a) Total organically degradable material in wastewater

TOW(STP1)=P*BOD*0.001*365

=33992*23*0.001*365

=285363 kg BOD/year

TOW(STP2)=P*BOD*0.001*365

=132468*23*0.001*365

=1112069 kg BOD/year

Where,

TOW=total organics in wastewater, kg BOD/year.

P =human population.

BOD=biochemical oxidation demand per capita ,g/person/day.

0.001=conversion from gram BOD to kg BOD.

b) Total organics in wastewater by Treatment/discharge pathway or system

TOW_j(STP1)=∑i[TOW(STP1)*U_i*T_{ij}*I_j]

=(285363*0.71*0*1)+(285363*0.08*0.98*1)+

(285363*0.21*0.99*1)

=81699 kg BOD/year

TOW_j(STP2)=∑i[TOW(STP2)* U_i*T_{ij}* I_j]

=(1112069*0.71*0*1)+(1112069*0.08*0.98*1)+

(1112069*0.21*0.99*1)

=318385 kg BOD/year

Where

TOW_j = total organics in wastewater,kg BOD/year for income group i and treatment/discharge pathway or system,j.

TOW= total organics in wastewater,kg BOD/year.

U_i =fraction of population in income group i.

T_{ij} =degree of utilization of treatment/ discharge pathway or system,j for each income group

I_j =correction factor for additional industrial BOD discharge into treatment / discharge pathway or system,j(for uncollected the default value is 1.00)

Step 2: Estimation of methane emission factor for domestic wastewater

a) CH_4 Emission Factor

EF_j=BO *MCF_j

=0.6*0.03

=0.018 kg CH_4/kg BOD

Where

EF_j=emission factor, kg CH_4/kg BOD.

BO=maximum CH_4producing capacity,kg CH_4/kg BOD

MCF =methane correction factor.

Step 3:Estimation of CH_4 emission from domestic wastewater

CH_4 Emission j= $\sum[(TOW_j - S_j)* EF_j - R_j]$

= [(TOW(STP1) – S)*EF-R]+ [(TOW(STP2) – S)*EF-R]

= [(81699-0)*0.018-0]+ [(318385-0)*0.018-0]

=1471+5731

=7202 kg CH_4/year

Where,

CH_4 Emission j = CH_4 emissions from treatment/discharge pathway or system,j, kg CH_4/year.

TOW_j = organics in wastewater of treatment/discharge pathway or system,j, kg BOD/year.

S_j =organic component removed from wastewater(in form of sludge) from treatment/discharge pathway or system,j,kg BOD/year.

j = each treatment/discharge pathway or system.

EF_j = emission factor for treatment/discharge pathway or system,j, kg CH4/kg BOD.

R_j = amount of CH_4 recovered or flared from treatment discharge pathway or system,j,kg CH_4/kg.

Global Warming Potential(GWP) for Methane=27.2

(Source:IPCC Sixth Assessment Report,2021)

Total CO_2e= 7202*27.2=195894.4 kg CO_2e/year

=196 t CO_2 e/year.

II. N_2O EMISSION CALCULATION

Steps for calculating N_2O emissions are as follows:

Step 1:Estimation of nitrogen in the effluent

a) Total Nitrogen in the domestic wastewater by treatment pathway

TN_{DOM} (STP1) =(P*Protein*FNPR*NHH*FNON-CON*FIND-COM)

=(33992*.0558*365*0.16*1.13*1.1*1.25)

=172109 kg N/year

TN_{DOM} (STP2) =(P*Protein* F_{NPR} * N_{HH} * $F_{NON\text{-}CON}$ * $F_{IND\text{-}COM}$)

=(132468*.0558*365*0.16*1.13*1.1*1.25)

=670717 kg N/year.

Where,

TN_{DOM} =total annual amount of nitrogen in wastewater effluent, kg N/year.

P =human population.

Protein=annual per capita protein consumption, kg protein/person/year.

F_{NPR} =fraction for nitrogen in protein, default=0.16 kg N/kg protein.

$F_{NON\text{-}CON}$ =factor for nitrogen in non-consumed protein disposed in sewer system, kg N/kg N.

$F_{IND\text{-}COM}$ =factor for industrial and commercial co-discharged protein into the sewer system, kg N/kg N.

N_{HH} = additional nitrogen from household products added to the wastewater.

b) Total nitrogen in domestic wastewater effluent discharged to aquatic environment

$N_2O_{EFFLUENT,DOM}$ (STP1)= ∑j[(TN_{DOM} * T_j)*(1- $N_{REM,j}$)]

=[(172109*1.97)*(1-0.10)]+[(172109*1.97)*(1-0.4)]

=508582 kg N/year

$N_2O_{EFFLUENT,DOM}$ (STP2)= ∑j[(TN_{DOM} * T_j)*(1- $N_{REM,j}$)]

=[(670717*1.97)*(1-0.10)]+[(670717*1.97)*(1-0.4)]

=1981968 kg N/year

Where,

$N_2O_{EFFLUENT,DOM}$ = total nitrogen in the wastewater effluent discharge to aquatic environment in inventory year,kg N/yr

TN_{DOM} = total annual amount of nitrogen in domestic wastewater, kg N/year.

T_j = Degree of utilization of treatment system in inventory year(∑Tij).

j= each wastewater treatment type used in inventory year.

$N_{REM,j}$ = fraction of total wastewater nitrogen removed during wastewater treatment type j.

Step 2:Estimation of emission factor and emission of N_2O

a) N_2O emission from domestic wastewater treatment plants

N_2O plant(STP1)=[∑ij(U_i * T_{ij}* EF_j)] *TN *44/28

=[(0.71*0*0.016)+(0.08*0.98*0.016)+(0.21*0.99*0.016)] *172109* 44/28

=1238 kg N_2O /year

N_2O plant(STP2)=[$\sum$ij(U_i * T_{ij}* EF_j)] *TN *44/28

=[(0.71*0*0.016)+(0.08*0.98*0.016)+(0.14*0.99*0.016)] *670717* 44/28

=4828 kg N_2O /year

Where,

N_2O plant= N_2O emission from domestic wastewater treatment plant in inventory year, kg N_2O /year.

TN =total annual nitrogen in wastewater,kg N/year.

U_i =fraction of population in income group i.

T_{ij} = degree of utilization of treatment/ discharge pathway or system,j.for each income group

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

j =each treatment/discharge pathway/system.

EF_j =emission factor fot treatment/discharge pathway or system j,kg N_2O -N/kg N.

The factor 44/28 is for the conversion of kg N_2O -N into Kg N_2O

b) N_2O emission from domestic wastewater effluent

$N_2O_{EFFLUENT,DOM}$ (STP1)= $N_{EFFLUENT,DOM}$ * $EF_{EFFLUENT}$ *44/28

=508582*0.005*44/28

=3996 kg N_2O /year

$N_2O_{EFFLUENT,DOM}$ (STP2)= $N_{EFFLUENT,DOM}$ * $EF_{EFFLUENT}$ *44/28

=1981968*0.005*44/28

=15573 kg N_2O /year

Where,

$N_2O_{EFFLUENT,DOM}$=N2O emissions from domestic wastewater effluent in inventory year ,kg N_2O /year.

$N_{EFFLUENT,DOM}$ =nitrogen in the effluent discharged to aquatic environment ,kg N/year

$EF_{EFFLUENT}$=emission factor for N2O emissions from wastewater discharged to aquatic system ,kg N_2O -N/kgN

The factor 44/28 is for the conversion of kg N_2O -N into Kg N_2O

Total N_2O emission = N_2O plant(STP1)+ N_2O plant(STP2)+ $N_2O_{EFFLUENT,DOM}$(STP1) + $N_2O_{EFFLUENT,DOM}$ (STP2)

=1238+4828+3996+15573 =25635 kg N_2O /year

Global Warming Potential(GWP) for Nitrous Oxide=273

(Source:IPCC Sixth Assessment Report,2021)

Total CO_2e= 25635*273= 6998355 kg CO_2e/year

=6998 t CO_2e/year

III)Emission from Diesel generator set

i)Emission from Banjhinpali STP1(t CO_2e/yr)=1

ii) Emission from Badeatermuda STP2(t CO_2e/yr)=1

Table 3:Total CO_2 equivalent direct emission from STPs

Plant	Total Diesel Consumption	Emission Factor (t CO_2eq/L)	Total CO_2 Equivalent Emission(t CO_2eq/yr)
Bade Atermuda Sewage Treatment Plant, Capacity-07MLD(STP1)	384	0.0029	1
Banzinpali Sewage Treatment Plant, Capacity-25MLD (STP2)	500	0.0029	1

The emission factor is taken from IPCC,2006 , volume 2, Energy.

Total CO_2 (t CO3e/yr)=1+1= 2 t CO_2e/year

3.2.2.Indirect GHG emissions

Indirect GHG emissions resulting from the off-site generation of electric power consumed at STP.The expected power use on the site was calculated based on the electricity consumption from the following components: a)pump house(b)Primary units(Grit mechanism, Grit conveyor)(c)C-T basins(d) Blower room (e)sludge pump (f) lighting in the premises etc.

i)Emission from Bade Atermuda STP1(t CO_2e/yr)=260

ii)Emission from Banjhinpali STP2(t CO_2e/yr)=637

Table 4:Total CO_2 equivalent indirect emission from STPs

Plant	Power Consumption (MWH/yr)	Emission Factor (t CO_2/MWH)	Total CO_2Equivalent Emission(t CO_2e/yr)
Bade Atermuda Sewage Treatment Plant, Capacity-07MLD	321.48	0.81	260.4
Banjhinpali Sewage Treatment Plant, Capacity-25MLD	786.636	0.81	637

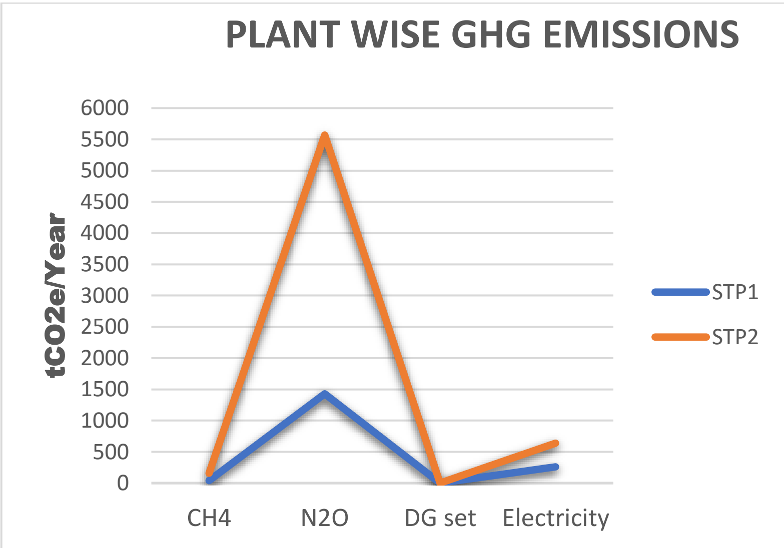
The emission factor is available from Central Electricity Authority, CO_2baseline database for Indian Power Sector 2022.

4.RESULT AND DISCUSSION

The result obtained shown in table 5, of greenhouse gas emissions from the sewage treatment plants in Raigarh city reveals that the facility contributes significantly to the emission of carbon dioxide, methane , and nitrous oxide.

Table 5:Plant wise detail of GHG emissions

Name of STP	Methane(CH_4) ($t\ CO_2$/year)	Nitrous Oxide (N_2O) ($t\ CO_2$/year)	DG set ($t\ CO_2$/year)	Electricity ($t\ CO_2$/year)
Bade Atermuda Sewage Treatment Plant, (STP1) Capacity-07MLD	40	1429	1	260 t CO_2e/year
Banjhinpali Sewage Treatment Plant, (STP2) Capacity-25MLD	156	5569	1	637 t CO_2e/year



The calculated direct GHG emission is 7196 t CO_2e and indirect GHG emission is 897 t CO_2e. Hence, the total GHG emission is 8093 t CO_2e.The study shows that major emission is from direct source i.e. due the treatment process followed in SBR and the rest is from indirect source i.e.electricity consumption in the treatment plant.

5. CONCLUSION

The study has estimated greenhouse gas emissions from SBR-based WWTPs in Raigarh city, Chhattisgarh for current operation. The GHGs emissions from the two STPs combined is 8093 t CO_2e/yr. The result indicates that the amount of on-site green house gases emissions were significantly higher than the off-site emissions. The sewage treatment plants which have been studied are the major treatment plants which combined together will treat more than 75% of the total sewage generated in Raigarh city.

The recommendations could be capturing of methane produced during the treatment process and use it for generation of energy,carbon dioxide from the power generation can be eliminated if primarily anaerobic processes are used and controlling the DO concentration at a proper level and raising the utilization rate of organic carbon in the influent for denitrification are the two most critically effective methods for N_2O reduction during the wastewater treatment.(Sun, Shichang; Bao, Zhiyuan; Sun, Dezhi,2015).

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