World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Ciphering of greenhouse gases from constructed wetlands in Lucknow (U. P. India)

Mamta Rao *, Mohit Kumar and Abhishek Verma

Department of Civil Engineering, Institute of Engineering and Technology, Lucknow, 226021, Uttar Pradesh, India.

World Journal of Advanced Research and Reviews, 2024, 24(01), 634–640

Publication history: Received on 27 August 2024; revised on 04 October 2024; accepted on 07 October 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.1.3056

Abstract

This study evaluates how greenhouse gases (GHGs) contribute to global warming, drawing attention to the substantial effect of human activity on GHG concentrations in the atmosphere. The lower atmosphere warms as a consequence of the absorption as well as the emission of thermal infrared radiation by greenhouse gases, which are both naturally occurring and created by human beings. Since the 1950s, it has been determined that carbon dioxide (CO_2) contributes a vital part in tweaking the environmental conditions, with other gases which include methane (CH4), nitrous oxide (N2O), and CFCs also playing a significant role. India is the third-biggest producer of greenhouse gases (GHGs) due to its enormous population and fast economic growth. This study looks into the GHG emissions from manmade wetlands (CWs) and seasonal assessments conducted in Lucknow and the neighboring wetlands. The emissions of nitrous oxide and methane from CWs are computed using particular formulas and parameters. Utilizing particular formulas and parameters, the emissions of methane and nitrous oxide from CWs are computed. The results emphasize the significance of efficient management techniques such as hydrological control, organic matter control, intermittent drying, shading, adding biochar, and hybrid systems in reducing greenhouse gas emissions from wetlands. The mitigation of the ecological consequences of chemical warfare and the fight against global warming necessitates these protocols.

Keywords: Greenhouse gas; Constructed Wetlands; Methane; Carbon Di-Oxide; Nitrous Oxide; Surface Flow; IPCC; BOD

1. Introduction

In the spectrum of thermal infrared radiation divulged by the Earth's surface, the atmosphere, and clouds, greenhouse gases are those gaseous components of the atmosphere that are both naturally occurring and man-made. They imbibe and emit radiation at particular wavelengths. Because of the world's growing anthropogenic activity and population growth, the concentration of greenhouse gases (GHGs) in the atmosphere has rapidly evolved, contributing to a notable rise in global temperatures. By virtue of these gases' swallowing up solar radiation, the lower atmosphere warms, a phenomenon known as the "natural greenhouse gas effect." Due to industrialization and urbanization, these effects were exacerbated by the expulsion of gases from other anthropogenic activities. Back in the 1950s, CO_2 was initially acknowledged as a factor in atmospheric changes based on an infrared absorption model. Many studies have now demonstrated that species of carbon (CO_2 and CH_4), nitrogen (N_2O), and CFCs play a critical role in climate change and global warming. Global warming is brought on by an increase in the concentration of specifically identified greenhouse gases. The concentrations of greenhouse gases in the atmosphere are now elevated due to soaring GHG emissions brought on by human activity in the post-industrial years of existence. The primary greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). About 77% of all greenhouse gas emissions worldwide are attributed to carbon dioxide, the gas that is ultimately accountable for global warming[1].

With 1.38 billion people living there (as of 2020), India is the second most populous and seventh largest country in the world. Scads of difficulties are brought about by the size and colossal population. The foremost of these is that there is a strong demand for energy: India, which is developing at one of the fastest rates in the world, utilized 1210 TWh of power in the 2018–19 fiscal year, while the country imports almost 80% of the crude oil it uses. Secondly, there exists an imbalance in the openness of energy: while the official declaration that the nation has 100% access to power is outstanding overall These difficulties ultimately result in serious environmental issues[2].

The moment looking at the top ten emitters with the largest gross domestic product (GDP) in the world, India ranks third in the realm of greenhouse gas emissions. In terms of economic expansion, urbanization, and modernization, India remains a developing nation that has made remarkable strides. Global climate change effects have been exacerbated concurrently with rising greenhouse gas emissions. An intentional consequence of rising GHG concentrations, especially CO_2, is rising mean global temperature. Carbon dioxide India's GDP soared by 357% between 1990 and 2019, in line with studies, but its share of GHG emissions increased by 180%[3].

4% of the world's freshwater resources are found in India, home to 16% of the world's population. According to data from the Asian Development Research Institute (ADRI), the Ganga-Brahmaputra-Meghna systems account for 43% of the catchment area in India, whereas just 12 major rivers span around 253 million hectares (mha). Apart from rivers, there are several other inland water resources that encompass around 7 million hectares of catchment regions, such as lakes, ponds, reservoirs, beels, oxbow lakes, derelict water, and brackish water. 50% of these inland waters are sporadically spread across West Bengal, Orissa, Andhra Pradesh, Gujarat, and Karnataka. Tropical climates, ideal for agriculture, are experienced by a large chunk of India. Because they provide food for heterotrophic microorganisms, the species has an impact on the health of freshwater ecosystems and subsequently increases greenhouse gas emissions. The main greenhouse gas contributors are CO_2 and CH_4, while N_2O is found to be very low, and nitrogen loading from inland water sources such wetlands, man-made reservoirs, hydropower reservoirs, and natural lakes is substantial. The quantity of GHGs stored by terrestrial ecosystems can be significantly countered by naturally occurring lakes and reservoirs. But, given that India is an impoverished country, the country's growing hydropower sector and the number of dams built there are sufficient to progressively offset quite a few of the carbon residing in fossil fuels[4].

Both fabricated and natural sources can produce greenhouse gases. For the purpose of creating a plan to govern and sluggish the rate of increase in greenhouse gas emissions, it is also crucial to identify and quantify all sources. Due to the production of CO_2, CH_4, and N_2O during the treatment process and necessitate wastewater treatment facilities (WWTP) are regarded as sources of greenhouse gas emissions. GHG emissions from numerous situations can be computed and assessed within a specified system boundary. Indirect emissions of greenhouse gases (GHGs) from sludge treatment include the procurement and consumption of electricity and chemicals for treatment plant operation and maintenance alongside sludge disposal. Direct emissions of GHGs from wastewater treatment include the following: 1) emissions of CO_2 due to the degradation of organic matter, emissions of N_2O during the nitrification and denitrification process, and emissions of CH_4 and N_2O from anaerobic digestion during sludge treatment. Besides that, the forwarding and manufacturing of building materials bring about indirect greenhouse gas emissions[5].

Methanogenesis evolves in the anoxic sediments of wetlands when there is a high organic matter content. Methanogenesis can occur on wetland plants solely due to their ability to produce root exudates and contribute to the fall apart of litter. They also act as a pathway for the maneuvering of methane from the sediment into the atmosphere. Methane production and oxidation in wet sediments can be altered by a number of biochemical, biophysical, and aquatic ecosystem trophic status variations[6].

2. Method and materials

2.1. Study area

The study region spans up to 100 kilometers and includes Lucknow and its surrounding areas. Uttar Pradesh's capital is located 123 meters above sea level and located at 26°51′N and 80°55′E. The summer months temperature is 25^0–45^0, and the winter months temperature is 2 °C–20 °C. The average annual rainfall is around 35.28 inches or 896.2 mm. The area of Lucknow is 2528 sq. km. The main river Gomti Springs is close to Pilibhit's Maldo Tada town.

The entire length of the river is roughly 900 kilometers in distance. This river encompasses tributaries, including Kukrail, Loni, Beta, and others. The Sai River enters Raebareli district in the east after gushing from the south of the city. It is embraced to the east by the Barabanki District, the west by the Unnao District, to the south by Raebareli District, and to the north by the districts of Sitapur and Hardoi. contrary to the 2001 census, Lucknow had 36, 81, 416 lac those who live there[7].

Seasonal surveys of wetland have been performed in accordance with the area's appropriateness. Using 10x50 binoculars, the open-ended line transect method was incorporated to conduct observations, and a Canon EOS 1000 DSLR camera was utilized for snapping the data. A total of eighteen wetlands were investigated during the study; alongside them, the Nawabganj Bird Sanctuary is a protected site; other wetlands that were not conserved were Behda Pond (in Nagar Chogwa), Chandnapur (Mahona), Unai Jheel (Village Haldarpur), Teekarhaar Jheel (Barabanki), a pond near Amausi airport (in front of Sainik School), Bhadesa Lake, Rain Lake, Purin Lake, Badela Lake and Dahi Pond (in Bichhiya block, Unnao), Anonymized Wetland (in Telibagh), Man-made Wetland Behind DeenDayal Park (PGI), Man-made Wetland in Mohanlal Ganj, Parewa Wetland, Nardahi Gunhari Wetland (in Mohanlal Ganj), Natural Wetland Behind Ambedkar Park (Gomtinagar), and Katotha Jheel (near Amity International School Gomtinagar)[8].

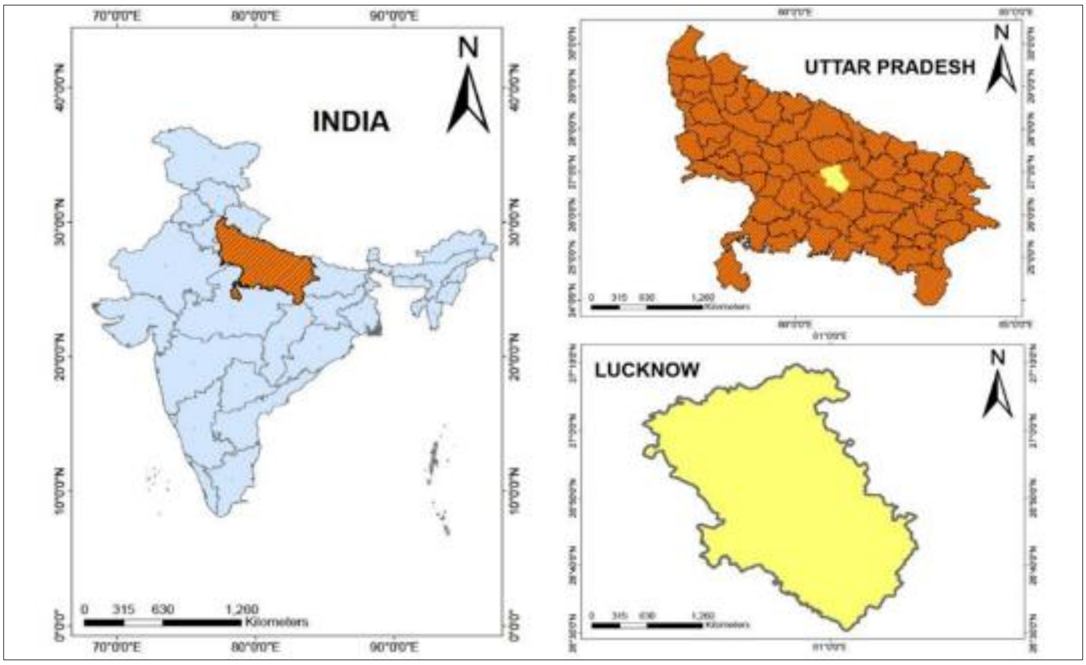

Figure 1 Map of Study Area

While many design parameters can be employed in categorizing constructed wetlands, the three that are the most important are flow path (horizontal and vertical), macrophyte growth form (emergent, submerged, free-floating, and floating leaved plants), and hydrology (water surface flow and subsurface flow). optimum advantage of the unique benefits of each system, various CW types can be consolidated to create hybrid or amalgamation systems.

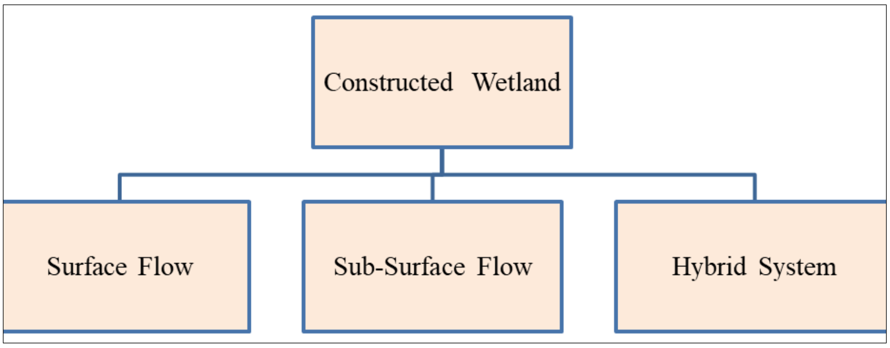

Figure 2 Types of constructed wetlands

Constructed Wetland with Surface Flow: Surface flow (SF) constructed wetlands, which are occasionally referred to as free water surface CWs, have sections that comprise open water as well as floating, submerged, and emergent vegetation.

Constructed Wetland with Sub-Surface Flow: In constructed wetlands with horizontal subsurface flow (HSSF CWs), wastewater crosses over the inlet and circumspectly moves via a porous medium beneath the surface of an emergent vegetation-planted bed to the outlet, where it is gathered and eventually exits through a structure that oversights water level.

Hybrid Constructed Wetland: Higher removal efficiency can be accomplished by combining different kinds of CWs, particularly for nitrogen. A handful of horizontal flow (HF) beds in series (VSSF-HSSF system) are placed after an assortment of parallel vertical flow (VF) beds in the first stage of the design. While denitrification and further organic and suspended solids removal are underway in the HSSF wetland, the purpose of the VSSF wetland is to remove organics and suspended solids and To exhort nitrification.

2.2. Method

Constructed wetlands systems are entirely man-made wetlands used for wastewater treatment. They employ a variety of technology designs and natural wetland processes related to soils, bacteria, plants, and wetland hydrology. The recyclables sector is required to put forth emissions from manmade and semi-natural treatment wetlands.

Only recommendations and a mathematical method for calculating greenhouse gas emissions from Constructed wetlands (CWs) and semi-natural treatment wetlands (SNTWs) for wastewater treatment are provided in IPCC 2006 chapter 6[9].

- Methane Emission

The equation provides a general infant formula for computing CH4 emissions from CWs treating household wastewater.

Total Organically Degradable in Domestic Wastewater

$$TOW = P*BOD*I*360*0.001$$

Emission Factor

$$EF = B_o*MCF$$

Table 1 Methane Correction Factors (mcf) by type of Constructed Wetland (CW)

Constructed Wetland type	Methane Correction Factor (MCF)	MCF Range
Surface Flow	0.4	0.08 – 0.7
Horizontal Surface Flow	0.1	0.07 – 0.13
Vertical Surface Flow	0.01	0.004 – 0.016

Methane Emission from Wastewater

$$CH_4 \text{ Emission (in Gg)} = (TOW*EF)/1000000$$

P = Population
I = Correction factor of Industrial BOD discharge into the sewer.
BOD = per capita BOD generation.
B_o = Maximum CH_4 producing capacity.
MCF = Methane correction factor.

- Nitrous Oxide Emission

Equation evokes the standard equation used to estimate N2O emissions from CWs the fact that treat wastewater from dwellings or corporations.

Total Nitrogen in Domestic Wastewater

$$N_{Total} = P* \text{Protein}* F_{NPR}*F_{NON\text{-}CON}*F_{IND\text{-}COM}$$

Total Nitrogen in Industrial Wastewater

$$N_{iTotal} = TN_i * W_i$$

Protein = Annual per capita protein consumption, kg/person/yr.
F_{NPR} = Fraction of nitrogen in protein (Given in IPCC guidelines).
$F_{NON-CON}$ =Factor for non-consumed nitrogen added to the wastewater (IPCC guidelines).
$F_{IND-COM}$ = Factor for industrial and commercial co-discharged protein into the sewer system (Value taken from IPCC guidelines).
TN_i = Total nitrogen concentration in wastewater from industry entering Constructed Wetlands in inventory year (kg N/m^3).
W_i = Flow rate of industrial wastewater entering the Constructed Wetland (m^3/yr)/[10]

3. Results and discussion

The wetlands constitute a point of crossover between perpetually flooded and unambiguously terrestrial areas where hydromorphic soils and hydrophytic vegetation are predominant. They are taken into consideration as the earth's natural water storage body and reservoir. A wetland's depth ranges from two to six meters. Wetlands are places where water plays a major role in regulating the surrounding ecosystem and the flora and fauna that inhabit them. Wetland functions can be inferred from birds, other species, and flora[11].

The scrutiny of local, regional, and national census data demonstrated significant spikes in Lucknow's municipal wastewater efficiency. Furthermore, there is a section on estimating the production of CH_4 from abandoned wastewater in the 2006 IPCC Guidelines.

This supplement pertains to constructed wetlands wherever an extra treatment tactic. It's possible that Constructed Wetlands and SNTWs are overgrown by the emission factors in this chapter. The IPCC software employs algorithms to determine the production of methane from constructed wetlands. To do the aforementioned, an inventory of the ten years is concocted, and the emission factor is then calculated. Afterwards, the methane emission is tracked.

Yearly increase in CH_4 emissions encompass 3% to 4%, exemplifies the primary cause of this increase in CH_4 emissions is the expansion of populations. Based solely on Constructed wetlands, these inventory findings show a year-over-year rise in CH_4.

There are an assortment of maneuvers to reduce greenhouse gas (GHG) emissions from constructed wetlands.

- Hydrology Management: regulating the water level adequate safeguards against extended anoxic conditions, which might trigger the generation of methane (CH_4).
- Organic Matter Management: Lower the amount of organic material in the substrate to restrict methane emissions during anaerobic breakdown.
- Intermittent Drying: Wetland drying on an ongoing schedule may prevent methane emissions.
- Shading: Reduce the water's temperature by planting trees or erecting shade structures to mitigate the microbial activity that renders methane.
- Shading: Reduce the water's temperature by planting trees or erecting shade structures to mitigate the microbial activity that renders methane.
- Biochar Addition: By rethinking the microbial populations in the wetland substrate, adding biochar might boost carbon sequestration and diminish methane emissions.
- Hybrid System: To considerably decrease overall greenhouse gas emissions, combine formulated wetlands with existing wastewater treatment technology[6].

4. Conclusion

Earth's lower atmosphere warms as a result of the ingestion and release of thermal infrared radiation, an endeavor known as the "natural greenhouse gas effect." Both naturally occurring and artificial beings' greenhouse gases (GHGs) play a crucial role in this process. Global warming has been prompted by the substantial increase in gas concentrations engendered by human activity, especially since industrialization. With 77% of emissions and an enormous part in climate change, carbon dioxide (CO_2) is the foremost greenhouse gas.

India, which ranks third internationally, contributes significantly to global greenhouse gas emissions due to its massive population and swift growth in the economy. Due to the strong need for energy throughout the nation, a significant amount of crude oil is imported. This energy use, along with the expansion of industry and cities, has resulted in higher emissions and environmental problems. The distinct topography and climate of India, in tandem with its freshwater resources and farming methods, all have an additional impact on greenhouse gas emissions, particularly with regard to wetlands.

Moreover being utilized for wastewater treatment, constructed wetlands (CWs) can be among the biggest causes of greenhouse gas emissions, foremost nitrous oxide (N_2O) and methane (CH_4). shifting CW types have varying efficiency and emission factors, including hybrid systems, surface flow, and horizontal subsurface flow. Methane emissions from coal-fired power plants (CWs) can be computed using particular formulas and parameters stipulated in guidelines like those published by IPCC 2006.

The inquiry on wetlands and their emissions in Lucknow and adjoining regions emphasizes how crucial it is to operate these ecosystems in order to lower GHG emissions responsibly. Controlling water levels, controlling organic matter, drying on and off, bringing in biochar, adding shade, and integrating hybrid systems are all good approaches. By alleviating methane emissions and improving carbon sequestration, these actions can lessen the effect of CWs on climate change. The results emphasize the necessity of focused interventions to rein in greenhouse gas emissions from wetlands as part of larger initiatives to impede global warming.

Compliance with ethical standards

Acknowledgement

The authors would like to extend their gratefulness to the Civil Engineering Department, Institute of Engineering and Technology Lucknow for providing the guidance and support that are required to conduct the study.

Disclosure of conflict of interest

All contributors declare that no relationships of interest occur.

Authors Contributions

Mamta Rao: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing, Validation, Software investigation. Mohit Kumar: Supervision, Validation, Visualization, Conceptualization. Abhishek Verma: Data curation, Investigation, Writing – review & editing, Validation.

Role of Funding Sources

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

References

[1] Ramachandra, T. V., Aithal, B.H., Sreejith, K.: GHG footprint of major cities in India, (2015)

[2] Dey, A., Thomson, R.C.: India's biomethane generation potential from wastes and the corresponding greenhouse gas emissions abatement possibilities under three end-use scenarios: electricity generation, cooking, and road transport applications. Sustain Energy Fuels. 7, 209–241 (2022). https://doi.org/10.1039/d2se01028c

[3] Mondal, B., Bauddh, K., Kumar, A., Bordoloi, N.: India's Contribution to Greenhouse Gas Emission from Freshwater Ecosystems: A Comprehensive Review, (2022)

[4] Li, H., You, L., Du, H., Yu, B., Lu, L., Zheng, B., Zhang, Q., He, K., Ren, N.: Methane and nitrous oxide emissions from municipal wastewater treatment plants in China: A plant-level and technology-specific study. Environmental Science and Ecotechnology. 20, (2024). https://doi.org/10.1016/j.ese.2023.100345

[5] Vijayan, G., Saravanane, R., Sundararajan, T.: Carbon Footprint Analyses of Wastewater Treatment Systems in Puducherry. Computational Water, Energy, and Environmental Engineering. 06, 281–303 (2017). https://doi.org/10.4236/cweee.2017.63019

[6] Pandey, J.S., Kumar, R., Wate, S.R., Chakrabarti, T.: Methane Emissions from Wastewater, Wetlands, Mangroves and Hydroelectric Dams: Developing Appropriate Emission Factors for Region-Specific GHGS (ERG). Asia-Pacific Business Review. VI, 29–41

[7] Kanaujia, A., Kumar, A., Kushwaha, S., Kumar, A.: Threats to Wetlands in and around Lucknow, Uttar Pradesh, India. (2015)

[8] Mansi Tripathi and S.K. Singhal: Contributing authors: The-Bharwara-Wastewater-Treatment-Plant.

[9] Archana, A., Ali, D., Yunus, M., Dutta, V.: Assessment of the status of municipal solid waste management (MSWM) in Lucknow – Capital city of Uttar Pradesh, India. IOSR J Environ Sci Toxicol Food Technol. 8, 41–49 (2014). https://doi.org/10.9790/2402-08524149

[10] Masuda, S.: Contributing Authors IPCC 2019 refine to 2006.

[11] Gautam, R.K., Verma, S., Islamuddin, More, N.: Sewage Generation and Treatment Status for the Capital City of Uttar Pradesh, India. Avicenna Journal of Environmental Health Engineering. 5, 8–14 (2018). https://doi.org/10.15171/ajehe.2018.02