Wastewater treatment facility energy utilization and greenhouse gas emission

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Abstract: Waste water treatment systems produce a substantial amount of greenhouse gases in addition to having a great deal of promise for reducing water contamination from various sources. Hence, lowering greenhouse gas emissions from wastewater treatment plants is the main issue.

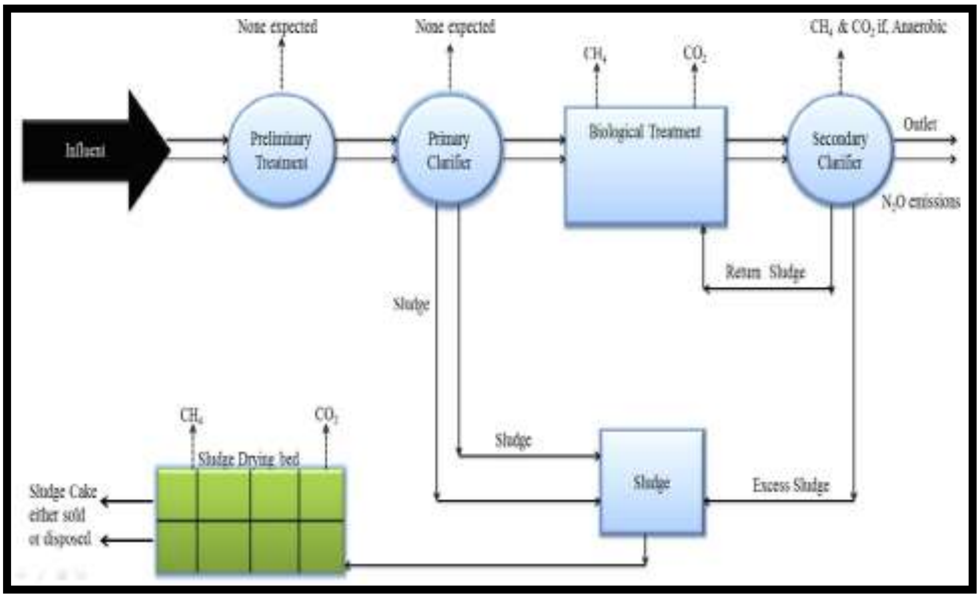
To meet this problem, it is crucial to accurately analyse and estimate the greenhouse gases released from various parts of the plant. This study has made an effort to assess and quantify the greenhouse gas emissions from the wastewater treatment system, primarily carbon dioxide, methane, and nitrous oxide. Because it uses less energy, produces usable biogas, and produces fewer particles than aerobic treatment, anaerobic wastewater treatment is a more environmentally friendly treatment method than aerobic treatment. The calculation of GHG emissions from wastewater treatment plants in this study is done in accordance with the IPCC Guidelines for National Greenhouse Gas Inventories. This study examines the environmental advantages and GHG contributions of aerobic and anaerobic treatment methods, as well as the GHG emissions for wastewater treatment.
Keywords: anaerobic treatment; greenhouse gases; GHGs; IPCC; inventories; climate change.

1 Introduction

Global awareness of climate change and its resulting environmental effects from human activities has increased interest in greenhouse gas (GHG) accounting. There is at least 90% likelihood that human activity is causing climate change, according to a recent study from the Intergovernmental Panel on Climate Change (IPCC), an organisation founded by the United Nations. Making a business or operation as "carbon-neutral" and green as possible is becoming a top priority from an economic, environmental management, and public relations/marketing perspective as the importance and awareness of climate-sensitive and "green" practises continue to rise throughout the world [US Environmental Protection Agency (EPA)]. Three gases, namely nitrogen (78.09%), oxygen (20.95%), and argon (0.93%), make up the majority of the atmosphere of Earth. Trace gases include carbon dioxide (CO2), methane (CH4), carbon monoxide (CO), nitrous oxide (NO2), nitric oxide (NO), chlorofluorocarbons (CFCs), water vapour (H2O), and ozone (O3). Due to their involvement in the greenhouse effect, these trace gases are referred to as greenhouse gases (GHGs).
The greenhouse effect is a process by which thermal radiation from the earth surface is absorbed by atmospheric GHGs, and is re-radiated in all directions. Since part of this re-radiation is sent back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases. The name comes from an analogy with the air inside in a greenhouse compared to the air outside the greenhouse. The role of GHGs in greenhouse effect is that these gases have the effect of acting like a thermal blanket around the globe, trapping energy radiated by surface, generating changes in the distribution of energy that contributed to increase the earth temperature in the atmosphere (Global Warming). The contribution of a greenhouse gas to global warming is commonly expressed by its global warming potential (GWP) which enables the comparison of global warming impact of the gas and that of a reference gas, typically CO_2. On a 100-year basis, the GWP of CO_2, CH_4 and NO_2 are 1, 25 and 298, respectively (Alley et al., 2007). Carbon dioxide equivalent (CO_2e) is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same GWP, when measured over a specified timescale (generally, 100 years) (MoEF, 2010).

Wastewater treatment can be a source of GHGs when treated either aerobically or anaerobically. It emits CO_2 when treated aerobically by the oxidation of organic matter in the activated sludge process and some through the primary clarifiers and CH_4 when treated anaerobically. It can also be a source of N_2O emissions when treated effluent is discharged into the environment. Figure 1 illustrates the generalised wastewater treatmentprocess.

Figure 1 Wastewater treatment plant process (see online version for colours)



The GHG emitted from waste water treatment plants depend upon the treatment technology employed therein. The paragraphs below detail the emissions sources of a particular GHG from a wastewater treatment plant. Primary GHGs of concern from wastewater treatment plants are (Watson et al., 2006):

1 *CO_2:* CO_2 production is attributed to two main factors; treatment process and electricity consumption. During anaerobic process the BOD_5 of wastewater is either incorporated into biomass or it is converted to CO_2 and CH_4. A fraction of biomass isfurther converted to CO_2 and CH_4 via endogenous respiration. Other emission sources of CO_2 are sludge digesters and from digester gas combustion.

In the aerobic process CO_2 is produced through the breakdown of organic matter inthe activated sludge process and some through the primary clarifiers.

2 *CH_4:* Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system. With increases in temperature, the rate of CH_4 production increases. This is especially important in uncontrolled systems and in warm climates.

3 *N_2O:* N_2O is associated with the degradation of nitrogen components in the wastewater, e.g., urea, nitrate (NO_3^-) and protein. Domestic wastewater includes human sewage mixed with other household wastewater, which can include effluent from shower drains, sink drains, washing machines, etc. Centralised wastewater treatment systems may include a variety of processes, ranging from lagooning to advanced tertiary treatment technology for removing nitrogen compounds. After being processed, treated effluent is typically discharged to a receiving water environment (e.g., river, lake, estuary, etc.). Direct emissions of N_2O may be generated during both NDN of the nitrogen present. Both processes can occur in the

plant and in the water body that is receiving the effluent. Nitrification is an aerobic process converting ammonia and other nitrogen compounds into NO_3^-, while denitrification occurs under anoxic conditions (without free oxygen), and involves the biological conversion of NO_3^- into nitrogen gas (N_2). N_2O can be an intermediate product of both processes, but is more often associated with denitrification.

This paper presents information on use of anaerobic biological processes and aerobic processes for the treatment of wastewater and compares the consumption of energy use and the generation of GHGs in the two processes.

2 Methodology

Study area

In this study an inventory of operational data was collected from two wastewater treatment plants in Delhi/NCR, India. The size and type of treatment plant is summarised in Table 1.

Table 1 Details of the plant

S. no.	*Name of the plant*	*Capacity*	*Process of treatment*
1	Sen Nursing Home	10 MLD	High rate Biofilters Densadeg technology
2	Indrapuram	56 MLD	Activated sludge process

Steps followed for preparing a GHG inventory are as follows

Step 1 Setting organisational boundaries: The organisational boundary for this study includes the WWTP and the grid from which the electricity is being imported.

Step 2 Setting operational boundaries: This study identifies following emissionsassociated with operation and the treatment process at WWTP:

- *Scope 1: Direct GHG emissions:* In scope 1 three gases, i.e., CO_2, CH_4 and N_2O are calculated for WWTP. CO_2 emissions from WWTP are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions. Biogenic origin means short cycle or natural sources of atmospheric CO_2 which cycles from plants to animals to humans as part of the natural carbon cycle and food chain do not contribute to global warming. Photosynthesis produced short-cycle CO_2,removes an equal mass of CO_2 from the atmosphere that returns during respiration or wastewater treatment.
- *Scope 2: Indirect GHG emissions:* Scope 2 emissions are from import ofelectricity, steam or gas.
- *Scope 3: Other indirect GHG emissions:* Scope 3 emissions have not beenincluded because of insufficient data.

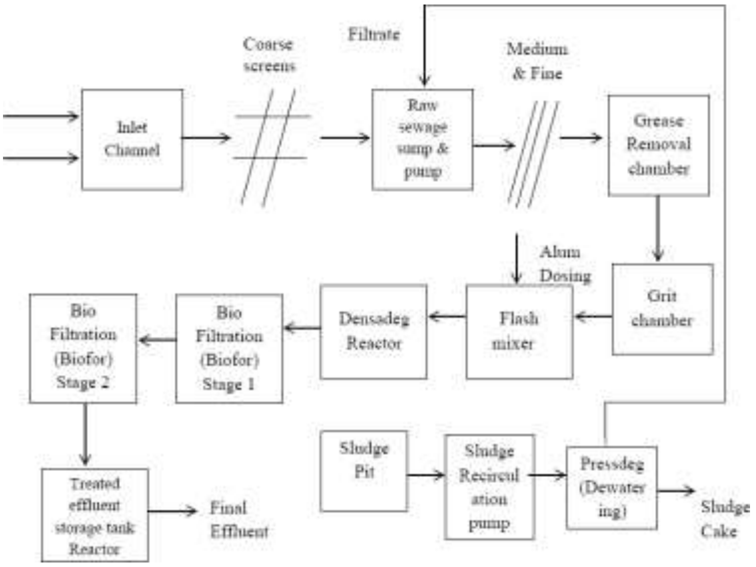
Step 3 *Tracking emissions over time:* In this study GHG emissions are calculated for aperiod of one year from Jan. 2011–Dec. 2011.

Step 4 *Identifying and calculating GHG emissions:* The IPCC Guidelines for NationalGreenhouse Gas Inventories, 2006 has been applied for calculating GHG emissions from WWTPs.

3 Case study – Sen Nursing Home treatment plant

The wastewater treatment plant at Dr. Sen Nursing Home drain has the capacity of 10 MLD [2.2 MGD] of average flow. It is located on the north bank of the Dr. Sen Nursing Home drain, east of the Ring road. This 10 MLD wastewater treatment plant is based on High rate Biofilters Densadeg technology.

Figure 2 Flow diagram of the process at Sen Nursing Home STP



Calculation of GHG emissions from the Plant

Scope 1: Direct GHG emissions

a CO_2 produced through breakdown of organic matter during the aerobic phases of theprocess.

b CH_4 emissions in small quantities, if aeration basins are improperly managed.

c N_2O emissions from the discharge of the effluent into the receiving environment.

Table 2 Total emissions from the plant

Area	*Source*	*CO_2e emissions*
Scope 1	Methane	27 t CO_2e
	Nitrous oxide	4 t CO_2e

Scope 2: Indirect GHG emissions

Indirect GHG emissions resulting from the off-site generation of electric power consumed at WWTP. The expected power use on site was calculated based on the electricity consumption from the following components:

- sump house
- grit chamber
- alum dosing/poly dosing
- primary clarifier
- biofilter blowers.

As such, the estimated scope 2 emissions are shown in Table 3:

Table 3 Scope 2 emissions of the plant

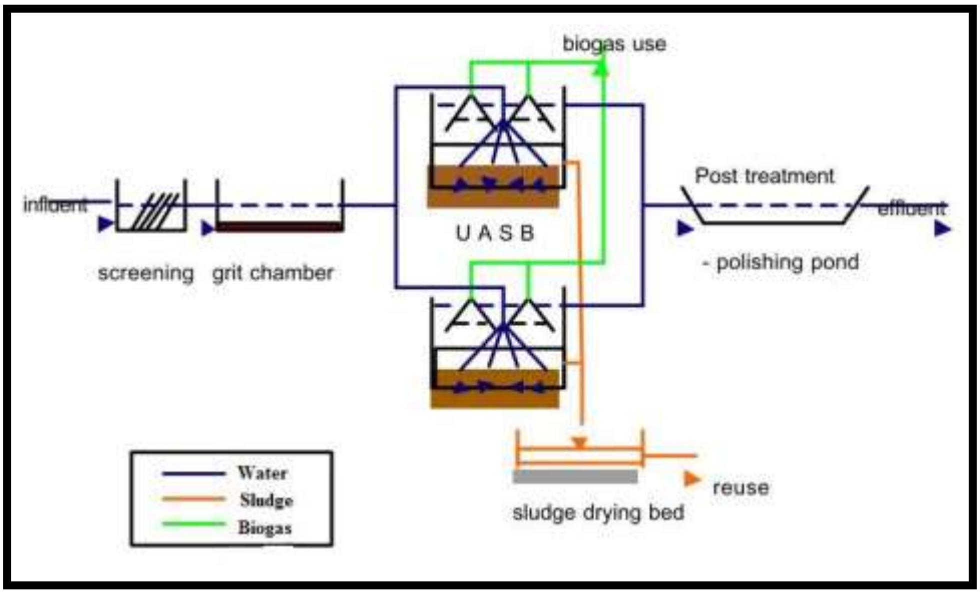
S. no.	*Area*	*Total MWh used yearly*	*Emissions factor (t CO_2/MwH)*	*Total scope 2 emissions CO_2e*
1	Sump house	152.48	0.91	138.75
2	Grit chamber	16.33	0.91	14.86
3	Alum dosing/poly dosing	65.34	0.91	59.45
4	Primary clarifier	19.60	0.91	17.84
5	Biofilter blowers	156.83	0.91	142.72
Total		*410.61*	*0.91 t CO_2/MwH*	*373.62 t CO_2e*

4 Indrapuram wastewater treatment plant

The plant is situated in Uttar Pradesh, Indrapuram. The capacity of the plant is 56 MLD at present. This 56 MLD wastewater treatment plant is based on upflow anaerobic sludge blanket (UASB) reactor.

The catchment area of the said WWTP comes under Trans Hindon area which includes Indrapuram, Vaishali, Vasundara, and Sahibabad, etc. 54 MLD (approx.) of sewage conveyed to this Indrapuram wastewater treatment plant.

Figure 3 Flow diagram of the UASB treatment plant (see online version for colours)



Calculations of GHG emissions of the plant

Scope 1: Direct GHG emissions

a CO_2 produced through breakdown of organic matter during the anaerobic phases ofthe treatment process.

b CH_4 emissions from the anaerobic digestion of organic matter in the UASB reactors.c N_2O

emissions from the discharge of the effluent into the receiving environment.

d CO_2 emissions from the DG sets used at SPS. There are two DG sets of 350 KVAwhich runs for 4 to 5 hrs daily which consumes 40 l of diesel/hr.

Table 4 Scope 1 emissions from the WWTP

Area	*Source*	*CO_2e emissions (t CO_2e)*
Scope 1	Methane	2,091
	Nitrous oxide	19

Scope 2: Indirect GHG emissions

Indirect GHG emissions resulting from the off-site generation of electric power consumed at WWTP. The expected power use on site was calculated based on the electricity consumption from the following components:

- sewage pumping station
- sludge sump
- filtrate pump.

As such, the estimated scope 2 emissions are shown in Table 5:

Table 5 Total scope 2 emissions of the plant

Area	*Total MWh used yearly*	*Emissions factor* (t CO_2/MWh)*	*Total scope 2 emissions (t CO_2e)*
Sewage pumping station	2,685	0.91	2,461
Sludge sump	16.32	0.91	14.85
Filtrate pump	8.03	0.91	7.3
Total	2,709	0.91 t CO_2/MWh	2,465

Source: *CEA (2011)

4.1 *Emissions from diesel generator sets*

There are 2 DG sets of 350 KVA which is used at sewage pumping station for pumping the sewage to the plant. It runs for 4 to 5 hours daily which consumes 40 l of diesel/hr. Emission factor of diesel used is calculated by multiplying emission factor for diesel as per 2006 IPCC guidelines with the density of diesel.

$$\text{Emission factor of diesel}: 74.1\frac{\text{t CO}_2\text{e}}{\text{TJ}}\times 43\frac{\text{TJ}}{\text{Gg}}\times 0.8\frac{\text{kg}}{1} = 0.00255\ \text{t CO}_2\text{e / l diesel}$$

Table 6 Diesel emissions of the plant

Total diesel consumption(l/year)	*Emission factor (t CO_2e/l) of diesel*	*Total CO_2e (t CO_2e/year)*
58,400	0.00255	148.92

5 Results and discussion

Anaerobic treatment is a green alternative to conventional aerobic treatment due to its lower solids generation rate, low electrical energy requirements, lower greenhouse gas emissions, and the production of a usable biogas, a renewable energy. The aerobic treatment system produced the least amount of GHG emissions compared to anaerobic treatment systems. The total GHG emissions of Sen Nursing Home and Indrapuram plants in terms of CO_2e are 404 and 4,724 t CO_2e/yr. The analysis reveals that the energy used is less in WW treated by aerobic process based on High Rate Biofilters Densadeg technology whereas, pumping of sewage to the plant at Indrapuram treatment plant consumes more energy and responsible for 95% of the total energy used at the plant.

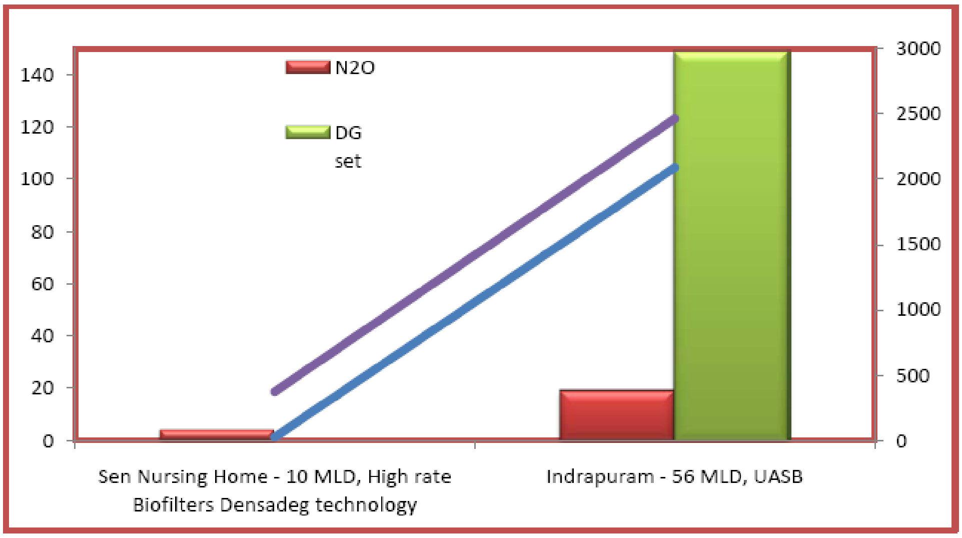
In the anaerobic treatment systems, the GHG emissions which are due to material usage during the treatment process, off-site energy generation, and degradation of carbonaceous material are substantially higher than the GHG emissions resulting from the treatment process itself. However, in the aerobic treatment system, the off-site emissions are higher due to consumption of electricity at site.

Overall, a largely anaerobic degradation of the wastewater pollutants seems economically, and technically feasible and would have major environmental benefits in terms of GHG production.

Table 7 Emissions of different technologies of sewage treatment plants

S. no.		*Capacity*	*Process of treatment*	*Emissions (t CO_2e/year)*			
				Scope 1		*Scope 2*	
				CH_4	*N_2O*	*DG set*	*Electricity*
1	Sen Nursing Home	10 MLD	High rate Biofilters Densadeg technology	27.23	3.98	NIL	373.62
2	Indrapuram	56 MLD	Upflow anaerobic sludge blanket reactor (UASB)	2,091	19.08	148.90	2,465

Figure 4 GHG contribution by the individual processes in the two plants (see online versionfor colours)



6 Conclusions

The study is used for making a GHG inventory and estimating energy use and GHG emissions from WWTPs based on different technologies. In this paper, a comparative analysis is done for two WWTPs based on High rate Biofilters Densadeg technology and UASB-based plant. The plausible reason is that the energy intensity and GHG emissions depends on the capacity of the treatment plant and the type of treatment technology used.

Based on the evidence of the study, it is stated that anaerobic treatment process seems economically, and technically feasible and would have major environmental benefits in terms of greenhouse gas production. CH_4 generation was maximum in UASB-based plant and used for generation of electricity or used as a fuel at site. Whereas, in High rate Biofilters Densadeg technology produces less CH_4. However, such a generalisation needs to be supported with a number of analyses for various types of treatment processes and wastewater characterisation in various regions of the world.

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