A

MAJOR

PROJECT REPORT

ON

GREENHOUSE GAS EMISSIONS INVENTORY OF WASTEWATER TREATMENT PLANTS OF DELHI/NCR

SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF

MASTER OF TECHNOLOGY

(ENVIRONMENTAL ENGINEERING)

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CERTIFICATE

It is certified that the work presented in this report entitled **"GREENHOUSE GAS EMISSION INVENTORY OF WASTEWATER TREATMENT PLANTS OF DELHI/ NCR"** by Diksha Gupta, Roll No. 03/ENV/2k10 in partial fulfillment of the requirement for the award of the degree of Master of Technology in Environmental Engineering, Delhi Technological University (Formerly Delhi College of Engineering), Delhi, is an authentic record. The work is being carried out by her under our guidance and supervision in the academic year 2012. This is to our knowledge has reached requisite standards.

The work embodied in this major project has not been submitted for the award of any other degree to the best of our knowledge.

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DECLARATION

I, hereby declare that the work being presented in the Project Report entitled **"GREENHOUSE GAS EMISSION INVENTORY OF WASTEWATER TREATMENT PLANTS OF DELHI/NCR"** is an original piece of work and an authentic report of our own work carried out during the period of 4th Semesteras a part of our major project.

The data presented in this report was generated & collected from various sources during the above said period and is being utilized by us for the submission of our Major Project Report to complete the requirements of Master's Degree of Examination in Environmental Engineering, as per Delhi Technological University curriculum.

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ABSTRACT

During the last 200 years the atmospheric concentrations of greenhouse gases (GHGs) have been increasing. Human activities such as agriculture, industry, waste disposal, deforestation, and especially increasing use of fossil fuels have been producing increasing amounts of GHGs. For example, the concentrations of CO_2 increased from approximately 280 part per million by volume (ppmv) in pre-industrial age to 372.3 ppmv in 2001 and it will continue to increase at about 0.5% per year[1], whereas current CH_4 atmospheric concentration is going up at a rate 0.02 ppmv per year[2]. Furthermore, the annual sources of N_2O have been increased from the surface of the Earth by about 40–50% over pre-industrial levels. As a result, variations in the radiative forcing of Earth's atmosphere could be produced, so leading to large and rapid changes in the earth's climate due to global warming produced by these gases.

Waste water treatment system generates significant amount of greenhouse gases mainly Methane (CH_4) and Nitrous Oxide (N_2O). Hence, reducing the emission of greenhouse gases from the Waste Water Treatment Plants (WWTPs) is the major concern. The correct understanding and estimation of the greenhouse gases emitted from different points of the plan is essential to tackle this challenge. The WWTPs are based in natural processes and provide a high removal of BOD, COD, organic carbon, nutrients and pathogenic microorganisms from wastewater. Furthermore, they allow recovering energy and nutrients of the wastewater treated, thus their application in developing countries can be appropriated. However, the different transformations and biochemistry processes of organic and nitrogen matter carried out in WWTP produce GHGs emissions, thus contributing to global warming.

Keywords: Radiative forcing, ppmv, BOD, biochemistry, transformations.

[1]IPCC Fourth Assessment Report: Climate Change 2007 (AR4)

[2]IPCC Guidelines for National Greenhouse Gas Inventories, 2001

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LIST OF ABBREVIATIONS

Abbreviation used	Meaning
GHG	Greenhouses Gases
WWTP	Wastewater Treatment Plants
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
CH_4	Methane
N_2O	Nitrous Oxide
O_3	Ozone
IPCC	Intergovernmental Panel on Climate Change
CFCs	Chlorofluorocarbons
PFCs	Perfluorocarbon
HFCs	Hydroflurocarbons
SF_6	Sulphur Hexaflouride
GHG	Greenhouse Gas
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
NDN	Nitrification Denitrification
MLD	Million litre per day
MGD	Million gallon per day
SBR	Sequential Batch Reactor
UASB	Upflow Anaerobic Sludge Blanket
EF	Emission Factor
MWh	Mega Watt Hour
ppm	parts per million
ppb	parts per billion
ppt	parts per trillion
kg	Kilogram
ppmv	parts per million by volume
DG	Diesel Generator
SPS	Sewage Pumping Station
RF	Radiative Forcing
EPA	Environment Protection Agency
WW	Wastewater

CHAPTER - 1
INTRODUCTION

1.1 Background

Earth's atmosphere primarily consists of three gases, nitrogen (78.09%), oxygen (20.95%), and argon (0.93%). Furthermore, there are trace gases as carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), nitrous oxide (NO_2), nitric oxide (NO), chlorofluorocarbons (CFC´s), water vapour (H_2O) and ozone (O_3). These trace gases are known as greenhouse gases (GHGs) because they contribute to the greenhouse effect.

The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. Since part of this re-radiation is 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 greenhouse gases in greenhouse effect is that these gases have the effect of acting like athermal blanket around the globe, trapping energy radiated by surface earth, generating changes in the distribution of energy that contributed to increase the temperature in the atmosphere (Global Warming).

The increase in greenhouse gases concentration modifies the climate. The important feature of GHGs in the atmosphere is that they absorb and re-radiate downward a large fraction of longer far infrared wavelengths (i.e. 8 to 12 μm) warming the Earth's surface. Without this heat trapping by the GHGs in the atmosphere, the surface of the Earth would be about 20^{o}C colder than it is. However, during the last 200 years, human activities as the agriculture, industry, waste disposal, deforestation, and especially fossil fuel have been producing increasing amounts of GHGs changing the composition of these gases in the atmosphere (Table 1.1). RF is generally defined as the change in net irradiance between different layers of the atmosphere. A positive forcing (more incoming energy) tends to warm the system, while a negative forcing (more outgoing energy) tends to cool it. Sources of radiative forcing include changes in insolation (incident solar radiation) and in concentrations of radiatively active gases and aerosols. The concept of RF is useful because a linear relationship has been determined between the global mean equilibrium surface temperature changes and the amount of RF. As a result, variations in the radiative forcing of Earth's atmosphere are produced and would cause large and rapid changes in theclimate due to global warming.

Table1.1: GHGconcentration in atmosphere with time

Gas	Pre-industrial level	Current level	Increase since 1750	Radiative forcing (W/m^2)
CO_2	280 ppm	396 ppm	116 ppm	1.46

Gas	Pre-industrial level	Current level	Increase since 1750	Radiative forcing (W/m^2)
CH_4	700 ppb	1745 ppb	1045 ppb	0.48
N_2O	270 ppb	314 ppb	44 ppb	0.15
CFC-12	0	533 ppt	533 ppt	0.17

Source: IPCC Fourth Assessment Report

Wastewater treatment can be a source of GHGs when treated either aerobically or anaerobically.It emits CO_2 when treated aerobically by the breakdown of organic matter in the activated sludge process and some through the primary clarifiers and CH_4 when treated or disposed anaerobically. It can also be a source of N_2O emissions when treated effluent is discharged into the environment.Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site, sewered to a centralized plant (collected) or disposed untreated nearby or via an outfall. Domesticwastewater is defined as wastewater from household water use, while industrial wastewater is from industrialpractices only. Treatment and discharge systems can sharply differ between countries. Also, treatment anddischarge systems can differ for rural and urban users, and for urban high income and urban low-income users.

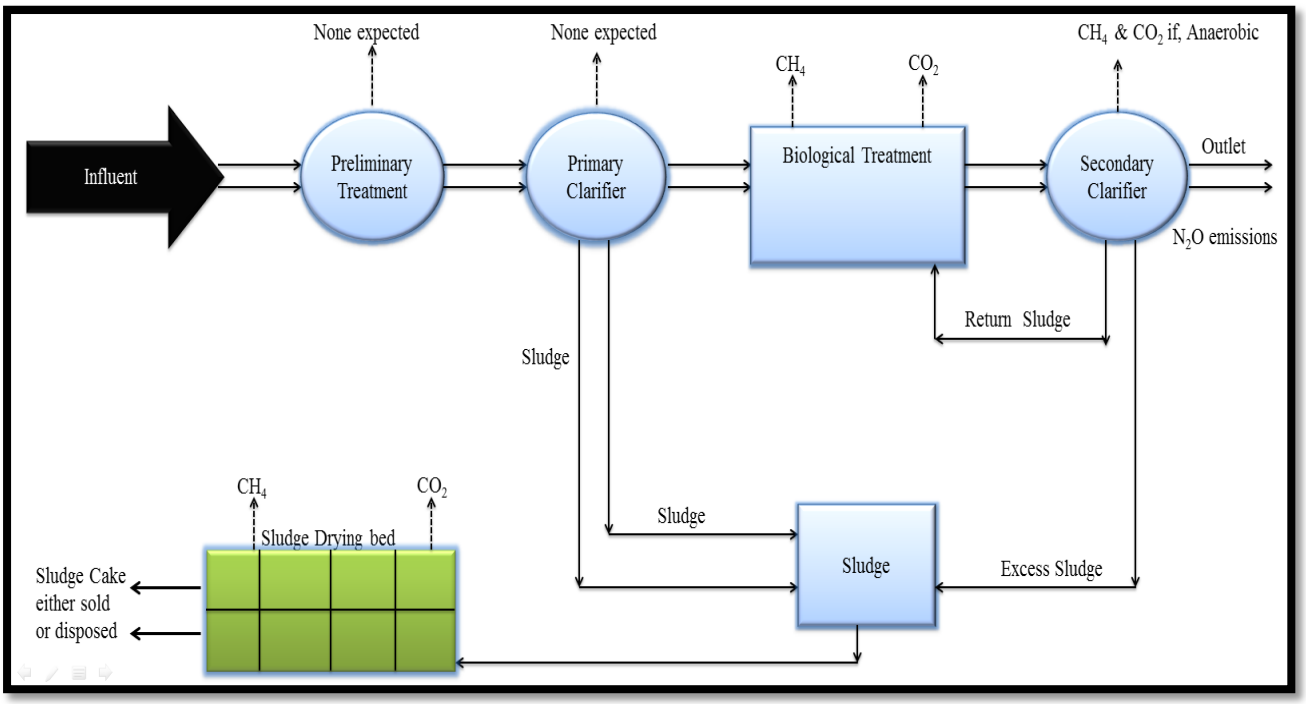
The most common wastewater treatment methods in developed countries are centralized aerobic wastewatertreatment plants and lagoons for both domestic and industrial wastewater. To avoid high discharge fees or tomeet regulatory standards, many large industrial facilities pre-treat their wastewater before releasing it into thesewage system. Domestic wastewater may also be treated in on-site septic systems. These are advanced systemsthat may treat wastewater from one or several households. They consist of an anaerobic underground tank and adrainage field for the treatment of effluent from the tank. Some developed countries continue to dispose ofuntreated domestic wastewater via an outfall or pipeline into a water body, such as the ocean.

The degree of wastewater treatment varies in most developing countries. In some cases industrial wastewater isdischarged directly into bodies of water, while major industrial facilities may have comprehensive in-planttreatment. Domestic wastewater is treated in centralized plants, pit latrines, septic systems or disposed of inunmanaged lagoons or waterways, via open or closed sewers. In some coastal cities domestic wastewater isdischarged directly into the ocean. Pit latrines are lined or unlined holes of up to several meters deep, which may befitted with a toilet for convenience. Figure 1 shows different pathways for wastewater treatment and discharge.

Centralized wastewater treatment methods can be classified as primary, secondary, and tertiary treatment. Inprimary treatment, physical barriers remove larger solids from the wastewater. Remaining particulates are thenallowed to settle. Secondary treatment consists of a combination of biological processes that promotebiodegradation by micro-organisms. These may include aerobic stabilisation ponds, trickling filters, and activatedsludge processes, as well as anaerobic

reactors and lagoons. Tertiary treatment processes are used to further purifythe wastewater of pathogens, contaminants, and remaining nutrients such as nitrogen and phosphorus compounds.This is achieved using one or a combination of processes that can include maturation/polishing ponds, biologicalprocesses, advanced filtration, carbon adsorption, ion exchange, and disinfection.Sludge is produced in all of the primary, secondary and tertiary stages of treatment. Sludge that is produced inprimary treatment consists of solids that are removed from the wastewater and is not accounted for in thiscategory. Sludge produced in secondary and tertiary treatment results from biological growth in the biomass, aswell as the collection of small particles. This sludge must be treated further before it can be safely disposed of.Methods of sludge treatment include aerobic and anaerobic stabilisation (digestion), conditioning, centrifugation,composting, and drying. Figure1.1 illustrates the generalized wastewater treatment process.

Figure1.1: Wastewater treatment system process



1.2 Greenhouse Gases from Wastewater Treatment Plants

Primary greenhouse gases of concern from wastewater treatment plants are:

- CO_2;
- CH_4; and
- N_2O

The greenhouse gas 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.

1.2.1 Carbon Dioxide (CO_2)

CO_2 production is attributed to two main factors; treatmentprocess and electricity consumption. Duringanaerobic process the BOD_5 of wastewater iseither incorporated into biomass or it is convertedto CO_2 and CH_4. A fraction of biomassis further converted to CO_2 and CH_4 via endogenousrespiration. Other emission sources of carbon dioxide are sludge digesters and from digester gas combustion.

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

1.2.2 Methane (CH_4)

Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. The extent of CH_4production 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 isespecially important in uncontrolled systems and in warm climates. Below 15°C, significant CH_4 production isunlikely because methanogens are not active and the lagoon will serve principally as a sedimentation tank.However, when the temperature rises above 15°C, CH_4 production is likely to resume.

The principal factor in determining the CH_4 generation potential of wastewater is the amount of degradableorganic material in the wastewater. Common parameters used to measure the organic component of thewastewater are the BOD and COD. Under thesame conditions, wastewater with higher COD or BOD concentrations will generally yield more CH_4 thanwastewater with lower COD (or BOD) concentrations.

The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The standardmeasurement for BOD is a 5-day test, denoted as BOD_5. The term 'BOD' in this work refers to BOD_5. Then COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable). Since the BOD is an aerobic parameter, it may be less appropriate for determining the organic components inanaerobic environments. Also, both the type of wastewater and the type of bacteria present in the wastewater influence the BOD concentration of the wastewater. Usually, BOD is more frequently reported for domesticwastewater, while COD is predominantly used for industrial wastewater.

1.2.3 Nitrous Oxide (N_2O)

N_2O is associated with the degradation of nitrogen components in the wastewater, e.g., urea, nitrate and protein. Domestic wastewater includes human sewage mixed with other household wastewater, which can include effluent from shower drains, sink drains, washing machines, etc. Centralized 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 nitrate (NO_3^-), while denitrification occurs under anoxic conditions (without free oxygen), and involves the biological conversion of nitrate into nitrogen gas (N_2). N_2O can be an intermediate product of both processes, but is more often associated with denitrification.

The table below presents the GHG expected to be emitted from various treatment units at WWTP.

Table 1.2: Expected GHG emissions from particular treatment units at WWTP

Treatment process	**Expected GHG emissions**
Preliminary Treatment	None expected
Primary Treatment	None expected
Secondary Treatment	None expected from well managed aerobic processes CH_4 from uncollected and uncontrolled anaerobic wastewater treatment processes (e.g. anaerobic lagoons)
Tertiary (Advanced)Treatment	N_2O emissions from NDN process
Solids (Sludge) handling	Fugitive CH_4 emissions from sludge handling processes such as digestion (these emissions may be considered as deminimus) CH_4 emissions resulting from incomplete combustion of digester gas.
Effluent discharge	N_2O emissions from denitrification of nitrogen species originating from wastewater effluent in receiving environment.

1.3 Objectives of this study

The objective of this study is to quantify GHGs emitted from five WWTPs of Delhi/NCR. Five WWTPs included in the study are:

1. Noida, Sector-54
2. Sen Nursing Home
3. Indrapuram
4. Delhi Gate

5. Yamuna Vihar (Phase-I)

This assessment will help in identifying opportunities to curtail energy use and associated GHG emissions.

CHAPTER-2

LITERATURE REVIEW

2.1GHG Emissions from WW Treatment at Global Level

Worldwide wastewater is the fifth largest source of anthropogenic CH_4 emissions, contributingapproximately 9%[3] of total global CH_4 emissions in 2000. India, China, UnitedStates, and Indonesia combined account for 49%[4] of the world's CH_4emissions from wastewater. Global CH_4emissions from wastewater are expected to grow by approximately 20%[5] between 2005 and 2020.

Also,worldwide wastewater as asource is the sixth largest contributor to N_2O emissions, accounting for approximately 3 %[6] of N_2Oemissions from all sources. Indonesia, the United States, India, and China accounted for approximately 50 %[7] of total N_2O emissions from domestic wastewater in 2000. Global N_2O emissions from wastewater are expected to grow by approximately 13%[8] between 2005 and 2020.

The highest regional percentages for CH_4 emissions from wastewater are from Asia (especially China, India) (US EPA, 2006). Other countries with high emissions in their respective regions include Turkey, Bulgaria, Iran, Brazil, Nigeria and Egypt. Total global emissions of CH_4 from wastewater handling are expected to rise by more than 45%[9] from 1990 to 2020 (Table 2.1) with much of the increase from the developing countries of East and South Asia, the middle East, the Caribbean, and Central and South America. The EU has projected lower emissions in 2020 relative to 1990 (US EPA, 2006).

Table 2.1: Global Trends for GHG emissions from waste using (a) 1996 and (b) 2006 IPCC inventory guidelines, extrapolations, and projections ($MtCO_2$-eq, rounded)

Source	1990	1995	2000	2005	2010	2015	2020
Wastewater CH_4[a]	450	490	520	590	600	630	670
Wastewater N_2O[a]	80	90	90	100	100	100	100

Notes: Emissions estimates and projections as follows:

[3]www.epa.gov/nonco2/econ-inv/international.html
[4]www.epa.gov/nonco2/econ-inv/international.html
[5]www.epa.gov/nonco2/econ-inv/international.html
[6]www.epa.gov/nonco2/econ-inv/international.html
[7]www.epa.gov/nonco2/econ-inv/international.html
[8]www.epa.gov/nonco2/econ-inv/international.html
[9] IPCC Fourth Assessment Report: Climate Change 2007.

[a] Based on reported emissions from national inventories and national communications, and (for non-reporting countries) on 1996 inventory guidelines and extrapolations (US EPA, 2006).
[b] Based on 2006 inventory guidelines and business-as-usual (BAU) projection (Monni et al., 2006).

CH_4 emissions from wastewater alone are expected to increase almost 50%[10] between 1990 and 2020, especially in the rapidly developing countries of Eastern and Southern Asia. Estimates of global N_2O emissions from wastewater are incomplete and based only on human sewage treatment, but these indicate an increase of 25%[11] between 1990 and 2020.

In 2010, for United States CH_4 emissions from domestic wastewater treatment were 7.8Tg CO_2eq[12]. Emissions gradually increased from 1990 through 1997, but have decreased since that time due to decreasing percentages of wastewater being treated in anaerobic systems, including reduced use of on-site septic systems and central anaerobic treatment systems.

With respect to N_2O, the United States identifies two distinct sources for N_2O emissions from domestic wastewater: emissions from centralized wastewater treatment processes and emissions from effluent that has been discharged into aquatic environments. In 2010, emissions of N_2O from centralized wastewater treatment processes and from effluent that has been discharged into aquatic environments were estimated to be 0.3 Tg CO_2 eq.[13] and 4.7 Tg CO_2eq[14] respectively. Total N_2O emissions from domestic wastewater were estimated to be 5.0 Tg CO_2eq[15]. N_2O emissions from wastewater treatment processes gradually increased across the time as a result of increasing United States population and protein consumption.

The table below presents emissions from WWTPs in United States from 1990 – 2010. This has also been presented in the graphical form in Figure 2.1

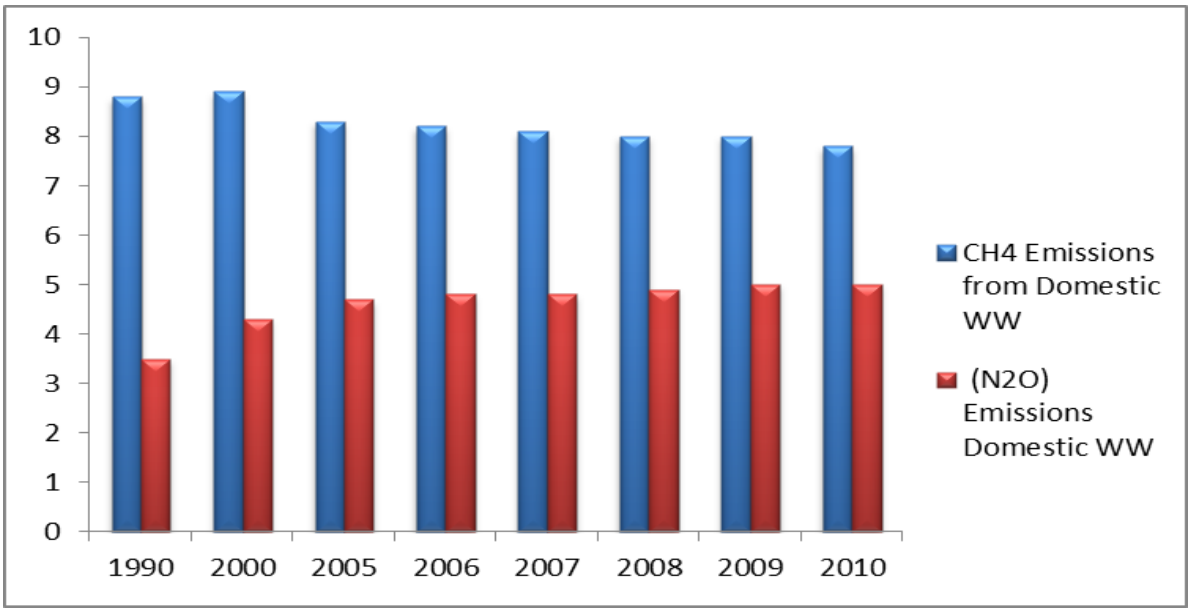
Table 2.2: CH_4 and N_2O emissions from domestic wastewater treatment in United States (Tg CO_2eq)

Activity	1990	2000	2005	2006	2007	2008	2009	2010
CH_4emissions from domestic WW	8.8	8.9	8.3	8.2	8.1	8.0	8.0	7.8
N_2Oemissions from domestic WW	3.5	4.3	4.7	4.8	4.8	4.9	5.0	5.0

Source: Inventory of U.S Greenhouse gas emissions and sinks (1990-2010)

[10] US EPA, 2006.
[11] US EPA, 2006.
[12] Inventory of U.S Greenhouse gas emissions and sinks (1990-2010)
[13] Inventory of U.S Greenhouse gas emissions and sinks (1990-2010)
[14] Inventory of U.S Greenhouse gas emissions and sinks (1990-2010)
[15] Inventory of U.S Greenhouse gas emissions and sinks (1990-2010)

Figure 2.1: CH_4 and N_2O emissions from domestic wastewater treatment in United States (Tg CO_2eq)



2.2 GHG Emissions from WW Treatment in India

The Indian government attaches great importance to climate change issues, and signed the United Nations Framework Convention on Climate Change (UNFCCC or Convention) in 1993.

The official GHG emission profile of India at 1994 level was prepared for the India's Initial National Communication submitted to the UNFCCC in June 2004.

The assessment of GHG profile 2007 provides information on India's emissions of GHG from WW sector.As per the India GHG emissions 2007, total CO_2e emissions from WW sources in India in 2007 were 45 million tons[16],which is 82% of the total CO_2 equivalent emissions fromthe waste sector. The total methane emitted in 2007 was1.9 million tons[17] (4.2%) and N_2O emitted was 15.8 thousand tons[18] (.035%).

Table 2.3: GHG emissions from waste water sector in India in 2007(thousand tons)

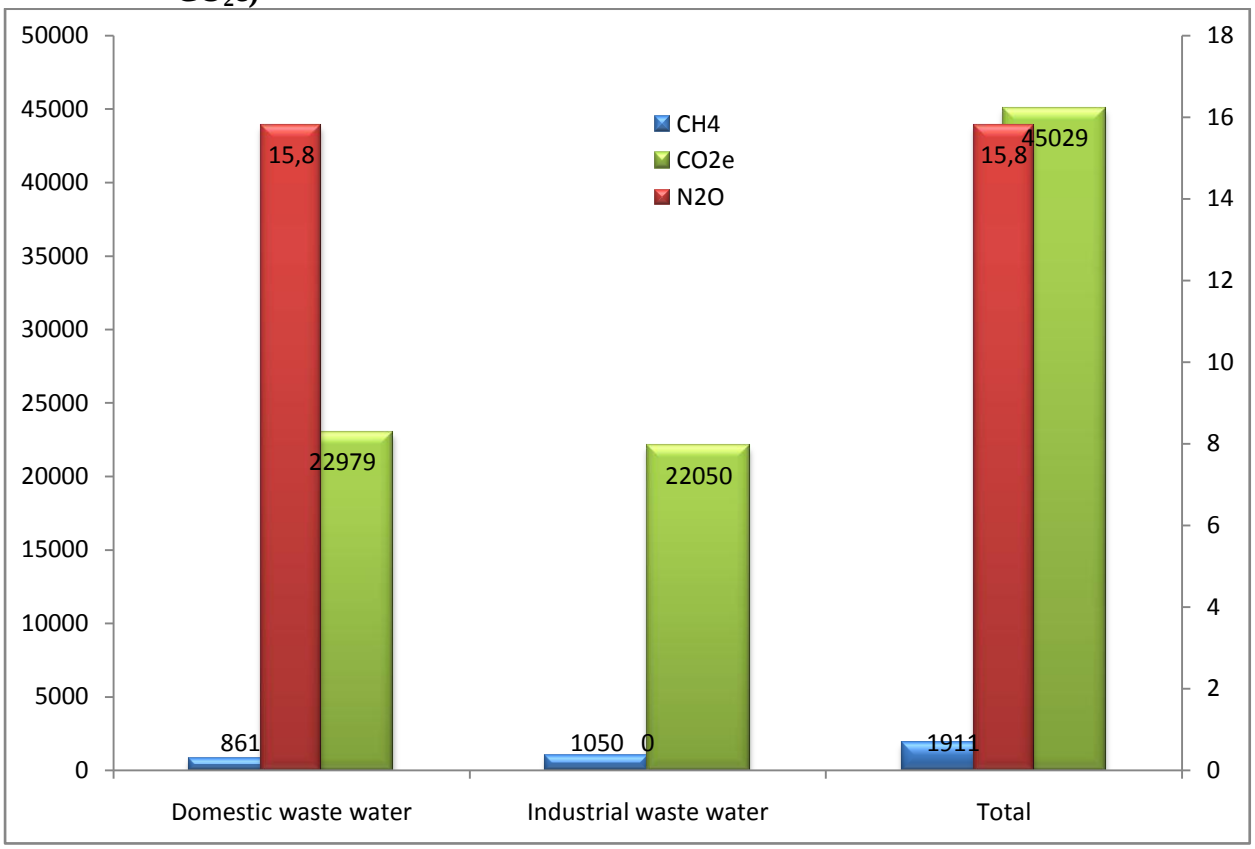
Activity	CH_4	N_2O	CO_2e
Domestic waste water	861	15.8	22979
Industrial waste water	1050	-	22050
Total	**1911**	**15.8**	**45029**

Source: India Greenhouse Gas emissions 2007, Ministry of Environment & Forests

[16]India Greenhouse Gas Emissions, 2007
[17]India Greenhouse Gas Emissions, 2007
[18]India Greenhouse Gas Emissions, 2007

Figure 2.2 shows the absolute values of GHG emission from this sector and also the emission distribution across its sub categories.

Figure 2.2: GHG emissions from Wastewater Treatment in Indiain 2007 (million tons of CO_2e)



CHAPTER - 3

METHODOLOGY USED FOR QUANTIFYING GHG EMISSIONS

We have followed the following internationally recognized protocols for quantifying GHG emissions:

1. GHG Protocol

2. IPCC Guidelines for National Greenhouse Gas Inventories

3.1 Salient features of GHG Protocol

The GHG Protocol is an internationally accepted protocol for quantifying GHG emissions. It is a joint initiative by WBCSD and WRI and serves as the premier source of knowledge about corporate GHG accounting and reporting.By the use of this protocol, companies and other organizations are able to achieve the following;

- Develop a credible GHG inventory underpinned by GHG accounting and reporting principles;
- Account and report information in a way that presents a clear picture of GHG impacts, and facilitates understanding as well as comparison with similar reports;
- Provide internal management with valuable information on which to build an effective strategy to manage and reduce GHG emissions;
- Provide GHG information that complements other climate initiatives and reporting standards, including financial standard; and

The steps followed for quantifying GHG emissions as per the protocol are:

3.1.1 Step 1: Setting OrganizationalBoundaries

In setting organizationalboundaries, a company selects an approach for consolidating GHGemissions and then consistently applies the selected approach to define thosebusinesses and operations that constitute the company for the purpose ofaccounting and reporting GHG emissions. For the purpose of accounting, GHG protocol established certain rules that depend on the structure of theorganization and the relationships among the parties involved.

3.1.2 Step2: Setting Operational Boundaries

Once a company has determined its organizational boundaries in termsof the operations that it owns or controls, it then sets its operationalboundaries. This involves identifying emissions associated with its operations,categorizing them as direct and indirect emissions, and choosing the scope ofaccounting and reporting for indirect emissions.

For effective and innovative GHG management, setting operational boundary are comprehensive with respect to direct and indirect emissions will help a company to better manage the GHG risks and opportunities that exist in its upstream and downstream operations. This involves making choices about how to account for direct and indirect GHG emissions. There are three scopes that are defined for GHG accounting and reporting are:

Scope 1: Direct GHG emissions

Scope 1 accounts for direct GHG emissions from sources that are owned or controlled by the reporting company. Scope 1 emissions are principally the result of the following activities:

- Emissions from combustion in owned or controlledboilers, furnaces, vehicles, etc.;
- Emissions from chemical production in owned or controlled process equipment;
- Physical or chemical processing, e.g. cement, adipic acid and ammonia manufacture;
- Transportation of materials, products, waste, and employees, e.g. use of mobile combustion sources, such as: trucks, trains, ships, airplanes, buses, and cars; and
- Fugitive emissions: intentional or unintentional releases such as: equipment leaks from joints, seals; methane emissions from coal mines; HFC emissions during the use of air conditioning equipment; and CH_4 leakages from gas transport

Scope 2: Indirect GHG emissions from imports of electricity, heat, or steam

Scope 2 accounts for indirect emissions associated with the generation of imported/purchased electricity, heat, or steam by the company. Purchased electricity is defined as electricity that ispurchased or otherwise brought into the organizationalboundary of the company. Scope 2 emissions physicallyoccur at the facility where electricity is generated.

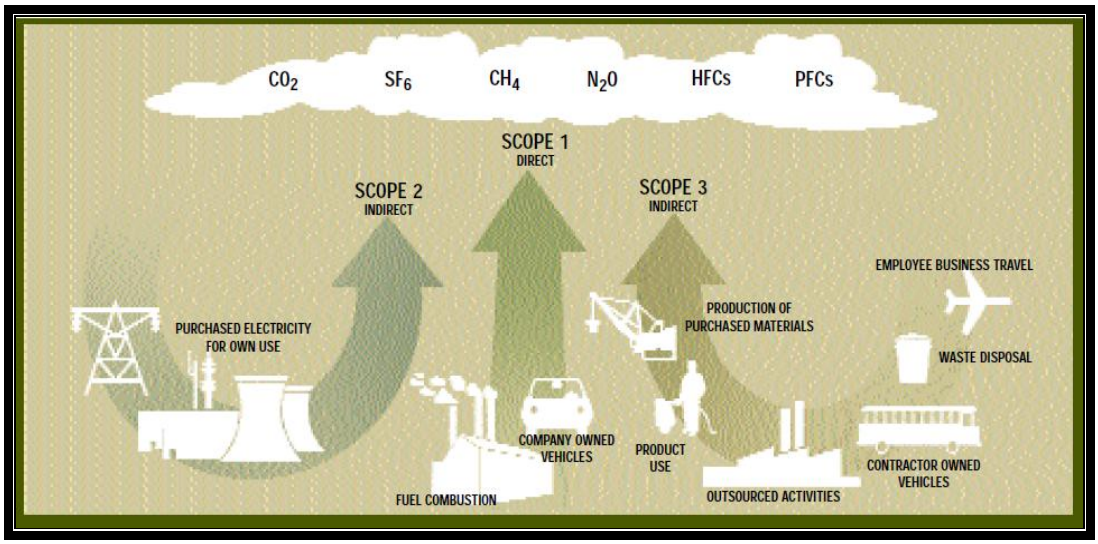
Scope 3: Other indirect GHG emissions

Scope3 emissions are consequences of the activities of thecompany, but occur from sources not owned orcontrolled by the company. Some examples of scope 3activities are:

- Extraction and production of purchasedmaterials;
- Transportation of purchased fuels;

- Use of sold products and services;
- Employee business travel;
- Transportation of products, materials, and waste;
- Employees commuting to and from work; and
- Production of imported materials

Figure 3.1: Overview of scopes and emissions



3.1.3 Step 3: Tracking emissions over time

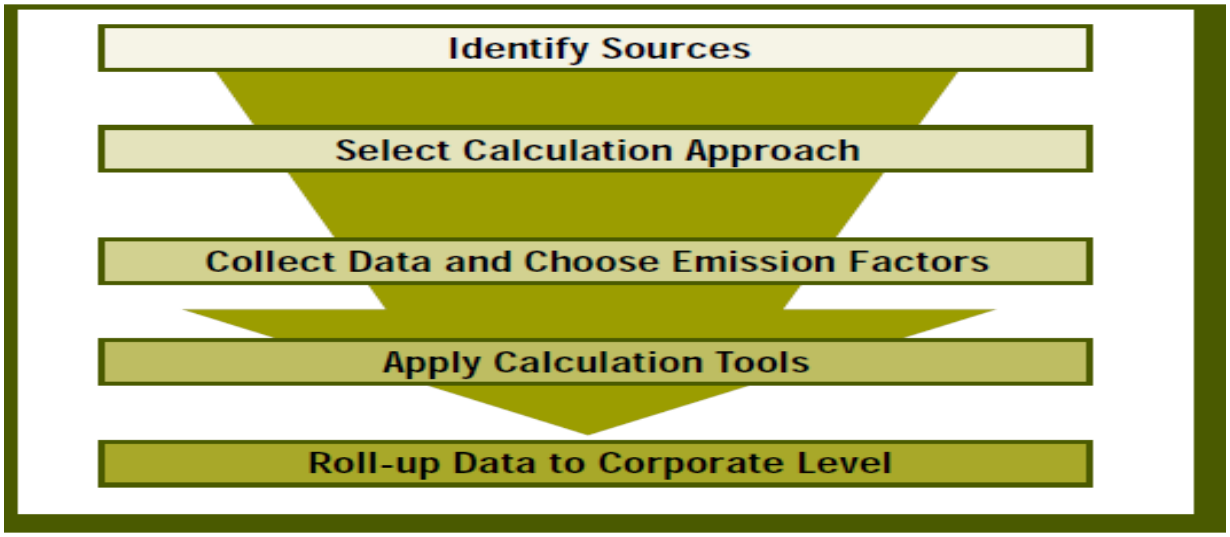
Companies may need to track GHG emissions over time.In order to maintain consistency over time historic emission data will have tobe recalculated. Companies have to choose and report a base year for which GHG emissions data is available and then calculate GHG emissions for that year.

3.1.4 Step 4: Identifying and Calculating GHG Emissions

Once the inventory boundary has been established, companies calculate GHG emissions using the following steps:

i. Identify GHG emissions sources
ii. Select a GHG emissions calculation approach
iii. Collect activity data and choose emission factors
iv. Apply calculation tools
v. Roll-up GHG emissions data to corporate level.

Figure 3.2: Identifyingand calculating GHG emissions



Source: Greenhouse Gas Protocol

For quantifying GHG emissions we have followed IPCC Guidelines for National Greenhouse Gas Inventories, 2006 in this study.

3.2 Salient features of IPCCMethodology for quantifying GHG emissions

IPCC Guidelines provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases.These guidelines takes intoconsideration the relevant work under the Kyoto Protocol and provide internationally accepted methodologies thatcountries currently use to estimate GHG inventories to report to the United Nations FrameworkConvention on Climate Change (UNFCCC).The steps followed for quantifying GHG emissions as per the IPCC Guidelines are:

3.2.1 Estimation of CO_2 Emissions from Domestic wastewater

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.

3.2.2Estimation of CH_4Emissions from Domestic Wastewater

The current IPCC methodology (2006), presents a general approach for estimating CH_4 emissions from domestic wastewater treatment that is based on the factors summarized in the following table:

Table 3.1: IPCC 2006 inventory methodology to estimate CH_4 emissions from domestic wastewater treatment

Factor	Value	Units
Fraction of population based on type	Location specific i.e (rural, urban)	Fraction
Degree of utilization of specific treatment/ discharge pathway	Location specific i.e (septic tank, latrine, sewer, other or none)	Fraction
Emission factor of methane from BOD • Maximum methane producing capacity • CH_4 correction factor	• Calculated, or • Default: 0.6 kg CH_4/kg BOD, • 0.25 kg CH_4/kg COD • Country specific • Based on treatment system processes (i.e., centralized aerobic treatment, anaerobic digestion, septic system, etc)	• kg CH_4 per kg BOD or COD • kg CH_4/kg BOD • Fraction
Total organically degradable material • Population • Per capita BOD • Correction factor for industrial BOD discharged into sewers	• Calculated • Country- specific • Country-specific: 85 g BOD/ person-day for the United states • Location- specific:1.25 for industrial wastewater collection, 1.00 if uncollected.	• kg BOD/yr • No people • g BOD/person-day • Fraction
Removal of organics as sludge	Location-specific	kg BOD/yr
Amount of CH_4 recovered	Location-specific	kg CH_4/ yr

Source: 2006 IPCC Guidelines for National Greenhouse Gas inventories.

This method does not account for CH_4 emissions resulting from the incomplete combustion of digester gas nor does it account for CH_4 fugitive emissions (e.g. from digestion and dewatering), which are expected to be small. The steps used in calculating CH_4 emissions from domestic wastewater are as follows:

Step 1: Total CH_4 emissions from domestic wastewater

$$\text{CH4 emissions} = [\sum (U_i T_{i,j} EF_j)](TOW\text{-}S)\text{-}R \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = organic component removed as sludge in inventory year, kg BOD/yr

Ui = fraction of population in income group *i*in inventory year.

$T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system, *j*, for each income group fraction *i*in inventory year.

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

EFj = emission factor, kg CH_4 / kg BOD

R = amount of CH_4 recovered in inventory year, kg CH_4/yr

Step 2: Choice of Emission Factor: The emission factor for a wastewater treatment discharge pathway and system is a function of the maximum CH_4 producing potential (Bo) and the methane correction factor (MCF) for the wastewater treatment and discharge system. The Bo is the maximum amount of CH_4 that can be produced from a given quantity of organics (as expressed in BOD or COD) in the wastewater. The MCF indicates the extent to which the CH_4 producing capacity (Bo) is realised in each type of treatment and discharge pathway and system. Thus, it is an indication of the degree to which the system is anaerobic.

CH_4 emission factor for each domestic wastewater treatment/discharge pathway or system iscalculated from equation 3.2.

$$\mathbf{EF_j = B_o \text{ X } MCF_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)}$$

where:

EF_j= emission factor, kg CH_4/kg BOD

j = each treatment/discharge pathway or system

Bo = maximum CH_4 producing capacity, kg CH_4/kg BOD

MCF_j = methane correction factor (fraction).

Good practiceis to use country-specific data for Bo, where available, expressed in terms of kg CH_4/kg BOD removed to be consistent with the activity data. If country-specific data are not available, a default value, 0.6 kg CH_4/kg BOD can be used. For domestic wastewater, a COD-based value of Bo can be converted into a BOD based value by multiplying with a factor of 2.4. Table 6 includes default maximum CH_4 producing capacity (Bo) for domestic wastewater.

Table 3.2 :Default Maximum CH_4 Producing Capacity (Bo) For Domestic Wastewater; Source: 2006 IPCC Guidelines for National Greenhouse Gas inventories.
0.6 kg CH_4/kg BOD
0.25 kg CH_4/kg COD

Step 3: Total organically degradable material in domestic wastewater: The total amount of organically degradable material in the wastewater (TOW is a function of human population and BOD generation per person. It is expressed in terms of biochemical oxygen demand (kg BOD/year). The equation 3.3 is used for calculating TOW is as follows:

$$TOW = P \text{ X } BOD \text{ X } 0.001 \text{ X } I \text{ X } 365 \quad \text{…...……} \quad (3.3)$$

Where,

TOW = Total organics in wastewater in inventory year, kg BOD/yr
P = country population in inventory year, (person)
BOD = country-specific per capita BOD in inventory year, g/person/day.
0.001 = conversion from grams BOD to kg BOD
I = correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00.)

The factor Ivalues in equation 3.3is taken from IPCC guidelines. It expresses the BOD from industries and establishments (e.g., restaurants, butchers or grocery stores) that is co-discharged with domestic wastewater.

3.2.3Estimation of N_2O Emissions from Domestic Wastewater

The methodology used for N_2O emissions from domestic wastewater are estimated for two pathways:

i. Emissions from treated wastewater effluent discharged to a receiving environment; and
ii. Emissions from (NDN) process

The factors used in estimating N_2O emissions from these sources are summarized in the following Table 3.3.

Table 3.3: IPCC 2006 inventory methodology to estimate N_2O emission from domestic wastewater

Factor	Value	Units
Nitrogen in the effluent discharged to the aquatic environment	• Calculate	• kg N/yr
• Population	• Country-specific	• No people
• Protein consumption	• Country-specific: 42.1 kg/person-yr	• kg/person-yr
• Fraction of nitrogen in protein	• Default:0.16 kg N/kg protein	• kg N/kg protein
• Factor for non-consumed protein added to wastewater	• Country-specific:1.4 for developed countries	• Fraction
• Factor for industrial and commercial co-discharge protein into the sewer system	• Default: 1.25	• Fraction
• Nitrogen removed with sludge	• Default: 0 kg N/yr	• kg N/yr
Emission factor for N_2O from discharges wastewater	Default: 0.005 kg N_2O-N/kg N	kg N_2O-N/kg N

Source: 2006 IPCC Guidelines for National Greenhouse Gas inventories.

Table 3.4: Factors used by IPCC to estimate N_2O emissions from NDN process

Factor	Value	Unit
Population	Country-specific	No people
Degree of utilization of modern centralized WWTP	Location-specific	Percent
Fraction of industrial and commercial co-discharged protein	Default: 1.25	Fraction
Emission factor	Default: 3.2 g N_2O/person-year	g N_2O/person-yr

Source: 2006 IPCC Guidelines for National Greenhouse Gas inventories.

Major of the N_2O emissions at WWTP are emissions from treated wastewater discharged into receiving body, based on a factor of 0.005 Kg N_2O-N/Kg nitrogen in the effluent. The IPCC states that direct emissions from NDN processes at WWTPs may be considered a minor source and that these emissions are typically much smaller than those from the effluent. However,

direct emissions of N_2O from wastewater processes are predominantly associated with advanced centralized wastewater treatment plants.

The steps used in calculating N_2O emissions from domestic wastewater are as follows:

Step 1: N_2O emissions from wastewater effluent

$$\mathbf{N2O\ Emissions = N\ Effluent \times EF\ Effluent \times \frac{44}{28}} \ldots\ldots\ldots\ldots\ldots \mathbf{(3.4)}$$

Where:

N_2O emissions = N_2O emissions in inventory year, kg N_2O/yr
$N_{effluent}$ = nitrogen in the effluent discharged to aquatic environments, kg N/yr
$EF_{effluent}$ = emission factor for N_2O emissions from discharged to wastewater, kg N_2O /kgN.
The factor 44/28 is the conversion of kg N_2O-N into kg N_2O.

Step 2: Choice of emission factor: The default IPCC emission factor for N_2O emissions from domestic wastewater nitrogen effluent is 0.005 (0.0005 - 0.25) kg N_2O-N/kg N. This emission factor is based on specific assumptions regarding the occurrence of nitrification and denitrification in rivers and in estuaries. The first assumption is that all nitrogen is discharged with the effluent. The second assumption is that N_2O production in rivers and estuaries is directly related to NDN and thus to the nitrogen that is discharged into the river.

Step 3: Total nitrogen in the effluent: The data that are needed for estimating N_2O emissions are nitrogen content in the wastewater effluent, country population and average annual per capita protein generation (kg/person/yr). Per capita protein generation consists of intake (consumption) which is available from the Food and Agriculture Organization (FAO, 2004), multiplied by factors to account for additional 'non-consumed' protein and for industrial protein discharged into the sewer system. For developed countries using garbage disposals, the default for non-consumed protein discharged to wastewater pathways is 1.4, while for developing countries this fraction is 1.1. Wastewater from industrial or commercial sources that is discharged into the sewer may contain protein (e.g., from grocery stores and butchers). The default for this fraction is 1.25. The total nitrogen in the effluent is estimated as follows:

$$\mathbf{Neffluent = P \times Protein \times Fnpr \times Fnon - con \times Find - com - Nsludge} \ldots\mathbf{(3.5)}$$

Where:

$N_{effluent}$ = total annual amount of nitrogen in the wastewater effluent, kg N/yr
P = human population
Protein = annual per capita protein consumption, kg/person/yr
F_{npr} = fraction of nitrogen in protein, default = 0.16, kg N/kg protein
$F_{non-con}$ = factor for non-consumed protein added to the wastewater

$F_{ind-com}$= factor for industrial and commercial co-discharged protein into the sewer system

N_{sludge}= nitrogen removed with sludge (default = zero), kg N/yr

This is the methodology that is used in this study for quantifying GHG emissions from five WWTPs of Delhi/ NCR.

CHAPTER– 4

GREENHOUSE GAS INVENTORY OF WASTEWATER TREATMENT PLANTS

We are quantifying GHG emissions from five WWTPs. These are as follows:

1. Noida, Sector -54
2. Sen Nursing Home
3. Indrapuram
4. Yamuna Vihar
5. Delhi Gate

Steps followed for preparing a GHG inventory are as follows:

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

Step 2: Setting operational boundaries: This studyidentifies following emissions associated 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 IPCCGuidelinesbecause 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 of electricity, steam or gas; and

- **Scope 3: Other Indirect GHG emissions:**Scope 3 emissions have not been included because of insufficient data.

Step 3: Tracking emissions over time: In this study GHG emissions are calculated for a period of one year from Jan. 2011 – Dec. 2011 (both months inclusive).

Step 4: Identifying and calculating GHG emissions: We have followed IPCC Guidelines for National Greenhouse Gas Inventories, 2006 for calculating GHG emissions from WWTPs.

4.1Greenhouse Gas Emission Inventory Of Wastewater Treatment Plant At Noida, Sec- 54

4.1.1 Details about the plant

The plant is situated in Uttar Pradesh, Noida Sector-54. The capacity of the plant is 33 MLD at present. It has started functioning in the year 2010-11. The plant was constructed by M/s HNB Engineers Pvt Ltd. The total cost of the plant is Rs 50 crores (approx). gets mixed wastewater from residential and industrial sectors.

1. **Principle of operation at the plant**

This 33 MLD sewage treatment plant is based on SBR technology. The operation of an SBR is based on a fill-and-draw principle, which consists of five steps

i. **Fill:** During the fill phase, the basin receives influent wastewater. The influent brings food to the microbes in the activated sludge, creating an environment for biochemical reactions to take place. Mixing and aeration can be varied during the fill phase.

ii. **React:** This phase allows for further reduction or "polishing" of wastewater parameters. During this phase, no wastewater enters the basin and the mechanical mixing and aeration units are on. Because there are no additional volume and organic loadings, the rate of organic removal increases dramatically.Most of the carbonaceous BOD removal occurs in the react phase. Further nitrification occurs by allowing the mixing and aeration to continue—the majority of denitrification takes place in the mixed-fill phase.

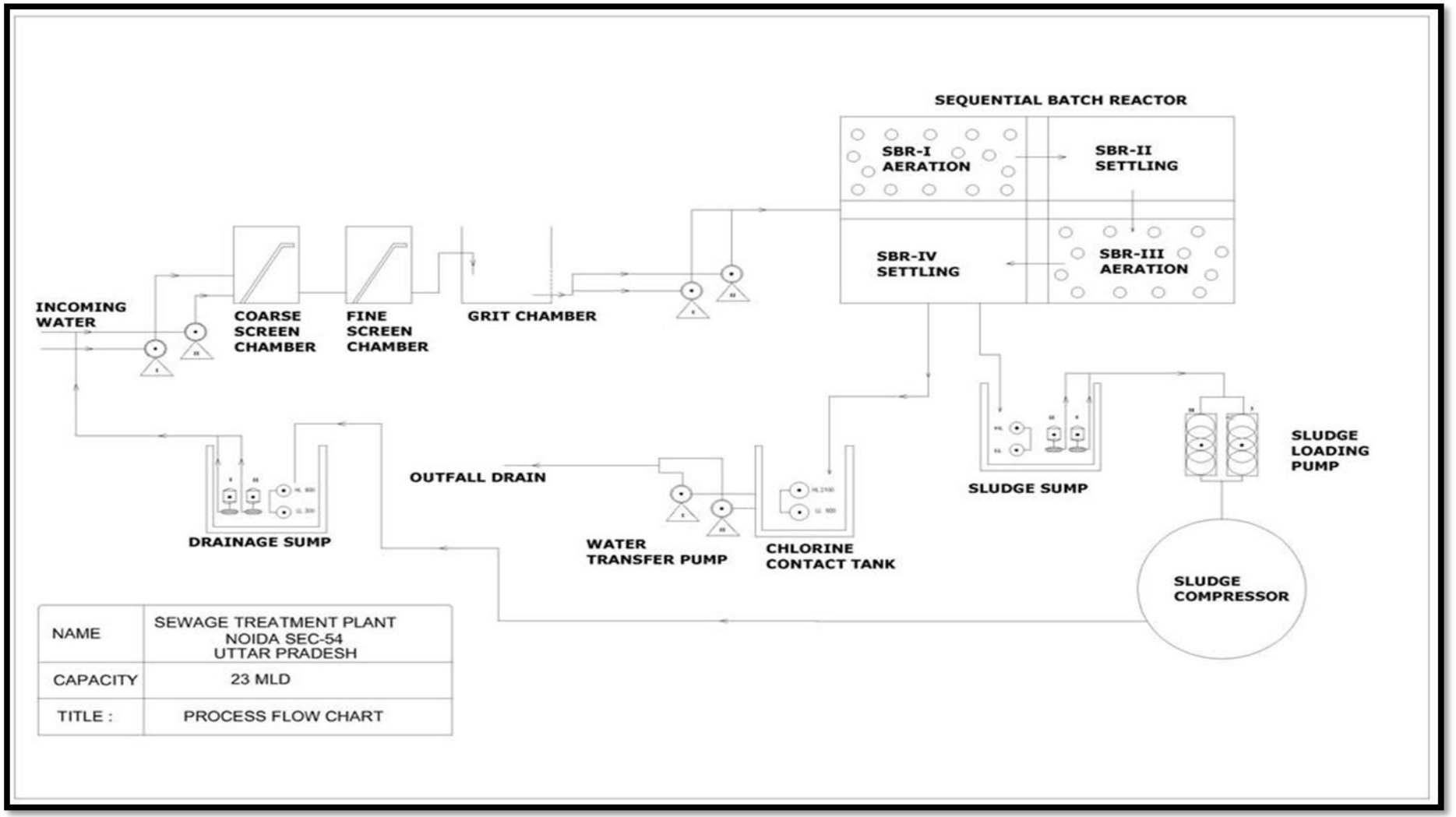
iii. **Settle:** During this phase, activated sludge is allowed to settle under quiescent conditions, no flow enters the basin and no aeration and mixing takes place. The activated sludge tends to settle as a flocculent mass, forming a distinctive interface with the clear supernatant. The sludge mass is called the sludge blanket. This phase is a critical part of the cycle, because if the solids do not settle rapidly, some sludge can be drawn off during the subsequent decant phase and thereby degrade effluent quality.

iv. **Decant:** During this phase, a decanter is used to remove the clear supernatant effluent. Once the settle phase is complete, a signal is sent to the decanter to initiate the opening of an effluent-discharge valve. There are floating and fixed-arm decanters. Floating decanters maintain the inlet orifice slightly below the

water surface to minimize the removal of solids in the effluent removed during the decant phase. Floating decanters offer the operator flexibility to vary fill and draw volumes.

v. **Idle:** This step occurs between decant and the fill phases. The time varies, based on the influent low rate and the operating strategy. During this phase, a small amount of activated sludge at the bottom of the SBR basin is pumped out, the processis called wasting.

Figure 4.1: Flow diagram of the plant



2. Infrastructural details of the plant

i. **Raw sewage pump house**: Sewage from rising main sewer line comes to the STP at the raw sewage sump. Then flow through manual coarse screen and mechanical coarse screen having 20mm clear opening. Screened sewage is pump to primary unit via pump house having capacity of 120 HP and 80 HP with 90 minutes cycle. In present STP, raw sewage pump of capacity 120 HP and 80 HP is used for 90 minutes and 4 times a day. At a time maximum two pumps are used having capacity of 120 HP and 80 HP.

Figure 4.2: Manual and mechanical fine screens

ii. **Primary unit**: Primary unit comprises of manual fine screen and mechanical fine screen equipped with belt conveyor. Fine screened sewage flows through gravity and enter into grit chamber, where inorganic grit separated or removed from the effluent.

Figure 4.3: Manual and Mechanical Fine Screens

iii. **C-Tech Basin**: After removal of grit, sewage is entered into C-Tech basin via Cl sluice gates and enters into distribution chamber for the feed to SBR basin.

Figure 4.4: C-Tech Basin

C-Tech basin equipped with the following pumps:

a) **Return Activated Sludge (RAS):** This pump is used for maintaining MLSS or organic growth for first cycle i.e. filling and aeration.

b) **Surplus activated sludge pump (SAS):** This pump is used for moving the surplus sludge from the second cycle i.e. settling.

c) **Blower Pump:** This pump is used for maintaining oxygen level or aeration.

d) Chlorination: During visit it was found that chlorination basin was not operational and it was proposed for future.

e) Sludge sump centrifuge platform and pump house: The surplus sludge from C-Tech basin is pumped or collected to sludge sump and with the help of centrifuge pump sludge is compacted.

4.1.2 Calculation of GHG emissions from the plant

The GHG emissions for the plant were estimated based on the design specifications of the plant and the anticipated energy used in the plant during operation.

Scope 1: Direct GHG emissions

a) CO_2 produced through breakdown of organic matter during the aerobic phases of the SBR process.

b) CH_4 emissions from SBR are primary clarifiers and aeration basins in small quantities or if improperly managed.

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

d) From the diesel generator used at the site. There is one DG set of 1250 KVA at the plant.

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:

i. Raw sewage pump and pump house

ii. Primary units
- Grit mechanism
- Grit screw conveyor

iii. C-Tech basins
- Return activated sludge pumps (RAS)
- Surplus activated sludge pumps (SAS)

iv. Blower room for C-Tech
- Blower for C-Tech
- Service water pumps for after cooler

v. Sludge sump, Centrifuge platform and pump house

- Blower for sludge sump
- Centrifuge feed pumps (roto pumps)
- DWPE dosing pumps
- DWPE agitators

vi. Chlorination room and pump house

- Booster pumps
- Blower for caustic soda pump
- Caustic solution pump
- Service water pumps for DWPE

The calculation for electricity consumption is represented as follows:

Carbon dioxide emissions = Total electricity use (MWh/yr) X Emission Factor (t CO_2/ MWh (metric tons/ year)

I. Steps for calculating CH_4 emissions are as follows:

Step 1: Estimation of organically degradable material in domestic wastewater is shown in Table 4.1.

Step 2: Estimation of methane emission factor for domestic wastewater is shown in Table 4.2.

Step 3: Estimation of CH_4 emissions from domestic wastewater is summarized in Table 4.3.

II. Steps for calculating N_2O emissions

Step 1: Estimation of nitrogen in effluentis shown in Table 4.4.

Step 2: Estimation of emission factor and emissions of indirect N_2O emissions from wastewateris shown in Table 4.5.

III. Emissions from DG set used at site are depicted in Table 4.6.

IV. Indirect GHG emissions from the consumption of electricity at WWTP are summarized in Table 4.7.

Calculations of CO_2, CH_4 and N_2O emissions are shown below in the following tables:

Table 4.1: **Estimation of organically degradable material in domestic wastewater**

Sector	**Waste**			
Category	**Domestic wastewater treatment and discharge**			
Sheet	**1 of 3 Estimation of organically degradable material in domestic wastewater**			
STEP 1				
	A	B	C	D
City (region)	Population (P) cap	Degradable organic component (BOD)[19] (kg BOD/cap/yr)[a]	Correction factor for industrial BOD discharged into sewers (I)[b]	Organically degradable material in wastewater (TOW) kg BOD/yr)
Uttar Pradesh (Noida)				D= A x B x C
	610394	12.41	1.25	9468736.925
a:g BOD/cap/day x .001x365 = kg BOD/cap/yr				
b: Correction factor for additional industrial BOD discharged into sewers, (for collected the defaultis 1.25, for uncollected the default is 1.00)				

Table 4.2: Estimation of methane emission factor for domestic wastewater

Sector	**Waste**		
Category	**Domestic wastewater treatment and discharge**		
Sheet	**1 of 2 Estimation of CH_4 emission factor for domestic wastewater**		
STEP 2			
	A	B	C
Type of treatment or discharge	Maximum methane producing capacity (Bo) (kg CH_4/ kg BOD)	Methane correction factor or each treatment system (MCF_j)	Emission factor (EF_j) (kg CH_4/kg BOD)
Aerobic treatment			C=AXB
	0.6[20]	0.05[21]	0.03

[19]Estimated value of BOD_5 for India is 34 g/person/day, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[20]2006 IPCC Guidelines for National Greenhouse Gas Inventories

[21]2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table 4.3: Estimation of CH_4 emissions from domestic wastewater

Sector	**Waste**										
Category	**Domestic wastewater treatment and discharge**										
Sheet	**3 of 3 Estimation of CH_4 emissions from domestic wastewater**										
STEP 3											
		A	B	C	D	E	F	G	F	H	I
Income group	Type of treatment or discharge	Fraction of Population income group (U_i)[22] fraction	Degree of utilization (T_{ij})[23] fraction	Emission factor (EFj) (kg CH_4/ kg BOD)	Organically degradable material in wastewater (TOW) (kg BOD/yr)	Sludge removed (S) (kg BOD/yr)	Methane recovered and flared (R) (kg CH_4/yr)	Net methane emissions (CH_4) (kg CH_4/yr)	GWP for CH_4	Total CO_2e kg CO_2e/yr	Total CO_2e t CO_2e/yr
	Aerobic treatment			Step 2 of 3	Step 1 of 3			G=[(AxBxC) x (D-E)]-F	25[24]		
Rural		0.71	0.1	0.03	9468736.92	0	0				
Urban high income		0.06	0.07								
Urban low income		0.23	0.03								
Total		**0.333**	**0.066**					**6243.11**		**156077.75**	**156.07**

[22]2006 IPCC Guidelines for National Greenhouse Gas Inventories

[23]2006 IPCC Guidelines for National Greenhouse Gas Inventories

[24]IPCC Fourth Assessment Report, 2007

Table 4.4: Estimation of nitrogen in effluent

Sector	**Waste**						
Category	**Domestic wastewater treatment and discharge**						
Sheet	**1 of 2 Estimation of nitrogen in effluent**						
	STEP 1						
	A	B	C	D	E	F	G
	Population (P)	Per capita protein consumption (Protein)	Fraction of nitrogen in protein (F_{npr})	Fraction of non-consumption protein ($F_{non-con}$)	Fraction of industrial and commercial co-discharged protein ($F_{ind-com}$)	Nitrogen removed with sludge (default is zero) (N_{sludge})	Total nitrogen in effluent ($N_{effluent}$)
Units	(people)	(kg/person/yr)	(kgN/ kg protein)	(-)	(-)	Kg	(kg N/year)
							G=(AXBXCXDXE)-F
	610394	0.056[25]	0.16[26]	1.4[27]	1.25[28]	0	9570.97

[25]Nutritional intake in India 2004-2005, National Sample Survey Organization, Ministry of Statistics &Programme Implementation,Government of India, NSS 61ST Round July 2004- June 2005.

[26]2006 IPCC Guidelines for National Greenhouse Gas Inventories

[27]2006 IPCC Guidelines for National Greenhouse Gas Inventories

[28]2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table 4.5: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater

Sector	**Waste**							
Category	**Domestic wastewater treatment and discharge**							
Sheet	**2 of 2 Estimation of emission factor and emissions of indirect N_2O emissions from wastewater**							
STEP 2								
	A	B	C	D	E	F	G	H
	Nitrogen in effluent	Emission factor	Conversion factor of kg N_2O-N into Kg N_2O	Emissions from wastewater plants (default as zero)	Total N_2O emissions	GWP for N_2O	Total CO_2e	Total CO_2e
Units	kg N/ year	(kg N_2O-N/kg N)	44/28	kg N_2O/ year	kg N_2O/ year	298[29]	kg CO_2e/ yr	tCO_2e/ yr
				E= (AxBxC)-D				
	9571	0.0005[30]	1.57	0	7.52	298	2240.98	2.24

Table 4.6: Emissions from DG set

Total Diesel consumption (l/year)	**Emission factor (t CO_2e/ l) of diesel**	**Total CO_2e (t CO_2e/ year)**
18200	0.00255[31]	46.41

[29]IPCC Fourth Assessment Report, 2007

[30]2006 IPCC Guidelines for National Greenhouse Gas Inventories

[31] Emission factor of Diesel: $74.1 \frac{t\ CO2e}{TJ} \times 43 \frac{TJ}{Gg} \times 0.8 \frac{kg}{l}$ = 0.00255 t CO_2e/ l diesel

Table 4.7: Scope 2 emissions of the plant

S.No	Area	Total MWh Used yearly	Emissions Factor 0.91[32] t CO_2e	Total Scope 2 Emissions CO_2e
1.	Pump house	215.715	0.91 t CO_2/ MWh	196 t CO_2e
2.	Primary units	39.420	0.91 t CO_2/ MWh	36 t CO_2e
3.	C-Tech basins	3.394	0.91 t CO_2/ MWh	3 t CO_2e
4.	Blower room	2842.642	0.91 t CO_2/ MWh	2587 t CO_2e
5.	Sludge pump	45.260	0.91 t CO_2/ MWh	41 t CO_2e
6.	Chlorination room	-	-	-
	Total	**3146**	**0.91 t CO_2/ MwH**	**2863 t CO_2e**

Power used for chlorination room is not included because it was not operational during visit.

4.1.3 Total emissions of the plant are shown below in Table 4.8.

Table 4.8: Total emissions from the plant

Area	GHG	CO_2e Emissions
Scope 1	CH_4	156 t CO_2e
	N_2O	2.2 t CO_2e
Scope 2	Electricity use	2863 t CO_2e
	DG set	46.41 t CO_2e
Area	Not Assessed	
Total 3067 t CO_2e		

[32]Central Electricity Authority

4.2 Greenhouse Gas Emission Inventory OfSen Nursing Home Waste Water Treatment Plant

4.2.1 Details about the plant

The Sewage Treatment Plant at Dr.Sen Nursing Home Nalla 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 Nalla, east of the Ring road.The plant was commissioned during 2003 and constructed by M/s Degramont Pvt Ltd. Total cost of the plant is 6.21 crore (approx).

1. **Principle of operation at the Plant**

   This 10 MLD sewage treatment plant is based on High rate BiofiltersDensadeg technology.

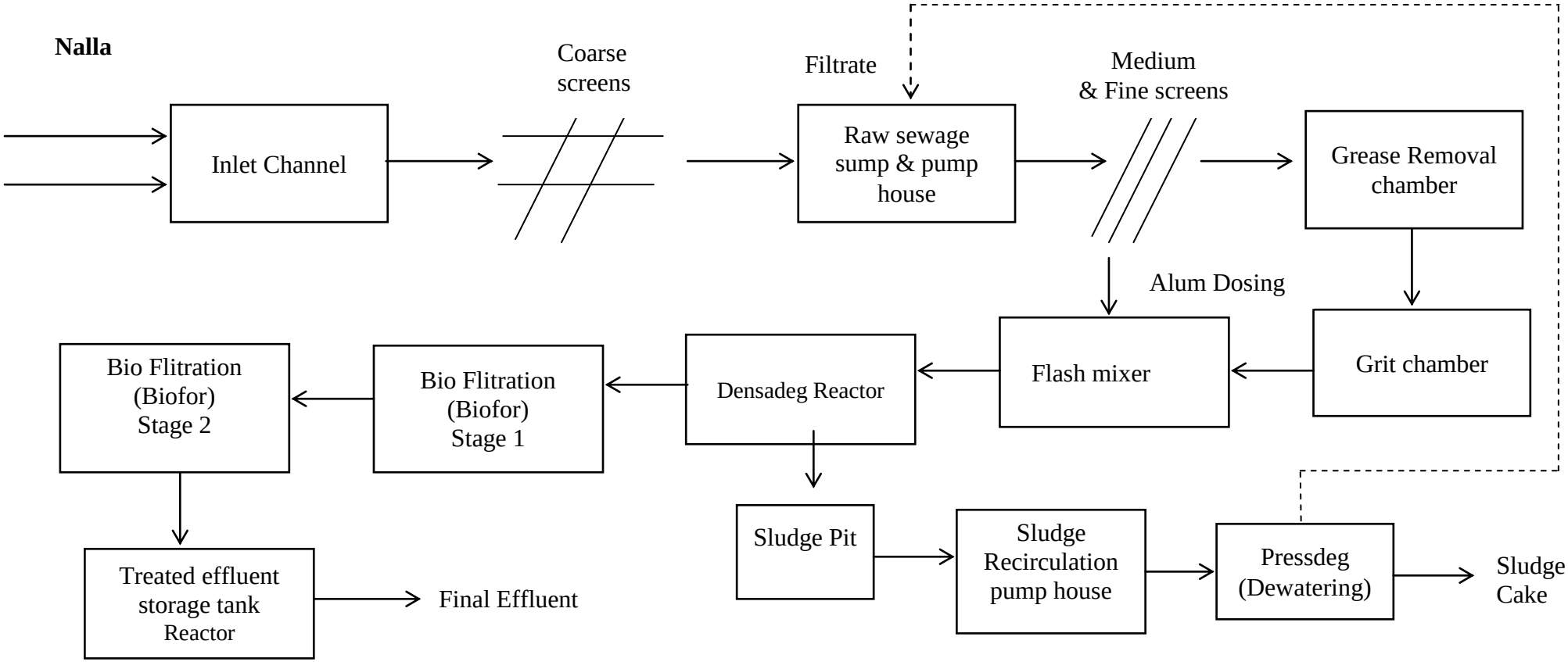
2. **Infrastructural details of the plant**

   i. **Raw sewage sump**

   Before flowing in to the raw sewage sump the Raw Sewage is passed through a Feeder channel and then two numbers of coarse screens (One working and one standby) equipped with 35mm opening for removing any floating material, which may cause damage to the downstream lifting pumps. These screens are cleaned manually. The raw sewage from the raw sewage sump is pumped up to the elevated structures to allow gravity flow in the further treatment process. Six nos. of horizontal centrifugal non-clog pumps are provided to pump the sewage to the Elevated structures.

Figure 4.5: Coarse Screens

Figure 4.6: Flow diagram of the process at Sen Nursing Home STP



ii. Grit and Grease Removing Unit

Once the Raw Sewage is pumped to the Elevated Structures it undergoes medium screening by 20 mm screens and fine screening with 5 mm screens. Then it flows to the grit and grease removal unit. The Grit and Scum Removal unit is an aerated chamber. The main objective is to eliminate larger types of solids such as grease, fiber, etc. Other than this it has additional advantages:

Figure 4.7: Grit and Scum removing chamber

iii. Physico Chemical Treatment

After pretreatment the effluent undergoes a physico chemical treatment to remove most of the suspended solids in the influent and thus reducing the BOD. The physicochemical comprises of flash mixing and flocculation followed by clarification.

After the parshall flume the sewage flows into the flash mixer wherein commercial alum is dosed for the coagulation of the sewage. The flash mixer ensures a perfect mixing of the coagulating alum with the raw sewage.

iv. Densadeg Clarifier

The Densadegis a high performance clarifier developed by Degremont.

Figure 4.8: Densadeg Clarifier

It consists of three main technological modules:

a) **Reactor Module:**The reactor Module for flocculation, uses two successive zones with a variable flocculation Energy. It is designed for both rapid flocculation and slow flocculation for floc growth with Sludge recycling. The resultant floc has a high level density which is enhanced by using a Polymer.

b) **The Pre-Settling**: Thickening Module leads to homogeneity to the settling and thickening of the Floc. Thickening is promoted by continuous scraping of the precipitated Sludge. Part of the sludge (i.e. 30 m^3/hr.) is recirculated in the Reactor.

c) **Lamella Clarifier:**The lamella clarifier ensures quality and stability. The residual floc is removed in this module with tube modules for fast settling producing the final quality of Primary Treated Sewage.

v. Dewatering Unit

The excess sludge is drawn off from the base of the pre-settling and thickening tank and its concentration is sufficient for it to be sent directly to the dewatering unit without having to undergo any additional thickening treatment. The excess sludge is stored in a 60 m^3 RCC tank, from where it is pumped to themechanical dewatering units.

vi. Pressdeg

The excess sludge produced in the plant is mechanically dewatered by presssdeg to reduce the handling volume of sludge. The pressdeg is designed to remove the water contained in the sludge by continuous filtration of sludge under pressure. It is necessary to remove a great part of the water contained in the sludge before applying the dewatering pressure. The preliminary drainage phase is essential as it makes it possible to quickly obtain thicker and much denser sludge, thus

increasing the pressing capacity. The sludge should be evenly distributed over the entire width of the belt to optimize the production capacity of the unit and the dry solid content of the cake produced. This cake of sludge is collected and sent to existing digester unit.

vii. Biological Filters / Biofors

The final stage of treatment is biological filtration. This stage reduces the content of suspended solids and the BOD in the effluent to the required levels. The biological filtration is carried out in two identical filtration is carried out in two identical successive stages and each stage consist of a battery of four filters operating simultaneously.

Figure 4.9: Biological Filters

viii. Alum Preparation Tank and Dosing

Alum solution is dosed in the Flash Mixer at the inlet of densadeg. Two nos. alum solution preparation tanks are provided with agitators**.** Alum tanks are provided with overflow drain lines along with drain valves. Alum solution preparation is carried out in one tank at a time while alum dosing will be carried out using the other. Two nos. reciprocating metering pumps are provided to transfer alum solution to flash Mixer of densadeg. The pumps are designed to operate on one working, one standby basis.

After the treatment, treated water is utilized for cooling towers at Pragati Power Corporation and finally to Yamuna river through open drain.

4.2.2Calculation 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 the process.
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.

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

I. Steps for calculating CH_4 emissions are as follows:

Step 1: Population estimation is shown in Table 4.9.

Step 2: Estimation of organically degradable material in domestic wastewater is calculated in Table 4.10.

Step 3: Estimation of methane emission factor for domestic wastewater is depicted in Table 4.11.

Step 4: Estimation of CH_4 emissions from domestic wastewater are summarized in Table 4.12.

II. Steps for calculating N_2O emissions

Step 1: Estimation of nitrogen in effluent is calculated in Table 4.13.

Step 2: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater are summarized in Table 4.14.

III. Indirect GHG emissions from the consumption of electricity at WWTP

The calculation for electricity consumption is represented as follows:

Carbon dioxide emissions = Total electricity use (MWh/yr) X Emission Factor (t CO_2/ MWh (metric tons/ year)

Calculations of CO_2, CH_4 and N_2O emissions are shown below in the following tables:

Table 4.9: Population estimation for the catchment area of the plant

Population estimation
Average flow = 11.51 MLD
Total water supply = average flow x (80/100) [Assuming that 80% of wastewater supplied get converted to wastewater]. $=\frac{11.50\ X\ 80}{100}$ = 14.38 MLD
Average water consumption/person/day = 135 l/person/day[33]
Population $=\frac{14.38\ \text{X}\ 1000000\ \text{l}}{135\frac{\text{l}}{\text{person}}/\text{day}}$ Population = **106518**

Table 4.10: Estimation of organically degradable material in domestic wastewater

Sector	**Waste**

[33]CPHEEO manual on water supply and treatment

Category	**Domestic wastewater treatment and discharge**			
Sheet	**1 of 3 Estimation of organically degradable material in domestic wastewater**			
STEP 1				
	A	B	C	D
City (region)	Population (P) cap	Degradable organic component (BOD)[34] (kg BOD/cap/yr)[a]	Correction factor for industrial BOD discharged into sewers (I)[b]	Organically degradable material in wastewater (TOW) kg BOD/yr)
Delhi (East)				D= A x B x C
	106518	12.41	1.25	1652360.47
a: g BOD/cap/day x 0 .001x365 = kg BOD/cap/yr				
b: Correction factor for additional industrial BOD discharged into sewers, (for collected thedefault is 1.25, for uncollected the default is 1.00)				

Table 4.11: Estimation of methane emission factor or domestic wastewater

Sector	**Waste**		
Category	**Domestic wastewater treatment and discharge**		
Sheet	**1 of 2 Estimation of CH_4 emission factor for domestic wastewater**		
STEP 2			
	A	B	C
Type of treatment or discharge	Maximum methane producing capacity (Bo) (kg CH_4/ kgBOD)	Methane correction factor or each treatment system (MCFj)	Emission factor (EFj) (kg CH_4/kg BOD)
Aerobic treatment			C= A x B
	0.6[35]	0.05[36]	0.03

[34] Estimated value of BOD_5 for India is 34 g/person/day, 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[35]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[36]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 4.12: Estimation of methane emissions from domestic wastewater

Sector	**Waste**										
Category	**Domestic wastewater treatment and discharge**										
Sheet	**3 of 3 Estimation of CH_4 emissions from domestic wastewater**										
STEP 3											
		A	B	C	D	E	F	G	F	H	I
Income group	Type of treatment or discharge	Fraction of Population income group (U_i)[37] fraction	Degree of utilization (T_{ij})[38] fraction	Emission factor (EFj) (kg CH_4/ kg BOD)	Organically degradable material in wastewater (TOW) (kg BOD/yr)	Sludge removed (S) (kg BOD/yr)	Methane recovered and flared (R) (kg CH_4/yr)	Net methane emissions (CH_4) (kg CH_4/yr)	Global warming potential (GWP) for CH_4	Total CO_2e kg CO_2e/yr	Total CO_2e t CO_2e/yr
	Aerobic treatment			Step 2 of 3	Step 1 of 3			G=[(AxBxC) x (D-E)]-F	25[39]		
Rural		0.71	0.1	0.03	1652360	0	0				
Urban high income		0.06	0.07								
Urban low income		0.23	0.03								
Total		**0.333**	**0.066**					**1089.46**		**27236.67**	**27.23**

[37] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

[38] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

[39] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

Table 4.13: Estimation of nitrogen in effluent

Sector	**Waste**						
Category	**Domestic wastewater treatment and discharge**						
Sheet	**1 of 2 Estimation of N_2O in effluent**						
STEP 1							
	A	B	C	D	E	F	G
	Population (P)	Per capita protein consumption (Protein)	Fraction of nitrogen in protein (F_{npr})	Fraction of non-consumption protein ($F_{non-con}$)	Fraction of industrial and commercial co-discharged protein ($F_{ind-com}$)	Nitrogen removed with sludge (default is zero) (N_{sludge})	Total nitrogen in effluent ($N_{effluent}$)
Units	(people)	(kg/person/ yr)	(kgN/ kg protein)	(-)	(-)	kg	(kg N/year)
							G=(AXB XCXDX E)-F
	106518	0.057[40]	0.16[41]	1.4[42]	1.25[43]	0	1700.02

[40]Nutritional intake in India 2004-2005, National Sample Survey Organization, Ministry of Statistics &Programme Implementation,Government of India,NSS 61ST Round July 2004- June 2005.

[41] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

[42] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

[43] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

Table 4.14: Estimation of nitrous oxide emissions

Sector	**Waste**							
Category	**Domestic wastewater treatment and discharge**							
Sheet	**2 of 2 Estimation of emission factor and emissions of indirect N_2O emissions from wastewater**							
STEP 2								
	A	B	C	D	E	F	G	H
	Nitrogen in effluent	Emission factor	Conversion factor of Kg N_2O-N into Kg N_2O	Emissions from wastewater plants (default as zero)	Total N_2O emissions	GWP for N_2O	Total CO_2e	Total CO_2e
Units	kg N/ year	(kg N_2O-N/kg N)	44/28	kg N_2O/ year	kg N_2O/ year	-	kg CO_2e/yr	tCO_2e /yr
	1700	**0.005**[44]	**1.571428571**	**0**	**13.357 14286**	**298**[45]	**3980.42 8571**	**3.98**

Table 4.15: Scope 2 emissions of the plant

S.No	**Area**	**Total MWh Used yearly**	**Emissions Factor 0.91**[46] **t CO2/ MWh**	**Total Scope 2 Emissions CO_2e**
1.	Sump house	152.48	0.91 t CO_2/ MWh	138.75
2.	Grit chamber	16.33	0.91 t CO_2/ MWh	14.86
3.	Alum dosing/ poly dosing	65.34	0.91 t CO_2/ MWh	59.45
4.	Primary clarifier	19.60	0.91 t CO_2/ MWh	17.84
5.	Biofilter blowers	156.83	0.91 t CO_2/ MWh	142.72
Total		**410.61**	**0.91 t CO_2/ MWh**	**373.62 t CO_2e**

[44] 2006 IPCC Guidelines for National Greenhouse Gas Inventory

[45]IPCC Fourth Assessment Report, 2007

[46] Central Electricity Authority, India

4.2.3 Total emissions of the plant are shown below in Table 4.16.

Table 4.16: Total emissions from the plant

Area	Source	CO_2e Emissions
Scope 1	CH_4	27 t CO_2e
	N_2O	4 t CO_2e
Scope 2	Electricity use	347 t CO_2e
Scope 3	Not Assessed	
Total		**378 t CO_2e**

4.3 Greenhouse Gas Emission Inventory Of 56 MLD Wastewater Treatment Plant At Indrapuram

4.3.1 Details about the plant

The plant is situated in Uttar Pradesh, Indrapuram. The capacity of the plant is 56 MLD at present. This has started functioning in year 1997. The total cost of the plant is Rs 50 crores (approx). Sewage Treatment Plant located at U.P, Indrapuram gets mixed wastewater from residential and industrial sectors.

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

1. **Principle of operation**

   This 56 MLD sewage treatment plant is based on UASB.

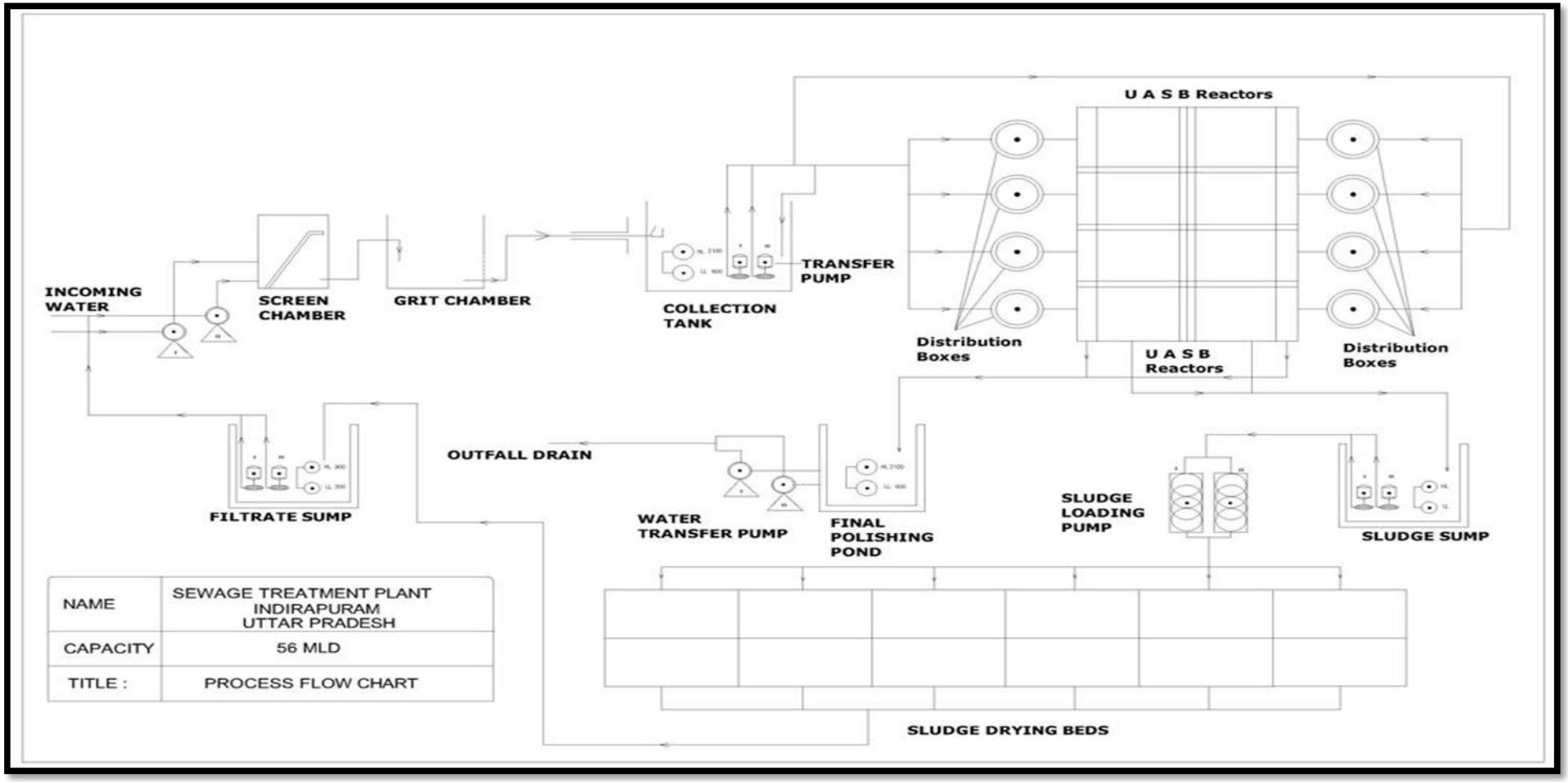
2. **Infrastructural details of the plant**

   i. **Sewage Pumping Station:** The SPS comprises of 3 Nos of pumps of 150 H.P each. The catchment area of the said SPS comes under Trans Hindon area which includes Indrapuram, Vaishali, Vasundara, and Sahibabad etc. 54 MLD (approx.) of sewage conveyed to this Indrapuram sewage treatment plant.

   ii. **Inlet Chamber:** Sewage from sewage pumping station is transferred to inlet chamber of STP. The volume of the inlet chamber is 20m X 6.2m X 3.75m.

Figure 4.10: Inlet Chamber

Figure 4.11: Flow diagram of the UASB plant



iii. **Screening:** Screen chamber equipped with two screens which is mechanical and another two screens that are manually operated.

Figure 4.12: Manually operated screens

iv. **Grit Chamber:** Screened sewage flows through grit chamber. In grit chamber, sewage flows by gravity and all inorganic grit gets trapped in a chamber. There are 4 No's of grit channels in the plant.

Figure 4.13: Grit chamber

v. **Distribution box:** This section distributes the sewage equally into the 8 No's of UASB reactors.

vi. **UASB:** The technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used in the treatment of wastewater.

Figure 4.14: UASB Reactors

The UASB reactor is a methanogenic (methane-producing) digester that evolved from the anaerobic clarigester. UASB uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank. Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. The blanket begins to reach maturity at around 3 months. Small sludge granules begin to form whose surface area is covered in aggregations of bacteria. In the absence of any support matrix, the flow condition creates a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferates. Eventually the aggregates form into dense compact biofilms referred to as "granules". Biogas with a high concentration of methane is produced as a by-product, and this may be captured and used as an energy source, to generate electricity for export and to cover its own running power. The technology needs constant monitoring when put into use to ensure that the sludge blanket is maintained, and not washed out (thereby losing the effect). The heat produced as a by-product of electricity generation can be reused to heat the digestion tanks.

vii. **Polishing Pond:** Treatedsewage from UASB reactor enters into polishing pond. The flow from the anaerobic unit can be treated in a simple pond of short detention to provide some aeration and settle some solids that may occasionally overflow from the anaerobic unit. Final polishing unit is a detention pond adopted for post treatment of the effluent from the UASB rector.

Figure 4.15: Polishing Pond

viii. **Sludge drying beds**: The sludge from UASB reactor is dewatered using sludge drying beds before disposal. **S**ludge from polishing pond is pumped to sludge drying beds, where it is dried and further dried cakes are sold as manure to farmers.

4.3.2 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 of the 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 KVA which runs for 4-5 hrs daily which consumes 40 l of diesel/hr.

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

I. Steps for calculating CH_4 emissions are as follows:

Step 1: Population estimation is calculated in Table 4.17.

Step 2: Estimation of organically degradable material in domestic wastewater is shown in Table 4.18.

Step 3: Estimation of methane emission factor for domestic wastewater is depicted in Table 4.19.

Step 4: Estimation of CH_4 emissions from domestic wastewater are summarized in Table 4.20.

II. Steps for calculating N_2O emissions

Step 1: Estimation of nitrogen in effluent is calculated in Table 4.21.

Step 2: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater are summarized in Table 4.22.

III. Indirect GHG emissions from the consumption of electricity at WWTP

Calculations of CO_2, CH_4 and N_2O emissions are shown below in the following tables:

Table 4.17: Population estimation for the catchment area of the plant

Population estimation
Average flow = 55.25 MLD
Total water supply = average flow x (80/100) [Assuming that 80% of water supplied get converted to wastewater] $=\frac{55.25 \text{ X } 100}{80}$ = 69 MLD
Average water consumption/person/day = 135 l/person/day[47]

[47]CPHEEO manual on water supply and treatment.

Number of persons = $\frac{69\ X\ 1000000\ l}{135\frac{l}{person}/day}$

Number of persons = **511111**

Table 4.18: Estimation of organically degradable material in domestic wastewater

Sector	**Waste**			
Category	**Domestic wastewater treatment and discharge**			
Sheet	**1 of 3 Estimation of organically degradable material in domestic wastewater**			
STEP 1				
	A	B	C	D
City (region)	Population (P) cap	Degradable organic component (BOD)[48] (kg BOD/cap/yr)[a]	Correction factor for industrial BOD discharged into sewers (I)[b]	Organically degradable material in wastewater (TOW) kg BOD/yr)
Uttar Pradesh (Indrapuram)				D= A x B x C
	511111	12.41	1.25	7928609.388
a:g BOD/cap/day x .001x365 = kg BOD/cap/yr				
b: Correction factor for additional industrial BOD discharged into sewers, (for collected thedefault is 1.25, for uncollected the default is 1.00)				

[48] Estimated value of BOD_5 for India is 34 g/person/day, 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 4.19: Estimation of CH_4 emission factor for domestic wastewater

Sector	**Waste**		
Category	**Domestic wastewater treatment and discharge**		
Sheet	**1 of 2 Estimation of CH_4 emission factor for domestic wastewater**		
STEP 2			
	A	B	C
Type of treatment or discharge	Maximum methane producing capacity (Bo) (kg CH_4/ kgBOD)	Methane correction factor or each treatment system (MCFj)	Emission factor (EFj) (kg CH_4/kg BOD)
Anaerobic treatment			C= A x B
	0.6[49]	0.8[50]	0.48

[49]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[50]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 4.20: Estimation of CH_4 emissions from domestic wastewater

Sector	**Waste**										
Category	**Domestic wastewater treatment and discharge**										
Sheet	**3 of 3 Estimation of CH_4 emissions from domestic wastewater**										
STEP 3											
		A	B	C	D	E	F	G	F	H	I
Income group	Type of treatment or discharge	Fraction of Population income group (U_i)[51] fraction	Degree of utilization (T_{ij})[52] fraction	Emission factor (EFj) (kg CH_4/ kg BOD)	Organically degradable material in wastewater (TOW) (kg BOD/yr)	Sludge removed (S) (kg BOD/yr)	Methane recovered and flared (R) (kg CH_4/yr)	Net methane emissions (CH_4) (kg CH_4/yr)	GWP for CH_4 25[53]	Total CO_2e kg CO_2e/yr	Total CO_2e t CO_2e/yr
	Anaerobic treatment			Step 2 of 3	Step 1 of 3			G=[(AxBxC) x (D-E)]-F	25		
Rural		0.71	0.1	0.48	7928609	0	0				
Urban high income		0.06	0.07								
Urban low income		0.23	0.03								
Total		**0.333**	**0.066**					**83642.38**		**2091059.62**	**2091.059**

[51]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

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[52]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[53]IPCC Fourth Assessment Report, 2007

Table 4.21: Estimation of nitrogen in effluent

Sector	**Waste**						
Category	**Domestic wastewater treatment and discharge**						
Sheet	**1 of 2 Estimation of nitrogen in effluent**						
STEP 1							
	A	B	C	D	E	F	G
	Population (P)	Per capita protein consumption (Protein)	Fraction of nitrogen in protein (F_{npr})	Fraction of non-consumption protein ($F_{non-con}$)	Fraction of industrial and commercial co-discharged protein ($F_{ind-com}$)	Nitrogen removed with sludge (default is zero) (N_{sludge})	Total nitrogen in effluent ($N_{effluent}$)
Units	(people)	(kg/person/yr)	(kgN/ kg protein)	(-)	(-)	kg	(kg N/year)
							G=(AXB XCXDXE)-F
	511111	0.057[54]	0.16[55]	1.4[56]	1.25[57]	0	8157.33

[54]Nutritional intake in India 2004-2005, National Sample Survey Organization, Ministry of Statistics & Programme Implementation,Government of India, NSS 61ST Round July 2004- June 2005.

[55]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[56]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[57]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

Table 4.22: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater

Sector	**Waste**							
Category	**Domestic wastewater treatment and discharge**							
Sheet	**2 of 2 Estimation of emission factor and emissions of indirect N_2O emissions from wastewater**							
STEP 2								
	A	B	C	D	E	F	G	H
	Nitrogen in effluent	Emission factor	Conversion factor of Kg N_2O-N into Kg N_2O	Emissions from wastewater plants (default as zero)	Total N_2O emissions	GWP for N_2O	Total CO_2e	Total CO_2e
Units	kg N/ year	(kg N_2O-N/kg N)	44/28	kg N_2O/ year	kg N_2O/ year	298[58]	kg CO_2e/ yr	tCO_2e /yr
					E= (AxBx C)-D			
	8157	0.005[59]	1.57	0	64.032	298	19081.6	19.08

Table 4.23: 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)**
58400[60]	0.00255[61]	148.92

[58]IPCC Fourth Assessment Report, 2007.

[59]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[60] Total diesel consumption/ yr = 40 x 4 x 365=54800 l/yr

[61]Emission factor of Diesel: 74.1 $\frac{t\ CO2e}{TJ}$ x 43 $\frac{TJ}{Gg}$ x 0.8 $\frac{kg}{l}$ = 0.00255 t CO_2e/ l diesel

Table 4.24: Total Scope 2 emissions of the plant

Area	Total MWh Used yearly	Emissions Factor 0.91[62] t CO_2/MWh	Total Scope 2 Emissions t CO_2e
Sewage pumping station	2685	0.91 t CO_2/ MWh	2461
Sludge sump	16.32	0.91 t CO_2/ MWh	14.85
Filtrate pump	8.03	0.91 t CO_2/ MWh	7.3
Total	**2709**	**0.91 t CO_2/ MWh**	**2483 t CO_2e**

4.3.3 Total emissions sources of the plant are shown below in Table 4.25.

Table 4.25: Total emissions sources of the plant

Area	Source	CO_2e Emissions
Scope 1	CH_4	2091 t CO_2e
	N_2O	19 t CO_2e
Scope 2	Electricity use	2465 t CO_2e
	DG set	148.92 t CO_2e
Scope 3	**Not Assessed**	
Total4724 t CO_2e		

[62]Central Electricity Authority of India.

4.4 Greenhouse Gas Emission Inventory Of 10 MGD Sewage Treatment Plant At Yamuna Vihar (Phase-I)

4.4.1 Details about the plant

The plant is situated in the East of Delhi in Shahdara area. The capacity of the plant is 10 MGD at present. This has start functioning in October 1998. The plant was constructed by M/s Geo Miller & Co (P) Ltd. Total cost of the plant is Rs 855.00 Lacs.

The catchment area of this plant is Yamuna Vihar through Yamuna vihar sewage pumping station. It is pumped to the plant by 450mm rising main. Zafrabad sewage pumping station with 13.5 MGD capacity will collect the sewage from under mentioned colonies

Kabool Nagar, Naveen Shahdara, Rohtash Nagar, Gorakh Park, Babarpur, Balbir Nagar, PanchsheelPark, Shivaji Park, Panchseel Garden, Mohan Park, DwarkPuri and Seelampur resettlement colonies phase III & IV.

1. **Principle of operation**

This 10 MGD sewage treatment plant is based on Activated Sludge Process (ASP).

2. **Infrastructure details of the plant**

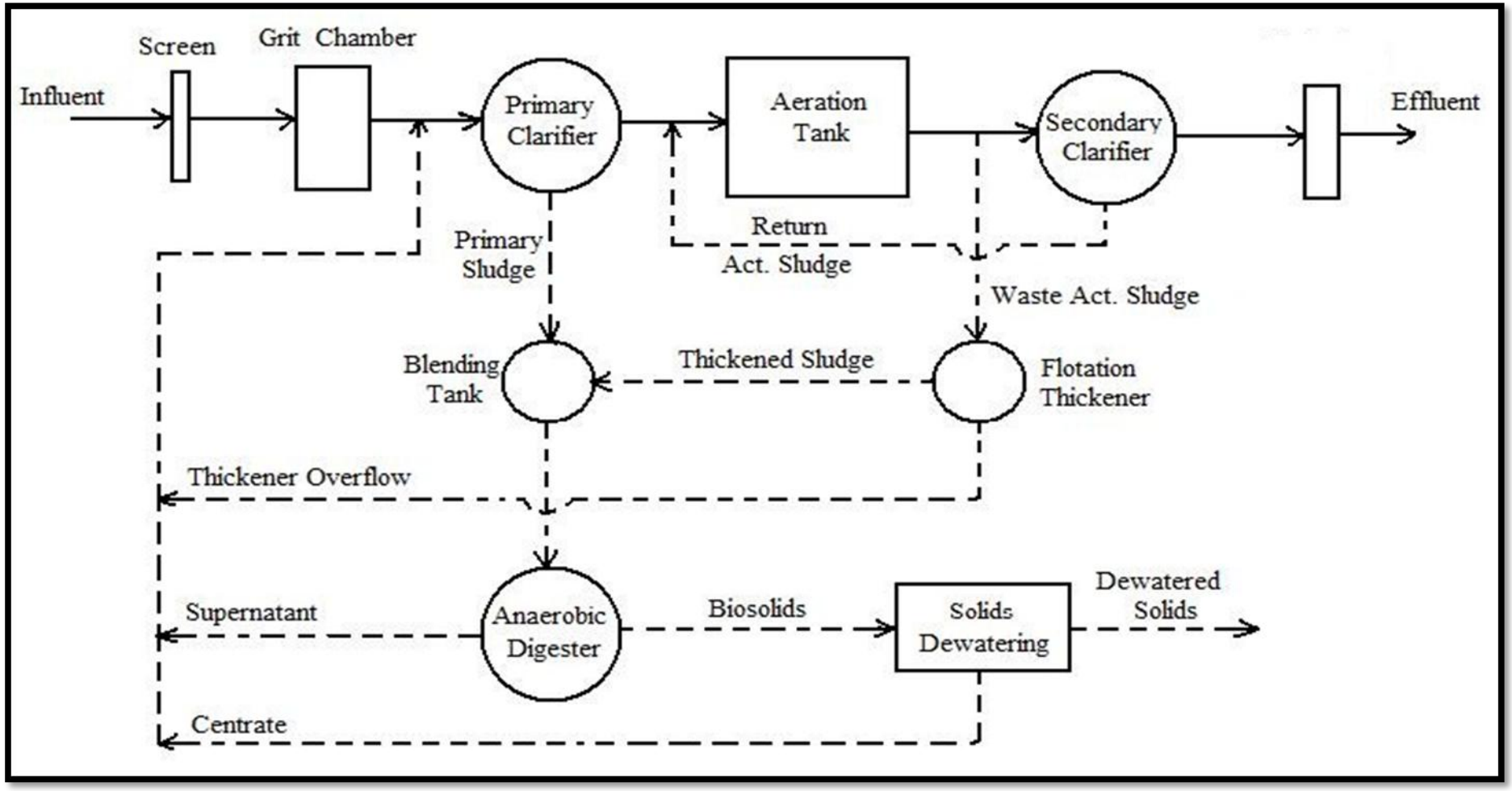
   Thesalient features of various units of Yamuna Vihar sewage treatment plant, Phase-I are as under:

   i. **Bar Screen:** There are two no's of mechanical bar screen with a clear spacing of 20mm. Debris and floating matter is removed here with rake mechanism, belt conveyor, trolleys and disposed off suitably.

   ii. **Fine Bar Screen:**There is one fine bar screen with clear spacing of 6mm. Sewage then flow to the grit chambers.

   iii. **Grit Chambers:** 2 No's of grit chambers are present with a detention period of 60 sec and velocity of 1.2m/sec. Here heavy organic matter of specific gravity more than 2.5 is allowed to settle down and then removed with the help of rake classifiers. The grit removed is used to fill low lying areas in and outside the plant. Parshall type flume measures the instant rate floe of sewage at the plant.

Figure 4.16: Flow diagram of the activated sludge process based plant



iv. **Primary Clarifiers:** The sewage after removing the grit is taken to primary clarifiers by gravity. There are two no's of primary clarifiers having diameter of 29.4 meters and detention period of 2 hrs. The raw sludge from the primary clarifiers is collected into the wet sump of raw sludge pump house.

v. **Raw Sludge Pump House:**Theraw sludge from the primary clarifiers is collected into the wet sump of raw sludge pump house.

vi. **Aeration Tanks:** There are two compartments with controlling gates each having 4 nos aerators of 40 HP each. The effluent of primary clarifiers is taken into aeration tanks for aerobic treatment. The process of treatment is achieved by activated sludge process with conventional surface aeration. A part of activated sludge from the final clarifiers is also mixed to get the desired quality of treatment. The bacteria eat the organic matter present in the sewage and form the heavy flocks of organic matter.

vii. **Final Clarifiers:** The sewage from the aeration tanks is taken to final clarifiers where most of the organic matter settles down and form activated sludge.The activated sludge is pumped back to aeration tank partly as per the requirement and rest before the primary clarifiers with the help of return sludge pumps.The final effluent (treated sewage) from the final clarifiers discharged into drain No 1.

viii. **Return Sludge Pump House:** Return sludge from the final clarifier is pumped back partly to aeration tank (as per requirement) and rest to the distribution chamber before the primary clarifiers.Raw sludge from the primary clarifiers is pumped to digesters for digestion. The digestion period range from 25 to 30 days. Here the complex organic compounds decompose to form methane, carbon-dioxide, nitrogen, hydrogen sulphide gas etc. This happen in the absence of air thus called anaerobic process.The mixing of the contents of digesters is done by gas mixing technology which is being done successfully first time in India at Yamuna Vihar sewage treatment plant.The digested mass (digested sludge) is drawn from the digesters to sludge drying beds by gravity.

ix. **Gas holder:** The gas produced in the digesters is collected in gas holder and recycled to digesters for mixing the digester contents with the help of compressors.

The excess quantity of gas is being burnt in gas burners at present. Action to install gas generating sets is in process, thereafter the gas produced will be utilized for generation electric power for operation of plant. But there is a planning to use the excess gas for domestic use in the nearby areas if economically viable.

x. **Sludge drying beds:** The digested sludge is dried in the drying beds and forms the sludge manure which can be used for horticulture purposes and by farmers as manure.

xi. **Use of effluent (Treated sewage):**Submersible pumps is provided at final effluent channel to use the treated sewage effluent for horticulture purposes and adjoining parks near the administrative building through piping network.

4.4.2 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 the process.

b) $CH_4$when sludge from the secondary and primary clarifiers conveyed to sludge digesters, where methane gas is produced from the sludge digester and from the aeration basinsin small quantities if improperly managed.

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

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:

- Screens (Bar and Fine screens)
- Grit chamber
- Primary clarifier
- Aeration tanks
- Final clarifier
- Raw sludge pump house
- Return sludge pump house
- Compressor unit
- Filtrate pumps

I. Steps for calculating CH_4 emissions are as follows:

Step 1: Population estimation is calculated in Table 4.26.

Step 2: Estimation of organically degradable material in domestic wastewater is shown in Table 4.27.

Step 3: Estimation of methane emission factor for domestic wastewater is depicted in Table 4.28.

Step 4: Estimation of CH_4 emissions from domestic wastewater are summarized in Table 4.29.

II. Steps for calculating N_2O emissions

Step 1: Estimation of nitrogen in effluent

Step 2: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater

III. Indirect GHG emissions from the consumption of electricity at WWTP is shown in Table 4.30.

Calculations of CO_2, CH_4 and N_2O emissions are shown below in the following tables:

Table 4.26: Population estimation for the catchment area of the plant

Population estimation
Average flow = 11MGD
Total water supply = average flow x (80/100) [Assuming that 80% of water supplied get converted to wastewater] $= \frac{11 \text{ X } 80}{100}$ = 13.75 MGD = 13.75 x 3.875 (1 MGD= 3.785 MLD) = 52.04 MLD
Average water consumption/person/day = 135 l/person/day[63]
No. of persons = $\frac{52.04 \text{ X } 1000000 \text{ l}}{135 \text{ l/person /day}}$ No. of persons = **385481**

[63] CPHEEO manual on water supply and treatment

Table 4.27: Estimation of organically degradable material in domestic wastewater

Sector	**Waste**			
Category	**Domestic wastewater treatment and discharge**			
Sheet	**1 of 3 Estimation of organically degradable material in domestic wastewater**			
STEP 1				
	A	B	C	D
City (region)	Population (P) cap	Degradable organic component (BOD)[64] (kg BOD/cap/yr)[a]	Correction factor for industrial BOD discharged into sewers (I)[b]	Organically degradable material in wastewater (TOW) kg BOD/yr)
Delhi(East)				D= A x B x C
	385481	12.41	1.25	5979774.013
a: g BOD/cap/day x .001x365 = kg BOD/cap/yr				
b:Correction factor for additional industrial BOD discharged into sewers, (for collected the default is 1.25, for uncollected the default is 1.00)				

Table 4.28: Estimation of CH_4 emission factor for domestic wastewater

Sector	**Waste**		
Category	**Domestic wastewater treatment and discharge**		
Sheet	**1 of 2 Estimation of CH_4 emission factor for domestic wastewater**		
STEP 2			
	A	B	C
Type of treatment or discharge	Maximum methane producing capacity (Bo) (kg CH_4/ kgBOD)	Methane correction factor or each treatment system (MCFj)	Emission factor (EFj) (kg CH_4/kg BOD)
Aerobic treatment			C= A x B
	0.8[65]	0.05[66]	0.04

[64] Estimated value of BOD_5 for India is 34 g/person/day, 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[65]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[66]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

In this plant CH_4 is not emitted into the atmosphere, but it is captured and collected in gas holder and recycled to digesters for mixing the digester contents with the help of compressors. After that CH_4 is burnt in flare and released as CO_2 into the atmosphere.

The amount of CO_2 released into the atmosphere is calculated below:

From equation 4.1 methane emissions are:

$$\textbf{CH}_4\textbf{ emissions} = \sum [\,(Ui\ Tij\ EFj)\ (TOW - S) = R \quad \textbf{.....4.1}$$

$$\textbf{CH}_4\textbf{ emissions} = 0 \quad \textbf{.....4.2}$$

Therefore, equating eq 4.1 and 4.2 we get,

$$\sum [\,(Ui\ Tij\ EFj)\ (TOW - S) = R$$

$$(1x\ 0.20x\ 0.3)(15799 - 0) = R$$

$$947.48 = R$$

Total amount of methane recovered in inventory year, R = 948 Kg CH_4/yr

When methane is burn with oxygen, it produces carbon-dioxide and water molecules and it is represented by the following equation 4.3.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \quad \textbf{.....4.3}$$

The equation shows that 1 molecule of methane produces 1 molecule of carbon-dioxide.

Therefore, 948 kg of CH_4/ yr produces = $\frac{948}{16}$ moles of CH_4/yr

= 59.25 moles of CH_4/ yr

= 59.25 moles of CO_2/yr

= 59.25 x 44[67] g of CO_2/yr

= 2607 kg of CO_2/yr

= 2.607 t CO_2e/yr

[67] 1 mole of CO_2 = 44g

Table 4.29: Estimation of N_2O effluent in domestic wastewater

Sector	**Waste**						
Category	**Domestic wastewater treatment and discharge**						
Sheet	**1 of 2 Estimation of nitrogen in effluent**						
STEP 1							
	A	B	C	D	E	F	G
	Population (P)	Per capita protein consumption (Protein)	Fraction of nitrogen in protein (F_{npr})	Fraction of non-consumption protein ($F_{non-con}$)	Fraction of industrial and commercial co-discharged protein ($F_{ind-com}$)	Nitrogen removed with sludge (default is zero) (N_{sludge})	Total nitrogen in effluent ($N_{effluent}$)
Units	(people)	(kg/person /yr)	(kgN/ kg protein)	(-)	(-)	Kg	(kg N/year)
							G=(AXBXC XDXE)-F
	385481	0.057[68]	0.16[69]	1.4[70]	1.25[71]	0	6152.27

[68]Nutritional intake in India 2004-2005, National Sample Survey Organization, Ministry of Statistics & Programme Implementation, Government of India, NSS 61ST Round July 2004- June 2005.

[69]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[70]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[71]2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 4.30: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater

Sector	**Waste**							
Category	**Domestic wastewater treatment and discharge**							
Sheet	**2 of 2 Estimation of emission factor and emissions of indirect N_2O emissions from wastewater**							
STEP 2								
	A	B	C	D	E	F	G	H
	Nitrogen in effluent	Emission factor	Conversion factor of Kg N_2O-N into Kg N_2O	Emissions from wastewater plants (default as zero)	Total N_2O emissions	GWP for N_2O	Total CO_2e	Total CO_2e
Units	kg N/ year	(kg N_2O-N/kg N)	44/28	kg N_2O/ year	kg N_2O/ year	-	kg CO_2e/ yr	tCO_2e/ yr
	6152	0.005[72]	1.57	0	48.2932	298[73]	14402.34	14.40

Table 4.31: Scope 2 emissions of the plant

Area	**Total MWh Used yearly**	**Emissions Factor 0.91[74] t CO_2e/ MWh**	**Total Scope 2 Emissions CO_2e**
Sewage pumping station	81	0.91 t CO_2/ MWh	73
Bar screens	16.06	0.91 t CO_2/ MWh	14.6
Coarse screens	12.76	0.91 t CO_2/ MWh	11.61
Fine screens	29.2	0.91 t CO_2/ MWh	26.5
Grit chamber	13.06	0.91CO_2/ MWh	11.88
Primary clarifier	6.53	0.91 t CO_2/ MWh	5.94
Aeration tanks	2091	0.91CO_2/ MWh	1903
Final clarifier	13.06	0.91 t CO_2/ MWh	11.88
Raw sludge pump house	24.45	0.91 t CO_2/ MWh	22.24
Return sludge pump house	912.5	0.91 t CO_2/ MWh	830
Compressor unit	65.33	0.91 t CO_2/ MWh	59.45
Filtrate pumps	5.44	0.91 t CO_2/ MWh	4.95
Total	**3189**	**0.91 t CO_2/ MWh**	**2974 t CO_2e**

[72]2006 IPCC Guidelines for National Greenhouse Gas Inventories.
[73]IPCC Fourth Assessment Report, 2007
[74]Government of India,Ministry of Power, Central Electricity Authority.

4.4.3 Total emissions sources of the plant are shown below in Table 4.32.

Table 4.32: Total emissions sources of the plant

Area	Source	CO_2e Emissions
Scope 1	CO_2	2.6 t CO_2e
	N_2O	14.4 t CO_2e
Scope 2	Electricity use	2974 t CO_2e
Scope 3	Not Assessed	
Total		**2991 t CO_2e**

4.5 Greenhouse Gas Emission Inventory Of Delhi Gate Sewage Treatment Plant

4.5.1 Details about the plant

The Sewage Treatment Plant at Delhi Gate has the capacity of 10 MLD of average flow. It is located near Delhi Gate nallah.The plant was commissioned during 2003 and constructed by M/s Degramont Pvt Ltd. Total cost of the plant is 6.21 crore (approx).

1. **Principle of operation**

This 10 MLD sewage treatment plant is based on High rate BiofiltersDensadegtechnology.

2. **Infrastructure details of the plant**

i. Raw sewage sump

Before flowing in to the Raw Sewage Sump the raw sewage is passed through a Feeder channel and then two numbers of coarse screens (One working and one standby) equipped with 35mm opening for removing any floating material, which may cause damage to the downstream lifting pumps. These screens are cleaned manually. The Raw Sewage from the Raw Sewage Sump is pumped up to the elevated structures to allow gravity flow in the further treatment process. Six nos. of horizontal centrifugal non-clog pumps are provided to pump the sewage to the Elevated structures.

ii. Grit and Grease Removing Unit

Once the raw sewage is pumped to the elevated structures it undergoes medium screening by 20 mm screens and fine screening with 5 mm screens. Then it flows to the grit and grease removal unit. The Grit and Scum Removal unit is an aerated chamber. The main objective is to eliminate larger types of solids such as grease, fiber, etc.

iii. Physico Chemical Treatment

After Pretreatment the effluent undergoes a Physico Chemical treatment to remove most of the suspended solids in the influent and thus reducing the Biological oxygen Demand. The Physico Chemical comprises of flash mixing and flocculation followed by clarification.

After the parshall flume the sewage flows into the flash mixer wherein commercial alum is dosed for the coagulation of the sewage. The flash mixer ensures a perfect mixing of the coagulating alum with the raw sewage.

iv. Densadeg Clarifier

The Densadegis a high performance clarifier developed by Degremont.

It consists of three main technological modules:

a) **Reactor Module:**The reactor Module for flocculation, uses two successive zones with a variable flocculation Energy. It is designed for both rapid flocculation and slow flocculation for floc growth with Sludge recycling. The resultant floc has a high level density which is enhanced by using a Polymer.

b) **The Pre – Settling**: Thickening Module leads to homogeneity to the Settling and Thickening of the Floc. Thickening is promoted by continuous scraping of the precipitated Sludge. Part of the Sludge (i.e. 30 m^3/hr.) is recirculated in the Reactor.

c) **Lamella Clarifier:**The lamella clarifier ensures quality and stability. The residual floc is removed in this module with tube modules for fast settling producing the final quality of Primary Treated Sewage.

ix. Dewatering Unit

The excess sludge is drawn off from the base of the pre-settling and thickening tank and its concentration is sufficient for it to be sent directly to the dewatering unit without having to undergo any additional thickening treatment. The excess sludge is stored in a 60 m^3 RCC tank, from where it is pumped to the mechanical dewatering units.

x. Pressdeg

The excess sludge produced in the plant is mechanically dewatered by presssdeg to reduce the handling volume of sludge. The pressdeg is designed to remove the water contained in the sludge by continuous filtration of sludge under pressure. It is necessary to remove a great part of the water contained in the sludge before applying the dewatering pressure. The preliminary drainage phase is essential as it makes it possible to quickly obtain thicker and much denser sludge, thus increasing the pressing capacity. The sludge should be evenly distributed over the entire width of the belt to optimize the production capacity of the unit and the dry solid content of the cake produced. This cake of sludge is collected and sent to existing digester unit.

xi. Biological Filters / Biofors

The final stage of treatment is biological filtration. This stage reduces the content of suspended solids and the BOD in the effluent to the required levels. The biological filtration is carried out in two identical filtration is carried out in two identical successive stages and each stage consist of a battery of four filters operating simultaneously.

xii. Alum Preparation Tank and Dosing

Alum solution is dosed in the Flash Mixer at the inlet of densadeg. Two nos. alum solution preparation tanks are provided with agitators**.** Alum tanks are provided with overflow drain lines along with drain valves. Alum solution preparation is carried out in one tank at a time while alum dosing will be carried out using the other. Two nos. reciprocating metering pumps are provided to transfer alum solution to flash Mixer of densadeg. The pumps are designed to operate on one working, one standby basis.

After the treatment, treated water is utilized for cooling towers at Pragati Power Corporation and finally to Yamuna river through open drain.

4.5.2 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 the process.

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.

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

I. Steps for calculating CH_4 emissions are as follows:

Step 1: Population estimation is calculated in Table 4.33.

Step 2: Estimation of organically degradable material in domestic wastewater is shown in Table 4.34.

Step 3: Estimation of methane emission factor for domestic wastewater is depicted in table 4.35.

Step 4: Estimation of CH_4 emissions from domestic wastewater are summarized in Table 4.36.

II. Steps for calculating N_2O emissions

Step 1: Estimation of nitrogen in effluent is calculated in Table 4.37.

Step 2: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater are summarized in Table 4.38.

III. Indirect GHG emissions from the consumption of electricity at WWTP are calculated in Table 4.39.

Calculations of CO_2, CH_4 and N_2O emissions are shown below in the following tables:

Table 4.33: Population estimation for the catchment area of the plant

Population estimation
Average flow = 10.77 MLD
Total water supply = average flow x (80/100) [Assuming that 80% of water supplied get converted to wastewater]. $= \frac{10.77\ X\ 80}{100}$
Average water consumption/person/day = 135 l/person/day[75]
No. of persons = $\frac{13.46 \text{ X } 100000 \text{ l}}{135 \text{ l/person /day}}$ No. of persons = **99703**

Table 4.34: Estimation of organically degradable material in domestic wastewater

Sector	**Waste**

[75] CPHEEO manual on water supply and treatment

Category	**Domestic wastewater treatment and discharge**			
Sheet	**1 of 3 Estimation of organically degradable material in domestic wastewater**			
STEP 1				
	A	B	C	D
City (region)	Population (P) cap	Degradable organic component (BOD)[76] (kg BOD/cap/yr)[a]	Correction factor for industrial BOD discharged into sewers (I)[b]	Organically degradable material in wastewater (TOW) kg BOD/yr)
Delhi (East)				D= A x B x C
	99703	12.41	1.25	1546642.788
a: g BOD/cap/day x .001x365 = kg BOD/cap/yr				
b:Correction factor for additional industrial BOD discharged into sewers, (for collected thedefault is 1.25, for uncollected the default is 1.00)				

Table 4.35: Estimation of CH_4 emission factor for domestic wastewater

Sector	**Waste**		
Category	**Domestic wastewater treatment and discharge**		
Sheet	**1 of 2 Estimation of CH_4 emission factor for domestic wastewater**		
STEP 2			
	A	B	C
Type of treatment or discharge	Maximum methane producing capacity (Bo) (kg CH_4/ kgBOD)	Methane correction factor or each treatment system (MCFj)	Emission factor (EFj) (kg CH_4/kg BOD)
Aerobic treatment			C= A x B
	0.6[77]	0.05[78]	0.03

[76] Estimated value of BOD_5 for India is 34 g/person/day, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[77]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[78]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

Table 4.36: Estimation of CH_4 emissions from domestic wastewater

Sector	**Waste**										
Category	**Domestic wastewater treatment and discharge**										
Sheet	**3 of 3 Estimation of CH_4 emissions from domestic wastewater**										
STEP 3											
		A	**B**	**C**	**D**	**E**	**F**	**G**	**F**	**H**	**I**
Income group	**Type of treatment or discharge**	**Fraction of Population income group (U_i)[79] fraction**	**Degree of utilization (T_{ij})[80] fraction**	**Emission factor (EFj) (kg CH_4/ kg BOD)**	**Organically degradable material in wastewater (TOW) (kg BOD/yr)**	**Sludge removed (S) (kg BOD/yr)**	**Methane recovered and flared (R) (kg CH_4/yr)**	**Net methane emissions (CH_4) (kg CH_4/yr)**	**GWP for CH_4**	**Total CO_2e kg CO2e/yr**	**Total CO_2e t CO2e/yr**
	Aerobic treatment			**Step 2 of 3**	**Step 1 of 3**			**G=[(AxBxC) x (D-E)]-F**	25[81]		
Rural		0.71	0.1	0.03	1546642.78	0	0				
Urban high income		0.06	0.07								
Urban low income		0.23	0.03								
Total		**0.333**	**0.066**					**1019.763451**		**25494**	**25.494**

[79]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[80]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[81] IPCC Fourth Assessment Report (2007).

Table 4.37: Estimation of nitrogen in effluent

Sector	**Waste**						
Category	**Domestic wastewater treatment and discharge**						
Sheet	**1 of 2 Estimation of nitrogen in effluent**						
STEP 1							
	A	B	C	D	E	F	G
	Population (P)	Per capita protein consumption (Protein)	Fraction of nitrogen in protein (F_{npr})	Fraction of non-consumption protein ($F_{non-con}$)	Fraction of industrial and commercial co-discharged protein ($F_{ind-com}$)	Nitrogen removed with sludge (default is zero) (N_{sludge})	Total nitrogen in effluent ($N_{effluent}$)
Units	(people)	(kg/person/ yr)	(kgN/ kg protein)	(-)	(-)	kg	(kg N/year)
							G=(AXBXCXDXE)-F
	99703	0.057[82]	0.16[83]	1.4[84]	1.25[85]	0	1591.25

[82]Nutritional intake in India 2004-2005, National Sample Survey Organization, Ministry of Statistics & Programme Implementation,Government of India, NSS 61ST Round July 2004- June 2005.

[83]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[84]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[85]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

Table 4.38: Estimation of emission factor and emissions of indirect N_2O emissions from wastewater

Sector	**Waste**							
Category	**Domestic wastewater treatment and discharge**							
Sheet	**2 of 2 Estimation of emission factor and emissions of indirect N_2O emissions from wastewater**							
STEP 2								
	A	B	C	D	E	F	G	H
	Nitrogen in effluent	Emission factor	Conversion factor of Kg N_2O-N into Kg N_2O	Emissions from wastewater plants (default as zero)	Total N_2O emissions	GWP for N_2O	Total CO_2e	Total CO_2e
Units	kg N/ year	(kg N_2O-N/kg N)	44/28	kg N_2O/ year	kg N_2O/ year	-	kg CO_2e/ yr	tCO_2e /yr
	1591.25	0.005[86]	1.57	0	12.50	298[87]	3725	3.725

Table 4.39: Scope 2 emissions of the plant

S.No	**Area**	**Total MWh Used yearly**	**Emissions Factor 0.91[88] t CO_2/Mwh**	**Total Scope 2 Emissions CO_2e**
1.	Sump house	152.48	0.91 t CO_2/ MWh	138.75
2.	Grit chamber	16.33	0.91 t CO_2/ MWh	14.86
3.	Alum dosing	65.34	0.91 t CO_2/ MWh	59.45
4.	Primary clarifier	19.60	0.91 t CO_2/ MWh	17.84
5.	Biofilter blowers	156.83	0.91 t CO_2/ MWh	142.72
Total		**410.61**	**0.91 t CO_2/ MWh**	**373.62 t CO_2e**

[86]IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

[87]Fourth Assessment Report, IPCC (2007).

[88]Government of India,Ministry of Power, Central Electricity Authority.

4.5.3 Total emissions of the plant are shown below in Table 4.40.

Table 4.40: Total emissions from the plant

Area	**Source**	**CO_2e Emissions**
Scope 1	CH_4	25 t CO_2e
	N_2O	3.7 t CO_2e
Scope 2	Electricity use	373.62 t CO_2e
Scope 3	Not Assessed	
Total 401.32 t CO_2e		

CHAPTER - 5

RESULT& DISCUSSION

5.1 Results

The results of the study are summarized in the following Table 5.1.

Table 5.1: Total emissions of different WWTPs

S. No	Name of the plant	Capacity (MLD)	Process of treatment	Emissions (t CO_2e/ year)					Total emissions (t CO_2e /yr)
				Scope 1				Scope 2	
				CO_2	CH_4	N_2O	DG set	Electricity	
1.	Noida, Sector - 54	33	Sequencing Batch Reactor (SBR)	NIL	156	2.24	46	2863	3067
2.	Sen Nursing Home	10	High rate BiofiltersDensadeg technology	NIL	27.23	4	NIL	373.62	378
3.	Indrapuram	56	Upflow anaerobic sludge blanket reactor (UASB).	NIL	2091	19.08	148.90	2465	4724
4.	Yamuna Vihar	45	Activated sludge process	2.6	NIL	14	NIL	2974	882988
5.	Delhi Gate	10	High rate BiofiltersDensadeg technology	NIL	25	3.7	NIL	373.62	401

The total energy use and GHG emissions from the five WWTPs are summarized in table 5.1. Based on the results following observations are made:

1. The Yamuna Vihar treatment plant has the highest energy consumptioni.e 3189MWh yearly. The reason of high energy consumption is the capacity of the plant (45 MLD) and the use of aeration tanks which consumes 2091 MWH electricity yearly, which is 70% of the total energy consumption of the plant. This energy used by the aeration tanks contribute to 1903 CO_2e yearly.

2. SBR technology also consumes more energy (3146 MWh/yr). It is because of the automization of the plant. This plant is based on Supervisory Control & Data Acquisition (SCADA) system. SCADA is computer monitored alarm, response, control and data acquisition system used by operators to monitor and adjust treatment process and facilities. Due to use of the SCADA system energy use of SBR plant is high.

3. Sen Nursing Home and Delhi Gate plants WW is treated by aerobic process based on High Rate BiofiltersDensadeg technology. Energy used by these two plants are less as compared to other plants i.e. 410 MWh/yr. The total CO_2e is 374 t CO_2e/yr by each plant.

4. The analysis reveals that 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.

5. At Yamuna Vihar treatment plant, CH_4 is not emitted into the atmosphere but it is captured. The gas produced in the digesters is collected in gas holder and recycled to digesters for mixing the digester contents with the help of compressors.The excess quantity of gas is being burnt in gas burners at present. Action to install gas generating sets is in process, thereafter the gas produced will be utilized for generation electric power for operation of plant.

Figure 5.1 shows the graph of CO_2e emissions of five treatment plants of the study. This graph compares CO_2, CH_4 and N_2O emissions in terms of total CO_2e emissions.

Figure 5.1: Graph showing CO_2e emissions of five Treatment Plants

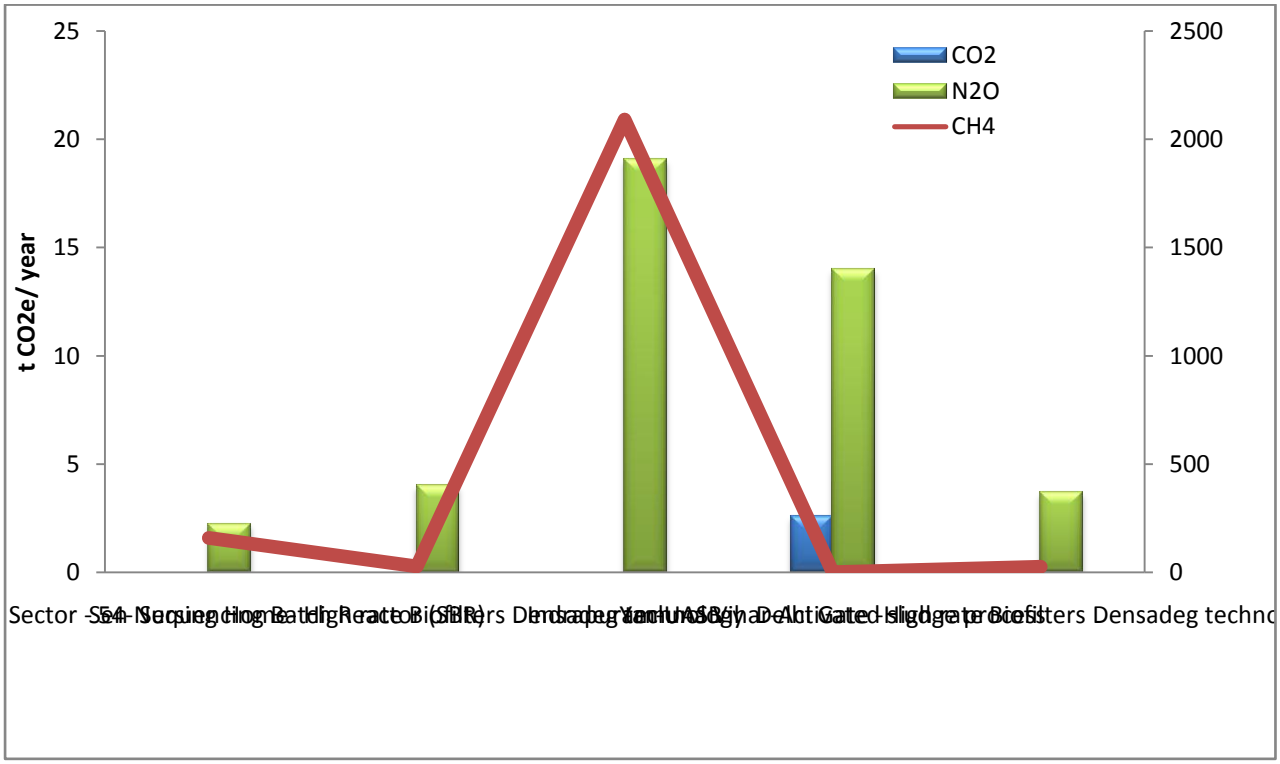


Table 5.2: GHG emissions in terms of t CO_2e/ML of WW treated

S. No	Name of the plant	Capacity (MLD)	Total emissions (t CO_2e /yr)	t CO_2e/ ML
1.	Noida, Sector - 54	33	3067	0.265
2.	Sen Nursing Home	10	378	0.108
3.	Indrapuram	56	4724	0.24
4.	Yamuna Vihar	45	2988	0.189
5.	Delhi Gate	10	401	0.114

An attempt has been made to assess the GHG Emissions from five WWTPs in terms of t CO_2e/ ML of wastewater treated.

Figure 5.2: Graph showing t CO_2e emissions per million liters of wastewater treated of five treatment plants

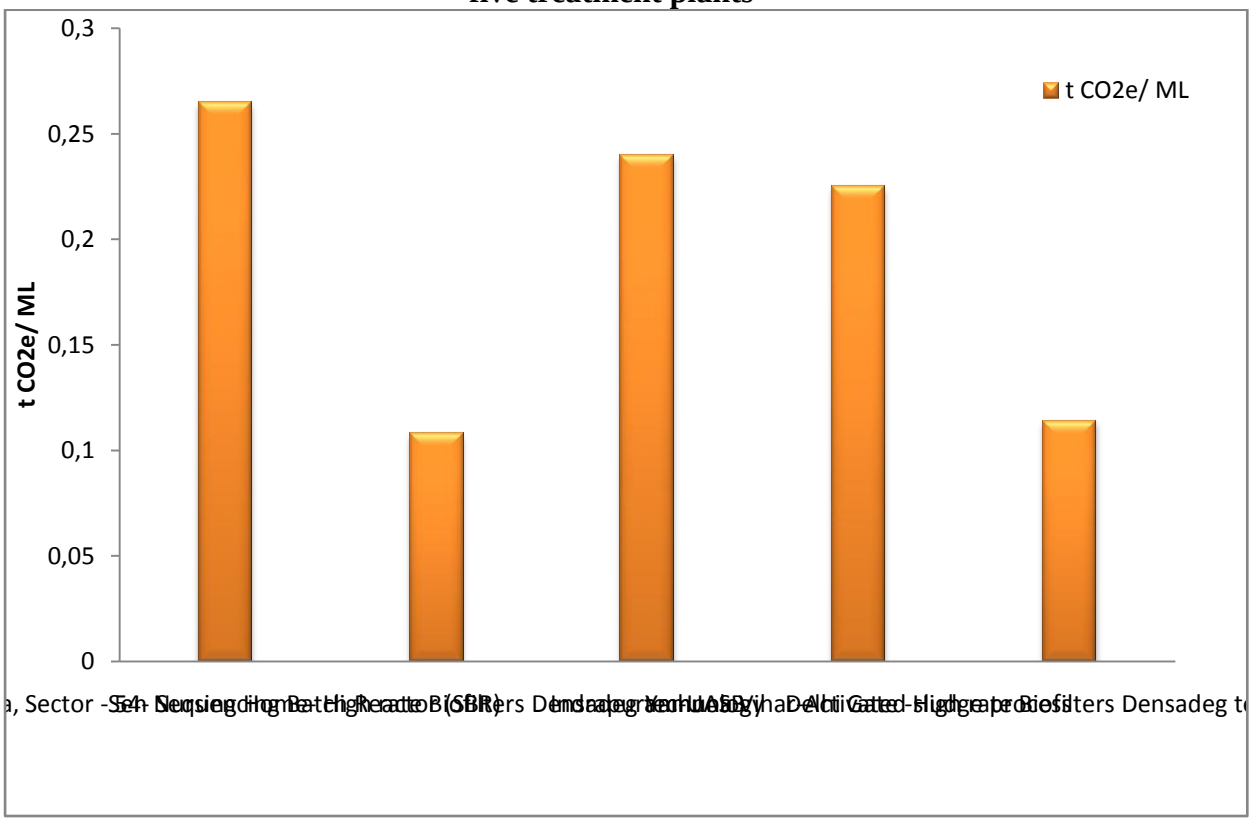


Figure 5.2 shows the comparison of CO_2e emissions per million litre of wastewater with respect to different technology and reveals that highest CO_2e emissions per million litre of wastewater is from SBR technology followed by UASB technology and least emission was observed from High-rate BiofiltersDensadeg technology.

CHAPTER – 6

CONCLUSION & RECOMMENDATIONS

6.1 Conclusions

Following conclusion are made from the above study:

1. The study is used for making a GHG inventory and used in estimating energy use and GHG emissions from WWTPs.

2. Worldwide WW is the fifth largest source of anthropogenic CH_4 emissions, contributing approximately 9%[89] of total global CH_4 emissions in 2000. India, China, United States, and Indonesia combined account for 49%[90] of the world's CH_4 emissions from wastewater.

3. Also, worldwide WW as a source is the sixth largest contributor to N_2O emissions, accounting for approximately 3 %[91] of N_2O emissions from all sources. Indonesia, the United States, India, and China accounted for approximately 50 %[92] of total N_2O emissions from domestic wastewater in 2000.

4. In 2007, total CO_2e emissions from WW sources in India were 45 million tons[93], which is 82% of the total CO_2e emissions from the waste sector. The total methane emitted in 2007 was 1.9 million tons[94] (4.2%) and N_2O emitted was 15.8 thousand tons[95] (.035%).

5. Electricity consumption of SBR was on the higher side in comparison to other technologies. The main reason for the high energy consumption is due to automization of plant whereas High rate BiofiltersDensadeg technology consumes less energy.

6. CH_4 generation was maximum in UASB based plant as the process work on the principle of anaerobic treatment.High rate BiofiltersDensadeg technology also produces minimum methane.

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[89] www.epa.gov/nonco2/econ-inv/international.html
[90] www.epa.gov/nonco2/econ-inv/international.html
[91] www.epa.gov/nonco2/econ-inv/international.html
[92] www.epa.gov/nonco2/econ-inv/international.html
[93] India Greenhouse Gas Emissions, 2007
[94] India Greenhouse Gas Emissions, 2007
[95] India Greenhouse Gas Emissions, 2007

7. With anaerobic treatment, the power generated from methane can largely offset the power required for the aerobic treatment process. Even by replacing the aerobic digestion in with an anaerobic digestion process, the CO_2 production from power generation can be reduced.

8. Indirect emissions from WWTPs operation were not included in this study. The inclusions of these emissions would have increased the operational estimates. The estimation of indirect GHGs could useful when analyzing their relative contribution.

6.2 Recommendations

Following recommendations are made from the above study:

1. The proposed future framework and methodology could help in evaluating gaseous emissions from aerobic, anaerobic wastewater treatment systems as wellas impact related to energy use.

2. Anaerobic treatment process wastewater seems economically, and technically feasible and would have major environmental benefits in terms of greenhouse gas production.

3. CH_4 produced in anaerobic treatment process should be captured and used for generation of electricity or used as a fuel at site, if it is not captured it will discharged into the atmosphere and which will cause increased concentration of GHGs in the atmosphere.

4. The opportunity exists for more effective implementation of emission mitigation strategies based on minimizing the consumption of energy, the recovery and use of biogas for energy generation to replace fossil fuel combustion.

5. The results of the study can be used to identify energy use and GHG emissions abatement strategies and can play a role in comparative studies assessing the environmental sustainability of innovative technologies for water conservation, such as rainwater harvesting and/or graywater reuse.

6. Water conservation programs and strategies can contribute significantly in reducing the operational energy consumption at WWTPs and thereby associated GHG emissions.

PAPERS COMMUNICATED

1. Greenhouse Gas Emission Inventory Of Wastewater Treatment Plants Of Delhi/ NCR: A Case Study Of Noida In The Journal Of Water Sustainability.

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