

EVALUATION OF GREEN HOUSE GASES EMISSIONS FROM SEWAGE TREATMENT PLANTS

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Abstract - Sewage treatment plants are considered as sources of GHGs (greenhouse gases) production mainly methane, carbon dioxide and nitrous oxide which are produced during biological sewage treatment process and off-site electricity production which is a major source of carbon dioxide generation. Reducing the green house gases from the sewage treatment plants is a major concern. The day to day increase in the global temperature is an alarming situation and the most prominent cause of which is increase in the emission of green house gases. In this study, it has been attempted to evaluate the emissions of green house gases from some of the major sewage treatment plants of Delhi. It has been observed that the indirect GHGs emission because of the generation of power at off-site is much more than the direct on-site GHGs emission as a result of sewage treatment by the Activated Sludge Process. The power consumption of the concerned plants are obtained the respective plants. The total power consumption of Okhla, Keshopur and Yamuna Vihar sewage treatment plants are obtained by the addition of the BSES electricity bills for each month (January-2014 to December-2014) provided by the engineers at the respective plants.

Key Words: Green House Gases, Activated Sludge Process, Methane Correction Factor, Methane, Global Temperature.

INTRODUCTION

The increasing concentration of GHGs in the atmosphere have led to further studies of GHGs estimation and its source. Waste water is received by wastewater treatment plant and produces treated water by the use of different processes such as aerobic treatment, anaerobic treatment[1]. The GHGs emissions from wastewater treatment processes and operations in recent years have become a significant concern and thus are increasingly measured and also assessed while determining the long term sustainability of a treatment

system[2]. The larger minor sources of GHGs emissions are wastewater treatment plants (WWTPs). Both directly and indirectly during the treatment processes these plants produce the three important GHGs namely carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). The gaseous byproducts such as CO₂, CH₄, and N₂O results in direct emissions and the indirect emissions are caused due to the use of energy and ancillary activities[3].

1.1 Objectives

In this study, the data from various sources including the sewage treatment plants have been collected for the more accurate and appropriate estimation of GHGs emissions and the objective of the project are:

To evaluate the direct GHGs namely CH₄, N₂O and CO₂ emissions from the four major sewage treatment plants in Delhi namely :

- Okhla Sewage Treatment Plant,
- Rithala Sewage Treatment Plant,
- Keshopur Sewage Treatment Plant and
- Yamuna Vihar Sewage Treatment Plant.

To quantify the indirect emissions of green house gases as result of electricity consumption by concerned sewage treatment plants.

2. METHODOLOGY

The data required for the evaluation of green house gases emissions were collected from the respective sewage treatment plants namely Okhla, Rithala, Keshopur and Yamuna Vihar. Also the visits were made to Delhi Jal Board (DJB) and Delhi Pollution Control Committee (DPCC) for obtaining the values for methane correction factor of the concerned treatment plants and other parameters required for estimating GHGs emissions. Procedures and protocols for

quantifying the emissions were followed as per IPCC 2006 guidelines.

2.1 Protocol and Procedure for Evaluating GHGs Emissions

The study is based on GHG protocol and IPCC Guidelines for National Greenhouse Gas Inventories (2006). The Greenhouse Gas (GHG) Protocol, developed by World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD), sets the global standard for how to measure, manage, and report greenhouse gas emissions. As per the protocol firstly, the organizational boundary and operational boundary are identified. The organizational boundary includes the STP and the grid from which the electricity is being imported.

The operational boundary includes the emissions associated with operation and the treatment process at STP. The operational boundary includes Scope1, Scope2 and Scope3 emissions.

In scope 1 three gases i.e. CO₂, CH₄ and N₂O are calculated for STP. CO₂ emissions from STP and should not be included in national total emissions. Biogenic origin means short cycle or natural sources of atmospheric CO₂ which cycles from plants to animals to humans as part of the natural carbon cycle and food chain do not contribute to global warming.

In Scope 2 emissions are from import of electricity and in Scope 3 emission other indirect emissions can be calculated but in this study it is not included because of insufficient data.

Secondly, the tracking of emissions over a fixed period of time is done. In this study the GHGs emissions are calculated for a period of one year i.e. from January 2014 to December 2014.

Thirdly, GHGs emissions from STP are calculated. We have followed IPCC 2006 Guidelines for National Greenhouse Gas Inventories for calculating GHG emissions from STPs.

The country specific values for the per capita BOD and methane correction factor is obtained from the Delhi Pollution Control Board and the sewage treatment plants which are established by Delhi Jal Board.

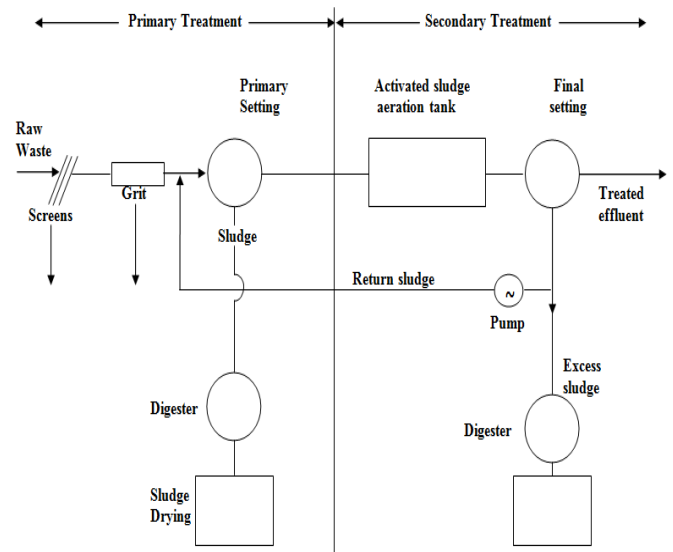


Fig -1: Flow Diagram of Sewage Treatment Plants at Okhla, Keshopur ,Yamuna Vihar and Rithala.

In the sewage treatment plant, the activated sludge process is a biological process that involves air or oxygen being introduced into a mixture of screened, and primary treated sewage combined with organisms to develop a biological floc which reduces the organic content of the sewage. The combination of wastewater and biological mass is commonly known as mixed liquor. In all activated sludge plants, once the wastewater has received sufficient treatment, excess mixed liquor is discharged into settling tanks and the treated supernatant is run off to undergo further treatment before discharge. Part of the settled material, the sludge, is returned to the head of the aeration system to re-seed the new wastewater entering the tank. This fraction of the floc is called return activated sludge.

3. RESULTS AND DISCUSSIONS

3.1 Calculation of Total Organics in Wastewater

$$\begin{aligned} \text{TOW (kg BOD/cap/yr)} \\ = P * \text{BOD} * 0.001 * I * 365 \end{aligned}$$

$$\begin{aligned} &= 16787941 * 46.8 * 0.001 * 1.25 * 365 \text{ (See Table 1)} \\ &= 358464510.2 \text{ kg BOD/cap/y} \text{-----(1)} \end{aligned}$$

3.2 Estimation of methane emission factor

$$\begin{aligned} \text{Methane Emission factor (EFj) (kg CH}_4\text{/kg BOD)} \\ = B_o * \text{MCF}_j \\ = 0.6 * 0.001 \text{ (See Table 1)} \\ = 0.0006 \text{----- (2)} \end{aligned}$$

B_o is the maximum CH₄ producing capacity, kg CH₄/kg BOD

Table -1: Parameter Values for Estimation of Direct GHGs.

Parameter	Value	Source	
Per Capita BOD(gBOD/day)	46.8	DPCC	
Population(P)	16787941	Statistical Abstract of Delhi 2014 Report, Govt. of NCT of Delhi	
Methane correction factor or each treatment system(MCFj),Bo	0.001,0.6 respectively.	DJB, Respective Sewage Treatment Plants, IPCC 2006	
Bo, FNPR, FNON-CON, FIND-COM	0.6,0.16,1.4,1.25 respectively.	IPCC 2006	
Ui	Rural	0.07	Housing Condition in India NSS Report 2010,MOEF Report 2011
	Urban High	0.66	
	Urban Low	0.27	
Tij	Rural	0.00	Housing Condition in India NSS Report 2010,MOEF Report 2011
	Urban High	0.95	
	Urban Low	0.99	

3.3 Calculation for methane emissions

Type of treatment or discharge is Aerobic.

Fraction of Population income group (Ui) fraction for Delhi is as follows:

- Rural = 0.07
- Urban High = 0.66
- Urban Low = 0.27
- Average total = 0.333

Degree of utilization of treatment, discharge pathway or method (Tij) for each income group:

- Rural = 0.00
- Urban High = 0.95
- Urban Low = 0.99
- Average Total = 0.65

Using the values of Ui and Tij form Table 1 and TOW and Emission factor from equation(1)&(2) in the governing equation, we get methane emissions as:

$$\text{Total CH}_4 \text{ Emissions} = [\sum_i (U_i * T_{i,j} * EF_j)](TOW-S)-R$$

Where,

S = Organic component removed as sludge, kg BOD/yr
 R = amount of CH4 recovered in inventory year, kg CH4/yr
 Default values of S and R are taken as zero as per IPCC 2006 guidelines.

$$\begin{aligned} \text{Total CH}_4 \text{ Emissions(kg CH}_4\text{/yr)} \\ &= 358464510.2 * 0.0006 * 0.65 * 0.333 \\ &= 46553.78. \end{aligned}$$

Global Warming Potential (GWP) for Methane = 25 (Source: IPCC Fourth Assessment Report (FAR),2007)

$$\text{Total CO}_2\text{e} = 46.55378 * 25 = \mathbf{1164 \text{ tCO}_2\text{e/yr}}$$

3.4 Total Nitrogen in the Effluent

Total Nitrogen in the Effluent

$$\begin{aligned} &= (P * \text{Protein} * \text{FNPR} * \text{FNON-CON} * \text{FIND-COM}) - \text{NSLUDGE} \\ &= 16787941 * 0.056 * 0.16 * 1.4 * 1.25 \text{ (See Table 1)} \\ &= 263234.9 \text{ kg N/year} \text{-----(3)} \end{aligned}$$

Where:

- NEFFLUENT = total annual amount of nitrogen in the wastewater effluent, kg N/yr
- P = human population
- Protein = annual per capita protein consumption, default=0.056 kg/person/yr
- FNPR = fraction of nitrogen in protein, default = 0.16, kg N/kg protein
- FNON-CON = factor for non-consumed protein added to the wastewater
- FIND-COM = factor for industrial and commercial co-discharged protein into the sewer system
- NSLUDGE = nitrogen removed with sludge (default = zero), kg N/yr

3.5 Calculation of N2O Emissions from the Sewage Treatment Plant

$$\begin{aligned} \text{Net N}_2\text{O Emission} \\ &= \text{NEFFLUENT} * \text{E}_{\text{EFFLUENT}} * 44/28 \\ &= 263234.9 * 0.005 * 1.57 \text{-----from(3)} \\ &= \mathbf{206.6 \text{ kg N}_2\text{O/year}} \end{aligned}$$

Where:

- N2O emissions = N2O emissions in inventory year, kg N2O/yr
- E_{EFFLUENT} = emission factor for N2O emissions from discharged wastewater, kg N2O-N/kg N
- The factor 44/28 is the conversion of kg N2O-N into kg N2O.

$$\begin{aligned} \text{GWP for N}_2\text{O} &= 298 \text{ (IPCC FAR,2007)} \\ \text{Total CO}_2\text{e Emission} \\ &= 61566.8 \text{ kgCO}_2\text{e/yr} = \mathbf{62 \text{ tCO}_2\text{/yr}} \text{(approx.)} \end{aligned}$$

Hence, Total Direct GHGs Emissions(CH4&N2O) = (Total CH4+Total N2O)Emissions = **1164+62 = 1226tCO2/yr.**

3.6 Methane Emissions

a.) Net CH₄ Emissions (kg CH₄/yr) from four STPs combined = 186216

b.) Net CH₄ Emissions (tCO_{2e}/yr) from four STPs combined = 4656

3.7 Nitrous Dioxide Emissions

a.) Net N₂O Emissions (kg N₂O/yr) from four STPs combined = 828

b.) Net N₂O Emissions (tCO_{2e}/yr) from four STPs combined = 248

The individual methane emissions and nitrous dioxide emissions from all the four STPs are same and the net emissions from all the four STPs are obtained by the addition of emissions by each sewage treatment plants. The methane emissions from each treatment plants is same because of the same MCF values which was provided by the Delhi Jal Board.

3.8 Indirect GHGs Emissions

a.) Emissions from Okhla STP(tCO_{2e}/yr) = 14240

b.) Emissions from Rithala STP(tCO_{2e}/yr) = 10560

c.) Emissions from Keshopur STP(tCO_{2e}/yr) = 17413

d.) Emissions from Yamuna Vihar STP(tCO_{2e}/yr) = 2933

Table -2 : Total CO₂ equivalent indirect emission from the STPs.

Plant	Power Consumption(MWH/Yr.)	Emission Factor (tCO ₂ /MWH)	Total CO ₂ Equivalent Emission(tCO _{2e} /yr)
Okhla STP	17365	0.82	14240
Rithala STP	12878	0.82	10560
Keshopur STP	21236	0.82	17413
Yamuna Vihar STP	3577	0.82	2933

The emission factor is available from Central Electricity Authority,CO₂ Baseline Database for Indian Power Sector 2014.

The net green house gases emissions are the sum total of the direct and the indirect emissions from the plants. It is found that Keshopur plant(72MGD) has the highest emissions which is 18640tCO₂/yr and Yamuna Vihar STP has the lowest emission of 4159tCO₂/yr.

The lowest emission of Yamuna Vihar STP is primarily because the volume of the sewage being treated at this plant is less as compared to the other plants. Directions by

the Delhi Jal Board have been given to Keshopur plant to reduce the power consumption so that the emission of green house gases can be minimized.

4.CONCLUSION

The direct GHGs emissions from four STPs combined is 4904 tCO_{2e}/yr while the combined indirect emissions is 45146 tCO_{2e}/yr. The result indicates that the amounts the indirect green house gases emissions were significantly higher than the direct emissions at all the four STPs.

CH₄ production from all the four plants is assessed as 4656 tCO_{2e}/yr and 248 t CO_{2e}/yr as N₂O emissions. The four sewage treatment plants which have been studied are the major treatment plants which combined together treats more than 70 percent of the total sewage generated in Delhi.

The Keshopur plant where the actual flow of the sewage to be treated is less as compared to flow at Okhla plant is producing more indirect emissions. The higher emissions from the Keshopur plant can be reduced by reducing the power consumption for various other miscellaneous activities.

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