving an estimation of biogas produced at Dandora Wastewater

Treatment Plant in order to be able to estimate the energy equivalent of the same. This study can then be replicated in other treatment plants in Kenya with the overall aim of determining the carbon footprints of wastewater treatment plants in Kenya.

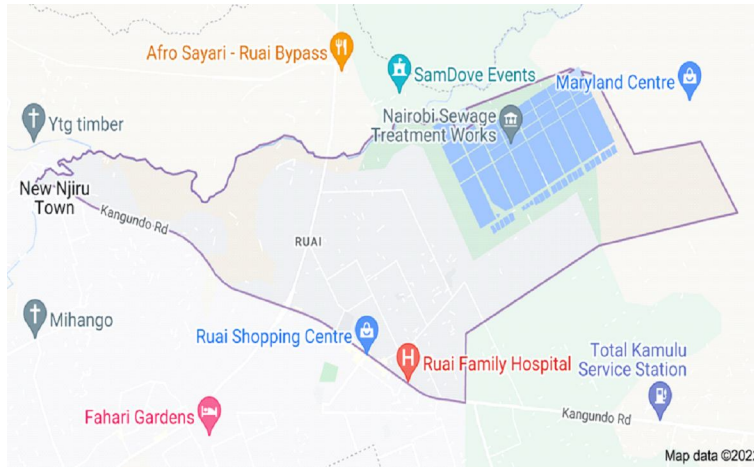
3. material and methods

3.1 The Study Area

This research was conducted at Dandora Wastewater Treatment Plant (DWWTP). DWWTP is located 30km to the East of Nairobi Central Business, at latitude $1^{\circ}14'S$ and longitude $37^{\circ} 15'E$ (Figure 1). It is designed to treat about $120,000m^3$ of sewage per day (80% of Nairobi's wastewater). The map below shows pictorial view of the treatment works site.

Figure 1: Map of DWWTP (Source: Meteorological Department)





The arrangement of the ponds is shown in **Figure 2** below;
 Figure 2: Layout of DWWT (Source: Google Earth, 2013)

3.2 Data collection and type

The study employed both primary and secondary data. Operational (secondary) data on the raw sewer in mg/l, COD and BOD levels was collected from DWWT which has been documented between 2007 and 2013. These years were settled on since the data was more consistent than all the other years. Additional primary data was collected in 2013 to confirm the consistency of operational data obtained from DWWT. This synthesized data was then analyzed in excel sheet to calculate the BOD loading and removal rates, total methane generated, thus energy equivalent and the emission reduction equivalent using the formulas given in the subsequent sub sections. The entire study was structured into tasks that were performed during the proposed study period as summarised below to achieve study objective;

- Computation of biogas generated at the Dandora Treatment Plant

Objective (i) was computed by following two steps as mentioned below;

Step 1: Estimation of BOD loadings and removals

(Formulas as per Mara, 2003).

Step 2: Computation of Biogas Generation

The emission of methane from wastewater treatment at DWWT was calculated according to (Mara, 2003) and (Pearson et al,1996) formulae.

The key variable in the methane estimation from domestic and commercial wastewater

is the Biochemical oxygen demand (BOD) from wastewater anaerobically treated.

From data analysis, the annual, monthly and daily averages of the BOD and COD effluent from the anaerobic ponds was computed to give the annual monthly and daily averages of the BOD and COD removals.

Biogas Generated = 90% of BOD Removed. (Mara, 2003)

- Computation of energy equivalent of biogas produced.

The second objective was completed after computation of energy equivalent of biogas produced by following the steps mentioned below;

(IPCC, 2006) and (Mara, 2003)

(Mara, 2003)

- Computation of emission reduction equivalent of converting biogas to energy

IPCC Guidelines for National Greenhouse Gas Inventories, (2006) were used to calculate Greenhouse Gas Emissions from Wastewater treatment plants. In principle, the IPCC has defined remaining methane emission as the total quantity of methane emission less the quantity of methane prevented from getting into the atmosphere through recovery (IPCC,2006).

(IPCC,2006)

In other words;

Emission getting into the atmosphere is the Net emission (NE), Total generated emission is the Gross emission (GE) and Methane prevented from getting into the atmosphere is the Recovered Methane, methane recovery (MR) or potential emission reductions (PER).

The computation is as follows:

(IPCC,2006)

- **Data Analysis and presentation**

Data was analyzed by use of MS excel. The results were presented in tables, bar charts and pie charts together with a summarised explanation in relation to the literature.

Correlation analysis was used to test relationship between the quantitative variables. In this case biogas generated, energy equivalent and emission reduction estimates.

Pearson correlation coefficient was then used to test the relationship between the two variables.

- **Research Design**

Correlation was used to discover the relationship between biogas converted to energy and climate change abatement. Correlation research design was chosen since it helps in prediction of future occurrences.

4. results and discussion

- **Daily inflows and outflows**

From the analyzed data between 2007 and 2013, it was apparent that the average inflow at the plant was 83648 m³/day which is about 52% of the design capacity of 160,000m³/day.

Table 1: Average flows at DWWTP

Year	July	Augt	Sept	October	November	December	January	February	March	April	May	June	Average
2007/08	75422	87857	82113	75486	92791	85980	77239	78911	81952	104251	91040	89672	85226
2008/09	74547	78882	78659	78659	100455	78529	63091	76219	72072	70889	86916	87709	78886
2009/10	75382	62910	51303	59030	82627	81692	107164	79672	96303	125069	120738	96378	86522
2010/11	86375	87126	89420	79561	91020	95458	82444	79244	80783	82644	83213	81744	84919
2011/12	88291	93633	90687	108262	110790	94175	77036	74507	67109	83014	92145	79526	88265
2012/13	75944	74657	68336	76507	84710	88279							78072
													83648

- **BOD Loading**

Between the years 2007 and 2013, the average BOD loading is estimated at 407 mg/l which represented 79% of the design capacity of 512mg/l.

Table 2: Average BOD Loading

Year	Jul	Aug	Sep	Oct	Nov	Dec	Ja	Feb	Mar	April	May	June	Average
2007/08	280	480	218	216	282	247	240	270	301	279	232	304	279
2008/09	383	416	417	417	403	427	524	586	652	590	518	531	489
2009/10	655	784	907	781	650	609	369	540	499	315	331	257	558
2010/11	428	523	522	516	272	379	581	517	359	498	477	391	455
2011/12	373	387	364	338	287	221	299	442	384	276	163	231	314
2012/13	294	306	379	318	247	198							290
Average	402	483	468	438	357	347	403	471	439	392	344	343	407

- **Biogas production and energy equivalent**

The plant was found to be generating approximately 2736m³/day of methane at the

calculated flow of 83648m³ daily.

Table 3: Daily methane generated for the period 2007-2013

Month	Methane generated(m ³ /day)
July	1668
August	3527
September	1825
October	1631
November	3821
December	5121
Jan	4453
Feb	1862
Mar	3009
April	2251
May	3137
June	2916
Average	2736

Figure 3: Methane generated(m³/day)

- **Energy equivalent of biogas produced**

The amount of energy that can be produced from methane was computed as 68,398 MJ/day.

(IPCC, 2006) and (Mara, 2003)

3600MJ = 1MWh

68398MJ = 18MWh daily =

Research from Burton and the Electric Power Research Institute (EPRI) in the US shows that anaerobic digestion with biogas utilization can produce about 525 KWh of electricity for every million gallons (3785m³) of wastewater treated at the plant (Ashlynn et al (2010). Using the same argument, DWWTP treating about 83643m³ of domestic and industrial waste daily would generates roughly about 12MWh and at full capacity when treating 160,000m³ daily would generate about 22.1MWh. These two figures relatively compare to my calculation of 18MWh.

To estimate the number of households that can be served by the amount of energy

generated, the following were the assumptions made;

- Most households within Ruai are dependent on 3kg LPG gas for cooking
- Calorific Value of LPG gas cylinder is 46.1MJ/kg (Edward, 2001)
- Total no. of households in the project area is 22755 (Kenya Population and Housing Census, 2019.)

The total energy that can be generated at DWWTP is estimated at 68,398MJ/day, and considering Calorific Value of LPG of 46MJ/kg, this is equivalent to 495 cylinders daily which can serve about 2974 households daily.

Economic value of 3kg cylinders can be estimated by 495*800/= which is equivalent to saving Kshs. 396,000 daily.

Ashlynn et al (2010) reiterates that Wastewater treatment plants with treatment capacities of less than 5 million gallons per day (18,900m³) do not produce enough biogas to make electricity generation feasible or cost-effective (Ashlynn *et al*, 2010). Based on this, it can be argued that Dandora generating about 83,643m³ per day can generate enough biogas to make energy or electricity generation feasible and cost effective.

- **Computation of emission reduction of converting biogas to energy**

For this calculation, the electricity generation for the baseline scenario is supplied by generators using Heavy Fuel Oil (HFO), with an Emissions Factor (EF) of 0.896 t CO₂/MWh. For this analysis, the biogas capture and combustion at the DESTP as calculated earlier generates about 18MWh per day, thereby displacing 18MWh per day of HFO-generated electricity each year. The baseline emissions are therefore approximated as:

$$\text{Total Baseline Emissions (tCO}_{2-e}\text{)} = \text{Electricity Generation} \times \text{EF}$$

$$= 18 \text{ MWh} \times 0.896 \text{ tCO}_{2-e}\text{/MWh}$$

$$= 16.1280 \text{ tCO}_{2-e} \text{ per day}$$

$$\text{Total Project Emissions (tCO}_{2-e}\text{)} = \text{Electricity Generation} \times \text{EF}$$

$$18 \times 0.0174 \text{ tCO}_{2-e}\text{/MWh}$$

$$= 0.3132 \text{ tCO}_{2-e} \text{ per day}$$

The GHG emission reductions attributed to this Project therefore the difference between the baseline and project emissions:

Potential Emissions Reductions (tCO_{2-e})

= Total Baseline Emissions (tCO_{2-e}) - Total Project Emissions (tCO_{2-e})

= 16.1280 tCO_{2-e} per day - 0.3132 tCO_{2-e} per day

= approx. 16 tCO_{2-e} per day

According to Greenhouse Gas Equivalencies calculator by EPA, 2023; the figure 16 tCO_{2-e} per day is equivalent to carbon sequestered by 240 tree seedlings grown for 10 years or equivalent to CO₂ emissions from 1633 gallons of gasoline consumed this emphasizes on the significance of this amount of emission reduction in combating climate change.

Pearson Correlation coefficient

The following formula was used to calculate the relationship between the two variables that is energy recovered and emission reductions. Ref.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Table 4: Correlation coefficient parameters

Energy Generated (y)	Methane Reduction	XY	X ²	Y ²
111325	27	3024643	12393255625	738
46544	11	528703	2166320664	129
75219	18	1380832	5657860352	337
56263	14	772550	3165468906	189
78425	19	1501059	6150480625	366
72894	18	1296789	5313498789	316
41688	10	424131	1737847656	104
88163	22	1896953	7772626406	463
45631	11	508175	2082210977	124
40781	10	405891	1663110352	99
95513	23	2226430	9122637656	543

128019	31	3999778	16388800352	976
880463	215	17965935	73614118359	4385

Based on the above the $r = 0.99$

The study's results on the correlation analysis between energy generated and emission reduction equivalent, showed a perfect positive correlation with a high value of $r = 0.99$ as shown below;

Figure 4: Correlation between biogas converted to energy and emission reduction

This confirms that energy recovery from Dandora Wastewater treatment plant is significant in mitigating climate change and thus rejects my null hypothesis that Conversion of Biogas to energy doesn't have significant effect on emission reduction.

5. Conclusion

- **Conclusion**

The study concludes that recovery of energy from waste water treatment plant can help in combating climate change.

This confirms that energy recovery from Dandora Wastewater treatment plant is significant in mitigating climate change.

In their last submission of Nationally Determined Contributions of 2020, Kenya is undertaking an ambitious mitigation contribution towards meeting the Paris Agreement of 2015 by abating her GHG emissions by 32% by 2030 relative to the Business As Usual (BAU) scenario of 143Mt CO₂eq. As per our estimations, this project will help reduce GHGs emissions by at least **16 tCO₂-e per day**. These findings give an impetus to the government of Kenya and other relevant stakeholders to develop green energy from methane generated at the treatment plant thereby reducing GHGs emitted to the atmosphere in line with Kenya's NDC commitment to abating the climate change menace.

- **Recommendation**

- This project can be one among many projects in the waste sector that Kenya can implement to meet its National Determined Contributions (NDC) as per Paris Agreement of 2015 that is abate climate change by 32% against Business As Usual of 143M tCO_{2-e} by 2030.
- Harnessing methane should be encouraged as an alternative green energy for use by the local community around the treatment plant.

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References

- Alexander, G. (1998). *Dandora Waste Water Treatment Plant, Phase 2, Final Design Report*.
- Ashlynn, S., David, C.& Michael, E. (2010). *Energy Recovery from Wastewater Treatment Plants in the United State; A case study of the Energy Water Nexus*. University of Texas at Austin.
- Braber, K., (1995). *Anaerobic Digestion of Municipal Solid Waste: A modern waste disposal option on the verge of a breakthrough*. Biomass and Bioenergy. SEA Change CoP, Phnom Penh, and UKCIP, Oxford.
- Droste, R.L., (1997). *Theory and Practice of Water and Wastewater Treatment*. John Wiley and Sons. New York, USA.
- Edward, S. R., (2001). *Introduction to engineering and the environment*. Carnegie Mellon University Press Energy, 35(12), 2666-2673.
- EPA, (2006). Design Manual: Municipal Wastewater Stabilization Ponds. Report No. EPA-625/1-83-015. Cincinnati: *Environmental Protection Agency*, Center for Environmental Research information.2006.
- Gebbie, P. (2013). *Feasibility Study and Preliminary Design of Energy Generating Facility at Dandora Waste Water Treatment?? Plant*. SMEC

- International Pty ltd, Nairobi Kenya.
- Government of Kenya (2016). Climate Change Act. Government Printers Nairobi, Kenya.
 - Government of Kenya (2018). National Climate Change Action Plan (Kenya): 2018-2022. Nairobi: Ministry of Environment and Forestry.
 - Government of Kenya (2020). Submission of Kenya's updated national determined contribution. Government Printers Nairobi. Kenya.
 - IPCC, (1997). Module 6 - Waste in Revised (1996) *IPCC Guidelines for National Greenhouse Gas Inventories, vol.2 - Workbook*. Intergovernmental Panel on Climate Change.
 - IPCC, (2006). Ch.6 - *Wastewater Treatment and Discharge* in H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe, editors. . IPCC, 2006a. Vol.1 – General Guidance and Reporting in H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe, editors. 2006
 - IPCC, (2006). *Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Program, vol.5 - Waste*. IGES, Japan. IPCC, 2006b. Vol.1 – General Guidance and Reporting in H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe, editors. 2006
 - J.H Reith, R.H. Wijffels and H. Barten. (2003). Status and perspectives of biological methane and hydrogen production. Energy Centre for The Netherlands.
 - KNBS (2019) Kenya population and housing census of 2019. Volume 1: population census.
 - L.J.P Snip and K.J. Keesman (2009). Quantifying the greenhouse gas emissions from waste water treatment plant. Wageningen University, Netherlands.
 - Lord, H., and Gregory, K., (2010). Fundamentals of biological wastewater treatment. Weinheim; Hoboken, N.J.: Wiley-VCH.
 - Lord, H., and Gregory, K., (2010). Fundamentals of biological wastewater treatment. Weinheim; Hoboken, N.J.: Wiley-VCH.
 - Mara, D., (2003). Domestic Wastewater Treatment in Developing Countries. Earthscan UK and USA.
 - NEMA, 2015. Second National Communication to the United Nations Framework Convention On Climate Change. Nairobi, Kenya.
 - Otieno, O. M. (1998), *Nairobi Master Plan for Sewer, Sanitation and Drainage, Third Nairobi Water supply Project*.
 - Parsons, T. (1996). *The Structure of Social Action*. McGraw Hill, New York.

- Rayhan, Abu & Kinzler, Robert & Rayhan, Rajan. (2023). *Climate Change and Global Warming: Studying Impacts, Causes, Mitigation, And Adaptation*. 10.13140/RG.2.2.23746.76489.
- UNFCCC/IPCC, (2004). *Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University. Press. Cambridge.
- Van Haandel, A.C., Lettinga, G. (1994). *Anaerobic Sewage Treatment: A Practical Guide for Regions with a Hot Climate*. John Wiley & Sons.
- Waluszewski, D., (2010). *Production potential for biogas in Stokholm region, Sweden*.

• APPENDIX 1: Data Analysis.

MONTHLY AVERAGES FOR THE YEAR 2007/2008														
Measurement	Unit	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	YEAR AVERAGES
Inflow	m ³ /d	75422	87857	82112.57	75486	82791	85980	77239	78911	81952	104251	91040	89672	85226
BOD	mg/l	280	480	218.33	261	282	247	240	270	301	279	232	304	283
COD	mg/l	568	650	710.15	648	777	722	595	745	706	585	648	691	671
TSS	mg/l	358	410	463.99	378	441	491	396	426	386	379	431	422	415
TS	mg/l	358	951	985.45	846	957	972	768	948	978	996	964	1048	898
TDS	mg/l	684	538	531.29	473	507	484	374	547	597	618	637	655	553
Chlorides	mg/l	656	57	68.32	70	66	47	55	50	68	64	50	61	109
NO2	mg/l	4	—	2.19	1.04	0.17	—	—	—	22.9	5.7	12.15	9.00	7
NO3	mg/l	38	—	31.00	6.143	0.98	—	—	—	—	—	7.92	8.57	15.42
PO4	mg/l	14.78	—	25.16	2.12	—	—	—	—	—	—	—	24.41	16.62
PH	PH	8.10	7.94	7.89	7.8	7.83	7.18	7.6	8.15	7.39	7.35	7.42	7.30	7.65
Temperature	°c	20.70	20.90	21.3	21.35	19.66	21.6	21.89	22.39	21.97	21.95	21.56	21.38	21.38
D.O	mg/l	2.27	5.82	1.01	0.34	—	1.00	7.25	4.91	0.35	0.14	0.08	0.30	2.13
Outfall 1Character														
BOD	mg/l	125	92	47.50	27	32	58	34	70	38	42	82	58	59
COD Total	mg/l	238	174	195.42	199	195	140	178	174	197	187	198	197	189
COD Filtered	mg/l	105	85	95.85	84	76	85	89	94	76	85	96	88	91
TSS	mg/l	35	85	108.50	121	138	75	85	109	124	109	112	115	102
TS	mg/l	87	659	689.64	690	689	613	669	684	716	700	668	690	629
TDS	mg/l	506	569	540.46	535	555	544	555	552	582	575	544	573	552
Chlorides	mg/l	572	99	105.05	115	126	99	118	109	110	97	94	96	145
NO2	mg/l	5	—	27.63	6.130	0.8	—	—	—	48	3.2	29.1	19.0	17.40
NO3	mg/l	2.02	—	25.70	49.50	2.1	—	—	—	—	—	14.3	24.6	19.70
PO4	mg/l	15.83	—	0	—	—	—	—	—	—	—	—	43.62	19.82
PH	PH	7.86	7.79	7.86	8.15	8.0	7.36	7.89	8.2	7.66	7.51	7.3	7	7.74
Temperature	mg/l	20.20	20.60	21.10	20.96	22	21.2	22.91	23	22.8	22	22	22	21.83
D.O	mg/l	13.95	18.40	5.61	3	6.8	15.61	21	1.2	0.18	0	5	8.32	—
Outfall 2Character														
BOD	mg/l	25	84	52	30	44	54	25	45	45	49	71	68	49
COD Total	mg/l	217	199	197	169	182	179	141	193	226	233	216	217	197
COD Filtered	mg/l	150	125	120	84	111	105	76	89	115	131	115	129	113
TSS	mg/l	68	89	90	65	117	66	52	81	108	113	79	100	86
TS	mg/l	78	637	655	613	654	574	591	615	714	683	631	672	591
TDS	mg/l	511	550	524	512	535	517	525	501	567	586	500	552	530
Chlorides	mg/l	603	99	103	105	114	89	99	94	105	92	88	94	140
NO2	mg/l	5.58	—	4.34	1.89	0.2	—	—	—	30.75	13.0	12.8	16.59	10.65
NO3	mg/l	0.81	—	48.18	13.54	0.6	—	—	—	—	—	4.6	7.68	12.55
PO4	mg/l	14.16	—	—	—	—	—	—	—	—	—	—	21.5	17.83
PH	PH	7.89	7.82	7.81	7.70	7.9	7.5	7.88	8.1	7.4	7.4	7.2	7.28	7.65
Temperature	°c	19.72	20.06	20.67	20.70	22.0	20.94	22.59	23.0	22.83	22.0	22.2	21.48	21.50
D.O	mg/l	12.75	13.01	4.04	2.6	5.80	18.15	20.9	1.04	0.2	0.2	6.20	7.71	—
Outfall 3Character														
BOD	mg/l	145	66	64	38	61	74	59	87	88	73	137	112	83
COD Total	mg/l	319	230	222	182	200	262	241	274	320	348	280	315	286
COD Filtered	mg/l	211	120	132	100	121	167	133	176	184	171	174	175	157
TSS	mg/l	81	119	112	71	124	107	104	121	155	145	136	160	120
TS	mg/l	103	675	657	596	657	637	539	650	755	740	676	732	618
TDS	mg/l	525	546	522	477	523	533	441	508	590	588	506	557	526
Chlorides	mg/l	613	98	101	103	113	89	75	91	93	93	88	94	138
NO2	mg/l	6	—	9	2.25	0.2	—	—	—	17.75	6.88	8.7	8.8	7
NO3	mg/l	0.83	—	43.37	12.55	0.7	—	—	—	—	—	6.4	9.23	12.18
PO4	mg/l	9.70	—	—	—	—	—	—	—	—	—	—	23.05	16.37
PH	PH	7.82	7.77	7.85	7.63	7.8	7.40	7.70	7.9	7.22	7.4	7.2	7.28	7.58
Temperature	°c	19.63	20.32	20.86	21.07	22.2	21.41	22.71	23.3	23.01	22.45	22.4	21.73	21.76
D.O	mg/l	16.11	22.10	3.26	3	3.39	11.05	11	0.60	0.16	0	6.26	7.00	—
Outfall														
1 for series 1 & 2	m ³ /d	22169	24515	14450	12510	14581	13554	11214	13209	15647	23830	14193	15910	16315
2 for 3,4,5 & 6	m ³ /d	32934	37481	34250	30122	37161	32325	25745	30885	39877	51704	41716	41002	36267
3 for 7 & 8	m ³ /d	28068	26609	24246	21763	11284	22399	27002	22434	15651	18782	21000	18888	21510
Total Outflow	m³/d	83170	88605	72946	64396	63026	68278	63962	66527	71175	94317	76910	75800	74093
Month														
Inflow		75422	87857	82113	75486	82791	85980	77239	78911	81952	104251	91040	89672	85226
Outflow		83170	88605	72946	64396	63026	68278	63962	66527	71175	94317	76910	75800	74093
BOD influent		280	480	218	261	282	247	240	270	301	279	232	304	283
BOD Effluent		86	81	55	32	46	62	40	67	57	54	97	79	64
BOD REMOVAL		182	399	164	229	236	185	200	203	244	225	135	226	219
% BOD REMOVAL		65%	83%	75%	88%	84%	75%	84%	75%	81%	80%	58%	74%	77%
COD influent		568	650	710	648	777	722	595	745	706	585	648	691	671
COD Effluent		257	201	205	184	192	194	186	214	247	255	231	243	217
BOD REMOVAL		311	449	505	465	585	528	409	531	458	330	417	448	453
% BOD REMOVAL		55%	69%	71%	72%	75%	73%	69%	71%	65%	56%	64%	65%	68%

Measurement	Unit	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	AVERAGE
Inflow	m ³ /d	74547	78882	78659	78659	100455	78529	63091	76219	72072	70889	86916	87709	78886
BOD	mg/l	383	416	417	417	403	427	524	586	652	590	518	531	489
COD Total	mg/l	764	1062	1134	1134	1067	1374	1541	1561	1406	1145	1052	1395	1219
TSS	mg/l	459	407	517	517	630	643	945	808	853	662	708	608	647
TS	mg/l	1181	1158	1350	1350	1347	1481	1864	1755	1613	1404	1475	1402	1448
TDS	mg/l	738	720	812	812	715	800	884	876	779	816	777	770	792
Chlorides	mg/l	72	75	80	80	82	85	94	87	97	96	94	103	87
NO ₂	mg/l	9.1	6.1	16.9	16.9	1.9			1.1		Trace	0.000	N/D	7.4
NO ₃	mg/l	22.76									2.5	5.000	13.750	11.00
PO ₄	mg/l	25.46	30.76	14.68	14.68	24.3								21.97
PH	PH	7.2	7.2	7.6	7.58	7.5	7.43	7.3	7.2	7.3963	7.5	7.9	7.9925	7.5
Temperature	°c	20.1	19.9	21.8	21.8	23.6	23.683	22.9	23.3	23.946	24.2	23.3	22.094	22.5
D O	mg/l	0.4	18.32	0.81	0.8	1.65	2.104	1.9	1.65	2.435	1.5	4.15	2.302	3.2
Outfall A Character														
BOD	mg/l	48.3	50	60	59.6	76	48	39.6	49	41	26.4	39	78	51.2
COD Total	mg/l	227.6	221	238	237.9	217	202	227.9	228	237	297.6	202	244	231.7
COD Filtered	mg/l	122.9	122.4	163.0	163.0	126.3	118	107.0	99.8	122	138.7	120.4	133	128.0
TSS	mg/l	93	88	104	104	92	95	109	108	94	97	116	134	103
TS	mg/l	715	741	803	803	786	732	771	830	917	894	829	814	803
TDS	mg/l	626	645	687	687	670	618	649	681	673	762	739	694	677
Chlorides	mg/l	104	114	112	112	111	108	114	121	123	130	124	116	116
NO ₂	mg/l	76	82.9	104	104	7.8			1.9		0.750	2.000	1.1667	42
NO ₃	mg/l	31.66									5.000	15.000	3.7500	13.85
PO ₄	mg/l	31.98	32.83	15.31	15.31	23.57								23.80
PH	PH	7	7.28	7.75	7.90	8.00	7.68	7.72	7.82	7.98	8.20	8.50	8.31	8
Temperature	mg/l	20	18.5	20.76	20.8	22.9	23.0	22.5	23.1	23.1	23.3	23.3	21.7	22
D O	mg/l	5.31	11.21	6.86	6.86	3.28	8.3	2.47	4.85	14.3	8.78	7.77	13.1	7.76
Outfall B Character														
BOD	mg/l	78	78	80	80	68	61	101	99	92	114	127	102	90
COD Total	mg/l	254	269	283	283	284	266	326	366	371	410	354	336	317
COD Filtered	mg/l	163	176	221	221	164	170	119	149	191	255	185	155	181
TSS	mg/l	120	117	130	130	114	120	167	186	184	229	213	150	155
TS	mg/l	754	722	807	807	714	715	843	879	862	929	840	789	805
TDS	mg/l	623	598	655	655	584	569	661	657	651	697	629	610	632
Chlorides	mg/l	105	118	107	107	96	94	108	113	113	111	103	104	106
NO ₂	mg/l	23	10.5	23	23	0.8					0.000	0.520	25.333	12
NO ₃	mg/l	13.80									2.500	3.750	3.750	5.95
PO ₄	mg/l	18.75	31.12	10.80	10.80	18.64								18.02
PH	PH	7	7.32	10.12	7.70	8.00	7.72	8	7.74	7.88	8	8.33	8.28	8
Temperature	°c	20.0	18.45	20.49	20.5	22.82	22.89	22.2	22.97	23.00	23.0	22.78	21.36	21.7
D O	mg/l	8	10.12	5.30	5	3.13	3.3744	2	3.22	11.49	5	7.00	10.31	6
Outfall C Character														
BOD	mg/l	96	106	117	117	89	101	132	100	110	112	113	118	109
COD Total	mg/l	360	326	352	352	299	376	438	464	451	498	399	403	393
COD Filtered	mg/l	242	214	258	258	165	243	167	186	219	369	241	185	229
TSS	mg/l	187	160	173	173	135	209	223	243	229	180	207	180	192
TS	mg/l	777	725	813	813	689	793	917	935	901	962	870	820	834
TDS	mg/l	589	561	615	615	543	568	683	669	624	723	655	618	622
Chlorides	mg/l	104	103	103	103	86	93	109	113	111	115	103	108	104
NO ₂	mg/l	12	8	26					2.44		0.0000	0.0000	N/D	8
NO ₃	mg/l	12.70			13.38	14.3					2.5000	2.5000	5.0000	8.40
PO ₄	mg/l	19.28	17.27	13.38	7.56	7.51	7.658							12.11
PH	PH	7.25	7.43	7.56	7.70	7.51	7.640	7.78	7.56	7.768	7.81	8.29	8.145	7.70
Temperature	°c	20.2	18.78	20.85	20.8	22.84	23.151	22.3	23.10	23.410	23.1	30.00	21.485	22.5
D O	mg/l	2.1	6.12	3.38	3.4	2.96	3.331	2.3	2.96	9.625	5.1	19.04	8.839	5.8
AVARAGES														
BOD	mg/l	74	78	85	85	78	70	91	83	81	84	93	99	83
COD	mg/l	281	272	291	291	267	281	331	353	353	402	319	328	314
COD FILTRED	mg/l	122	112	140	140	97	120	91	95	114	169	120	106	119
TSS	mg/l	133	122	135	135	114	141	167	179	169	169	179	155	150
TS	mg/l	749	729	808	808	730	747	843	881	893	928	846	808	814
Outflow														
Outfall A (Series 1&2)	m ³ /d	13214	11051	14424	14424	18811	11187	9872	10815	10637	15696	14342	14549	13252
Outfall B series 3,4,5&6	m ³ /d	35386	32765	33589	33589	58521	39560	31948	36868	29882	32669	44416	47172	38031
Outfall C Series 7 & 8	m ³ /d	16427	16545	15705	15705	21967	13950	9869	13075	11039	9545	11470	12960	14021
Total outflow	m ³ /d	65027	60360	60529	60529	99299	65701	61689	60381	61558	54814	70226	74571	64557

Measurement	Unit	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Averages
Inflow	m ³ /d	86375	87126	89420	79561	91020	95458	82444	79244	80783	82644	83213	81744	84919
Inflow character														
BOD	mg/l	428	523	522	516	272	379	581	517	359	498	477	391	455
COD Total	mg/l	853	1096	1512	1187	858	1086	1394	1513	1108	1179	856	883	1127
TSS	mg/l	445	568	605	545	542	511	642	678	421	574	634	580	562
TS	mg/l	1071	1281	1296	1303	1202	1197	1389	1489	1141	1304	1437	1317	1286
TDS	mg/l	617	690	643	656	627	646	700	745	687	739	780	720	688
Chlorides	mg/l	85	86	94	98	99	91	86	106	107	91	102	99	95
NO ₂	mg/l	0.86	2.14	5.98	1.51	1.34	1.17	0.12	0.25	0.33	1.53	0.27	0.28	1.31
NO ₃	mg/l		21.46	6.35	13.54	15.73	8.59		3.31	5.00	3.50	2.00	2.75	8.22
SO ₄ ²⁻	mg/l	22.00					#REF!	#REF!	#REF!	167.40	236.63			#REF!
PO ₄ ³⁻	mg/l	8.14	31.39	#REF!	25.22	23.40	21.10	11.80		#REF!				#REF!
pH	PH	7.43	7.11	6.97	7.28	7.12	7.18	7.05	7.20	7.24	6.97	6.92	7.07	7.13
Temperature	°C	74.4	19.4	19.69	21.29	20.9	20.7	22.5	22.8	23.0	23.30	22.31	21.36	25.95
D.O	mg/l							0.74	1.17	1.58	2.39	5.10	1.87	2.14
Outfall A Character														
BOD	mg/l	46	43	45	61	57	31	33	28	31	62	47	31	43
COD Total	mg/l	147	172	194	338	241	187	180	195	201	183	203	174	201
COD Filtered	mg/l	84	90	78	96	79	66	60	72	63	91	110	102	83
TSS	mg/l	54	69	74	108	91	99	95	86	87	81	102	82	86
TS	mg/l	578	606	648	750	697	669	705	739	763	752	766	773	704
TDS	mg/l	515	529	552	616	604	561	591	635	661	660	638	682	604
Chlorides	mg/l	94	97	99	109	108	111	105	113	147	120	114	117	111
NO ₂	mg/l	1	2.06	9.68	0.92	0.86	0.87	0.10	0.59	1.25	0.592	0.502	0.363	1.56
NO ₃	mg/l	9	23.20	14.40	8.52	11.23	12.37		36.75	8.75	6.067	5.000	2.778	12.55
SO ₄ ²⁻	mg/l		31.33		35.69		#REF!	#REF!		#REF!	#REF!			#REF!
PO ₄ ³⁻	mg/l	29		30.09		24.39	20.62	4.53	3.34		37.675			21.43
pH	PH	8	7.71	7.63	7.78	7.87	8.06	7.51	7.89	7.75	7.535	7.537	7.715	7.73
Temperature	mg/l	20	19.41	19.96	21.21	21.57	21.22	22.84	22.50	22.80	23.489	22.147	21.489	21.57
D.O	mg/l							0.87	1.82	1.54	3.368	6.528	4.964	3.182
Outfall B Character														
BOD	mg/l	81	108	121	111	90	52	68	62	52	63	52	60	76
COD Total	mg/l	212	254	315	343	271	238	251	279	243	238	213	242	258
COD Filtered	mg/l	116	87	94	95	93	99	81	118	93	125	160	121	107
TSS	mg/l	96	125	180	167	107	121	116	128	97	93	103	108	120
TS	mg/l	620	687	723	785	726	691	726	781	766	742	767	804	735
TDS	mg/l	512	551	569	620	609	573	594	664	648	638	661	692	611
Chlorides	mg/l	97	99	101	108	108	105	99	109	115	111	110	114	106
NO ₂	mg/l	2	2.60	20	3	2.09	1.30	0.38	0.31	0.46	1.288	0.404	0.474	2.817
NO ₃	mg/l	16	23.16	9	21	19.14	10.42		5.75	5.83	18.785	4.515	3.017	12.453
SO ₄ ²⁻	mg/l						#REF!	#REF!		#REF!	#REF!			#REF!
PO ₄	mg/l	18	25.75	16.71	19.32	21.30	13.45	2.62	3.13		1.99			13.56
PH	PH	8	7.64	7.51	7.59	7.62	7.70	7.66	7.79	7.68	7.43	7.52	7.54	7.62
Temperature	°C	20	19.53	19.85	20.20	21.29	21.30	22.50	22.12	22.57	23.10	21.96	21.23	21.32
D.O	mg/l							0.92	1.25	2.40	3.22	7.22	3.81	3.14
Outfall C Character														
BOD	mg/l	111	136	150	116	146	51	75	86	62	94	64	86	98
COD Total	mg/l	294	361	373	423	326	270	334	462	382	281	267	284	338
COD Filtered	mg/l	141	98	115	111	134	118	127	199	133	153	186	161	140
TSS	mg/l	154	208	205	188	164	134	141	167	162	118	132	142	160
TS	mg/l	690	776	800	841	769	729	783	903	911	797	828	845	806
TDS	mg/l	505	560	585	642	636	584	621	709	722	673	685	701	635
Chlorides	mg/l	98	99	101	106	108	105	102	114	120	125	113	109	108
NO ₂	mg/l	1	2.08		1.53	1.27	1.12	0.032						1.238
NO ₃	mg/l	15	23.06		13.69	15.01	10.13		5.0625	5	3.833	3.250	1.450	9.50
SO ₄ ²⁻	mg/l									197.5	136.6		3.188	112.42
PO ₄	mg/l	17	20.55		17.39	20.03	11.17	2.44	1.88		43.7			16.76
PH	PH	8	7.52		7.46	7.63	7.60	7.55	7.76	7.67	7.47	7.46	7.45	7.58
Temperature	°C	20	19.44		21.11	21.41	21.30	22.51	22.15	22.21	23.52	22.15	21.50	21.61
D.O	mg/L							1	1.20	1.04	3.418	20.310	4.002	5.2
Average Outfall A,B,C														
BOD	mg/l	79	96	105	96	98	46	59	58	47	70	53	59	72
COD Total	mg/l	217	262	294	368	279	248	257	312	268	234	228	234	267
COD Filtered	mg/l	114	92	96	101	102	102	90	130	94	123	152	128	110
TSS	mg/l	102	134	153	154	121	125	118	127	112	97	113	111	122
TS	mg/l	629	690	723	792	730	712	738	805	803	764	786	807	748
TDS	mg/l	511	547	569	626	616	576	602	688	671	657	661	692	616
Chlorides	mg/l	96	98	100	108	108	106	102	112	127	119	112	113	109
NO ₂	mg/l	1.4	2.25	9.04	1.71	1.41	1.14	0.17	0.40	0.78	0.4	0.4	0.4	1.6
NO ₃	mg/l	13.3	23.14		14.39	15.13	10.43		13.53	6.53	5.0	4.0	2.2	
SO ₄ ²⁻	mg/l		31.33		35.69					129.8	109.9		3.2	62.0
PO ₄	mg/l	21	23.15	21.33	18.36	21.90	12.80	3.20	2.78		36.1			17.9
PH	PH	8	7.62		7.61	7.70	7.71	7.56	7.81	7.71	7.5	7.5	7.6	
Temperature	°C	20	19.46		20.84	21.42	21.32	22.55	22.26	22.61	23.4	22.1	21.4	
D.O	mg/l							0.94	1.42	2.10	3.4	4.3	4.3	2.7
Outflow														
Outfall A (Series 1&2)	m ³ /d	18440	19639	20577	17033	21536	19790	18796	14457	15041	16852	14716	13379	17521
Outfall B series 3,4,5&6	m ³ /d	44220	54913	56355	49161	63514	56517	43556	39906	35401	30402	30449	30328	44560
Outfall C Series 7& 8	m ³ /d	18543	23850	21969	21331	11143	11323	11969	7768	10804	9674	19506	18376	15512
Total outflow	m ³ /d	89657	92928	98911	87168	96191	87630	74321	62131	61246	56929	64761	62083	77830

MONTHLY AVERAGES FOR THE YEAR 2011/2012														
Measurement	Unit	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	AVERAGE
Inflow	m ³ /d	88291	93633	90687	108262	110790	94175	77036	74507	67109	83014	92145	79526	88265
BOD	mg/l	373	387	364	338	287	221	299	442	384	276	183	231	314
COD Total	mg/l	898	972	901	930	729	769	650	951	705	746	402	574	769
TSS	mg/l	515	502	483	542	549	438	357	479	355	393	385	329	442
TS	mg/l	1165	1271	1203	1210	1178	1054	941	1251	1057	1040	896	914	1098
TDS	mg/l	626	686	644	613	572	550	524	720	703	645	520	578	615
Chlorides	mg/l	91	101	102	101	91	91	99	111	81	77	64	102	93
pH		7.14	7.56	7.22	7.15	7.15	7.17	7.07	7.22	7.14	7.45	7.52	7.46	7.27
D.O	mg/l	3	3	3	4	2	3	3	3	4				2.92
Outfall A Character														
BOD	mg/l	49	34	36	38	54	30	21		42	50	32	23	37
COD Total	mg/l	183	184	187	239	218	190	150		291	225	167	156	199
COD Filtered	mg/l	100	96	89	98	73	59	36		156	100	77	84	88
TSS	mg/l	79	88	96	127	106	134	112		147	131	60	55	103
TS	mg/l	772	786	824	799	729	667	613		939	858	611	559	742
TDS	mg/l	663	697	682	672	800	558	552		774	709	546	486	649
Chlorides	mg/l	117	121	127	130	122	109	112		151	127	90	85	117
pH		7.52	7.62	7.99	8.01	7.55	7.55	7.41		7.94	7.70	7.78	7.76	7.71
D.O	mg/l	3.22	3.82	3.07	5.06	2.36	3.51	3.28		3.78				3.51
Outfall B Character														
BOD	mg/l	97	75	66	62	56	32	29	51	48	45	31	32	52
COD Total	mg/l	263	263	258	259	231	153	145	218	244	211	175	167	216
COD Filtered	mg/l	129	152	128	95	86	91	83	171	161	138	89	95	118
TSS	mg/l	133	128	109	117	101	79	76	100	124	124	92	77	105
TS	mg/l	806	777	730	725	694	602	632	767	883	868	625	610	726
TDS	mg/l	652	647	620	598	594	534	588	672	738	730	524	521	617
Chlorides	mg/l	111	110	108	111	102	90	106	126	136	132	92	93	110
NO ₂ ⁻	mg/l	0.43	0.92	0.37	0.43	0.54	0.35	0.33	0.33	0.38	0.73	0.25	0	0.44
NO ₃ ⁻	mg/l	4.50	5.00	3.06	2.93	3.21	2.57	2.50	2.50	2.50	3.54		4	3.31
PO ₄ ³⁻	mg/l													
pH		7.35	7.43	7.54	7.52	7.47	7.36	7.36	7.57	7.60	7.91	7.94	8	7.58
Temperature	°C	20.00	19.36	20.14	21.42	22.51	22.73	21.84	22.26	22.58	22.72	22.64	21	21.62
D.O	mg/l	4.44	3.09	3.48	4.32	2.02	3.16	2.56	2.03	3.03				3.13
Outfall C Character														
BOD	mg/l	85	71	86	80	71	41	28	58	59	65	43	34	60
COD Total	mg/l	318	289	328	328	300	177	162	233	311	323	189	194	263
COD Filtered	mg/l	184	198	190	99	107	100	96	177	213	218	115	114	151
TSS	mg/l	146	123	139	154	129	91	73	93	141	180	83	51	117
TS	mg/l	849	839	816	775	729	626	643	806	928	943	666	614	769
TDS	mg/l	674	713	679	612	589	539	594	711	757	749	568	546	644
Chlorides	mg/l	110	119	114	108	151	90	103	122	135	127	93	89	114
NO ₂ ⁻	mg/l	0.3						0.31	0.25	0.25	0.36	0.25	0.08	0.25
NO ₃ ⁻	mg/l	2.5	2.92	3.02	2.83	2.92	2.50	2.50	2.50	2.50	1.75		4.48	2.77
PO ₄ ³⁻	mg/l													
pH		7.5	7.58	7.46	7.50	7.43	7.38	7.29	7.44	7.34	7.77	7.67	7.74	7.51
Temperature	°C	20.4	19.15	20.30	21.58	22.73	22.89	22.11	22.29	22.57	22.89	22.64	21.43	21.75
D.O	mg/l	0.7	3.94	3.06	5.28	1.98	3.40	2.34	2.07	2.92				2.86
Average Outfall A,B,C														
BOD	mg/l	75	60	64	60	61	34	28	54	50	53	35	29	50
COD Total	mg/l	233	241	262	275	250	176	154	226	276	253	177	172	224
COD Filtered	mg/l	122	142	138	97	88	91	89	174	177	152	94	97	122
TSS	mg/l	111	112	116	132	112	98	78	97	136	145	78	61	106
TS	mg/l	792	796	784	766	717	632	639	786	907	890	634	594	745
TDS	mg/l	655	682	662	627	661	544	582	692	745	729	546	518	637
Chlorides	mg/l	113	117	115	117	125	96	105	124	140	129	92	89	113
NO ₂ ⁻	mg/l	0.54	0.86	0.51	0.69	0.66	0.49	0.31	0.29	0.45	0.73	0.25	0.20	0.50
NO ₃ ⁻	mg/l	4.36	4.60	3.42	3.30	3.46	2.67	2.50	2.50	2.50	3.06		4.10	3.32
PO ₄ ³⁻	mg/l													
pH		7.42	7.53	7.63	7.67	7.49	7.41	7.33	7.51	7.56	7.79	7.80	7.80	7.58
Temperature	°C	20.07	19.48	20.26	21.47	22.65	22.87	21.97	22.28	22.58	22.77	22.67	21.36	21.70
D.O	mg/l	3.37	3.65	3.07	4.93	2.14	3.33	2.48	2.04	2.90				3.10
Outflow														
Outfall A (Series 1&2)	m ³ /d	13181	8233	7786	13283	18472	11574	1609		16903	33003	34464	20718	16293
Outfall B series 3,4,5&6	m ³ /d	50732	46126	41847	51536	59086	50428	33277	34804	12963	36947	40967	25174	40324
Outfall C Series 7 & 8	m ³ /d	7541	21958	20813	28002	30922	28652	18426	17437	7763	12978	18415	13100	18834
Total outflow	m ³ /d	67453	71925	70446	92822	100855	90655	47253	47719	34248	82927	93646	58992	71595

MONTHLY AVERAGES FOR THE YEAR 2012/2013														
Measurement	Unit	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	AVERAGE
Inflow	m ³ /d	75944	74657	68330	70507	84710	88279							73072
BOD	mg/l	294	308	379	318	247	168							290
COD Total	mg/l	813	670	813	679	555	479							635
TSS	mg/l	346	308	370	346	323	289							330
TS	mg/l	999	933	1304	954	896	795							960
TDS	mg/l	834	605	658	612	537	466							585
Chlorides	mg/l	86	83	93	74	71	61							78
NO ₂ ⁻	mg/l	0.042	1.125			0.140								0.436
NO ₃ ⁻	mg/l	2.735	2.500	101.167	78.017									46.105
PO ₄ ³⁻	mg/l													#DIV/0!
pH		7.6	7.5	7.3	7.1	7.3	7.4							7.36
Temperature	°C	19.5	19.5	20.2	21.4	21.9	21.5							20.66
D.O	mg/l													#DIV/0!
Outfall A Character														
BOD	mg/l	31	35	50	41	54	33							41
COD Total	mg/l	156	171	240	204	233	166							195
COD Filtered	mg/l	74	94	129	125	135	101							110
TSS	mg/l	81	78	103	82	98	91							89
TS	mg/l	843	660	713	742	751	713							704
TDS	mg/l	552	564	601	640	634	604							597
Chlorides	mg/l	100	109	118	126	122	109							114
NO ₂ ⁻	mg/l	4.153	1.375			0.280								1.936
NO ₃ ⁻	mg/l	2.267	2.500	23.000	35.050									15.704
SO ₄ ²⁻	mg/l													#DIV/0!
PO ₄ ³⁻	mg/l													
pH		7.5	7.7	7.9	7.8	7.8	7.8							7.75
Temperature	mg/l	20.1	20.0	20.7	21.9	18.8	22.2							20.79
D.O	mg/l					23								23.17
Outfall B Character														
BOD	mg/l	44	44	50	47	52	33							45
COD Total	mg/l	190	206	234	224	216	184							209
COD Filtered	mg/l	105	138	151	143	135	112							130
TSS	mg/l	89	84	88	95	96	89							90
TS	mg/l	653	683	717	709	723	680							704
TDS	mg/l	549	585	619	680	666	671							599
Chlorides	mg/l	103	117	122	127	117	107							116
NO ₂ ⁻	mg/l	0.058	0.375			0.170								0.201
NO ₃ ⁻	mg/l	0.978	3.750	24.833	43.133									18.174
PO ₄ ³⁻	mg/l													
pH		8.0	8.0	8.1	7.9	8.1	8.0							8.01
Temperature	°C	19.9	19.9	20.5	21.7	22.6	22.1							21.11
Outfall C Character														
BOD	mg/l	33	31	54	52	39	38							41
COD Total	mg/l	186	204	285	279	240	221							236
COD Filtered	mg/l	100	137	188	186	173	135							153
TSS	mg/l	84	72	107	111	92	68							89
TS	mg/l	658	662	740	805	1034	688							770
TDS	mg/l	564	608	627	674	641	602							619
Chlorides	mg/l	106	115	119	128	115	105							115
NO ₂ ⁻	mg/l	0.018	0.250			0.130								0.133
NO ₃ ⁻	mg/l	1.350	2.500	30.500	54.833									22.298
PO ₄ ³⁻	mg/l													
pH		8.03	8.04	7.95	8.02	8.03	7.98							8.01
Temperature	°C	19.95	20.01	20.57	21.83	22.78	22.31							21.24
D.O	mg/l													#DIV/0!
Average Outfall A,B,C														
BOD	mg/l	36	37	51	47	48	35							42
COD Total	mg/l	177	184	254	236	230	190							213
COD Filtered	mg/l	93	123	156	151	147	116							131
TSS	mg/l	85	77	99	96	95	83							89
TS	mg/l	652	678	723	772	836	694							726
TDS	mg/l	555	586	612	658	627	662							605
Chlorides	mg/l	103	114	120	127	118	107							115
NO ₂ ⁻	mg/l	1.410	0.667			0.193								0.757
NO ₃ ⁻	mg/l	1.5	2.9	26.1	43.9									18.61
PO ₄ ³⁻	mg/l													
pH		7.8	7.9	8.0	7.9	8.0	7.9							7.93
Temperature	°C	20.0	20.0	20.6	21.8	21.7	22.2							21.04
D.O	mg/l					23								23.17
Outflow														
Outfall A (Series 1&2)	m ³ /d	19721	18047	16117	21217	24250	24703							20676
Outfall B series 3,4,5&6	m ³ /d	23820	21383	21881	30327	32303	40516							28372
Outfall C Series 7 & 8	m ³ /d	10442	10495	12855	11351	16538	16675							13093
Total outflow	m ³ /d	53983	49925	50853	62896	67444	57513							57069