GREENHOUSE GAS DIFFUSIVE FLUX ASSESSMENT FROM FEWINDIAN RESERVOIRS

G. Anvesh[1], C. Giri Prasad[2]

ABSTRACT:
There is a growing interest and concern regarding Green House Gas (GHG) emissions as these is the major contributors of global warming. Carbon dioxide (CO_2) and Methane (CH_4) are two main GHGs which get emitted from both natural aquatic and terrestrial ecosystems as well as from anthropogenic activities. In natural aquatic system water storage is an important aspect for meeting the requirements of drinking water, food, and energy. However, development of such water bodies will impact the environment. Recent studies have shown that water bodies play a significant role as the sources of GHG emission, particularly in tropical climatic zones. One possible reason for this is the annual water temperature is much higher in tropical climates. This means that the rate of decomposition is faster leading to higher CO_2 and CH_4 flux in the water. Indian reservoirs indicate the complete spectrum of different types of reservoir found in the world. Their performance in terms of emission of GHGs is more difficult to trace out. In this paper pathways of GHG emission from a reservoir have been discussed and a tool as suggested by UNESCO/IHA has been used to assess the GHG emission from four existing reservoirs in India. These reservoirs are of different age and are located in different parts and climatic zones of India. Predicted diffusive fluxes in CO_2eq have been estimated for the year 2013 as well as over the 100 years of their existence in terms of Tonnes CO_{2eq}.

Index Terms—Co2, CH4, GHG, Pa, Pw

1 INTRODUCTION:

The increasing anthropogenic activities have nowadays resulted in increasing concentration of natural gases CO_2 and CH_4 resulting in GHG effect (Houghton, 1996). According to the European Environment Agency (EEA), CO_2emissions account for the largest share of GHGs equivalent of 80–85% of the emissions. Fossil fuel combustion for transportation and electricity generation are the main sources of CO_2 contributing to more than 50% of the emissions (Goldenfum, 2009). In India generation of electricity with coal based thermal power plant contributing to more than 55% (Mishra, 2004), Hydroelectricity and natural gases represent respectively more than 15% and 5% of electric generation capacity. So far hydro power has been consider as the clean source of energy. Nevertheless, for the last few years GHG emission from freshwater reservoirs and their contribution has been a big issue regarding generation of electricity (Tremblay, 2005). Recent studies showed that the carbon which is transferred to water body will undergo decomposition under oxic and anoxic conditions and produces CO_2 and CH_4(Farrèr and Senn, 2007).

- *Anveshgunjuluri is currently working as environmental engineer at Vitya Consultancy, Hyderabad, India, PH-8439432312. E-mail: gunjulurianvesh@gmail.com*
- *GiriPrasad is currently working as a Associate Professor at Guntur Engineering College,Guntur,AP,and,AP, India, PH-09502601577. E-mail: profgiriprasad2015@ gmail.com*

Once CO_2 and CH_4 are produced, they are not immediately released into the atmosphere, this gases are soluble in the water until a chemical event occurs that causes the gases to be released (Kansal, 2013). In this paper it briefly discusses exactly how reservoirs become a greenhouse gas and the mechanism behind the emission are been pointed out clearly and the predicted emissions of CO_2 and CH_4 in the form of diffusive flux from Indian reservoirs located in different climatic zones are been assessed using UNESCO/IHA GHG Risk Assessment Tool.

2. GHGS EMISSION BY CREATING RESERVOIR

While considering without a reservoir creation over a flowing water bodies only natural emission like conduction, deposition and emission will take place. On creation of a reservoir, emission from different parts of the reservoir will takes place Figure 1 shows detail sources of GHGs emission from the reservoir. The OM (Organic Matter) which present in the soil and plants is imported from the catchment in addition to that OM which preexisting in the reservoir together will decomposes aerobically and anaerobically and emits CO_2 and CH_4 gases to the atmosphere with the help of some parameters (primary and secondary) (Goldenfum, 2009). Macrophytes which are present on the surface of water are alsoresponsible for some amount of CH_4 emission to the atmosphere.

ISSN 2229-5518

2.1 Reactions involved in emissions

The OM which is present in the water bodies and which has been inputted by surface and sub-surface runoff decomposes under oxic condition and produce CO_2 (1). And at the bottom the OM which is stored in the sediments decompose under anoxic conditions and produces CO_2 and CH_4 (2).

Decomposition under oxic conditions:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \quad (1)$$

Decomposition in anoxic conditions (Methanogenesis):

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3\,CH_4 \quad (2)$$

CO_2 and CH_4 emissions to the atmosphere from reservoirs include:

1. Bubble fluxes (ebullition) from the shallow part of water bodies.
2. Diffusive fluxes which are emitted from water surface of the reservoir;
3. Diffusion through macrophytes.
4. Degassing at downstream of reservoir outlet(s).
5. Increased diffusive fluxes along the downstream part of the reservoir

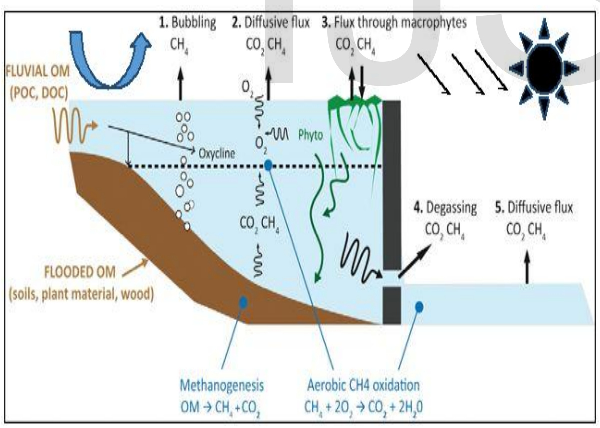


Figure1: Pathways of GHG Emissions from a Reservoir (IPCC 2007).

2.1a. Main parameters/factors influencing GHG emissions

Parameters that effect in the production of CO_2 and CH_4 are divided into two types

1. Primary Parameters
2. Secondary Parameters

Primary parameters	**Secondary parameters**
Biomass of plants, algae, bacteria and animals in the water bodies	Wind speed and direction.
Sediment load, Stratification of the water body OM storage, concentrations and C/N, C/P and N/P ratios in water and in sediments	Reductions in hydrostatic pressure as water are released through low level outlets.
Nutrients supply; Temperature of water	Water current speeds.
Light (absence of turbidity)	Rainfall.
Dissolved oxygen concentrations	Water body depth and changes in water body depth

3. CALCULATION OF DIFFUSIVE FLUX FROM AQUATIC ECOSYSTEM

At Air water interface this both CO_2 and CH_4 will be transferred by diffusion from the aquatic ecosystems. This pathway happens at reservoir upstream and downstream and it is based on the Henry's law difference of partial pressure of a gas between the air (Pa) and the water (Pw). If Pw is higher than Pa the gas diffuses from the water to the atmosphere because a chemical compound always diffuses from the most concentrated layer to the less concentrated(Farrèr, 2007). Several parameters control the intensity of the diffusive fluxes and the level ofdiffusive flux emissions can be estimated using the UNESCO/IHA Risk Assessment Tool with a confidence interval of 67% from the reservoir by giving the required inputs into the model.

3.1 UNESCO/IHA GHG Risk Assessment Tool Model formulas

Several alternative formulations were attempted by the UNESCO/IHA GHG emissions from freshwater reservoirs research project the following general expression has been given as the best fitting expressions (3), (4), and (5) which consider the parameters which are responsible for the emission of $CO_2$and CH_4 (C-CO2, C-CH_4 in mg/m^{-2}*d^{-1}) from the reservoir by considering the age of reservoir.

$$Flux\ C - CO_2 = 186.0 + 0.148 \times R + \left(944.485 + 1.91 \times T + 0.09727 \times T^2\right) \times e^{-0.044 \times \left[52.339 - 0.7033 \times T - 0.0358 \times T^2\right] \times Age} \quad (3)$$

Formula for reservoir aged ≤ 32 years

$$C-CH_4 = 10^{\left(1.46+0.056\times T-0.00053\times P-0.0186\times Age+0.000288\times Age^2\right)} \quad (4)$$

Formula for reservoir aged > 32years up to 100 years

$$C-CH_4 = 10^{\left(1.16+0.056\times T-0.00053\times P\right)} \quad (5)$$

R- Runoff (mm/year), Age- Age of the reservoir, T- Mean annual Temperature (^{0}C), P- Mean annual Precipitation (mm/year).
Reason for consideration of these parameters is:

- Max CO_2 emission occurs after flooding so positive factor of temperature
- The new long term equilibrium emission (after the initial pulse) is a positive factor of runoff. Higher the runoff higher the CO_2 emission from the reservoir
- The steepness of the initial decline (the exponential term) is a negative function of temperature.
- For older reservoirs (>32 years), diffusive CH_4emissions are constant in time at a level which is determined by temperature and precipitation only.

3.1a Range of variability of the estimates
The predicted values "lower limit" and the "upper limit" can be estimated as a function of the predicted values of gross GHG fluxes (of CH4 and CO2) and the mean square errors. Table 1 expresses how to estimate the values of the limits of the 67% confidence interval, for the models adopted in GHG Risk Assessment Tool.

Predicted Value	Lower limit	Upper limits
Gross C-CO_2 Flux	**1/2.3***"Predicted Gross C-CO_2 Flux"	2.3* "Predicted Gross C-CO_2 Flux"
Gross C-CH_4 Flux	1/**3.55***"Predicted Gross C-CH_4Flux"	3.55* "Predicted Gross C-CH_4 Flux"

Table 1: Limits of predicted values of the 67% confidence interval

4. PREDICTION OF DIFFUSIVE FLUX FROM INDIAN RESERVOIRS

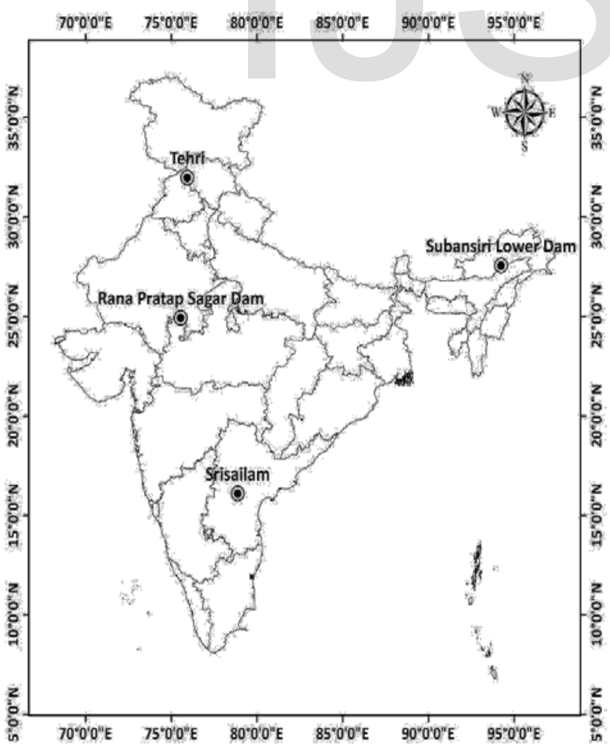
Indian reservoirs indicate the complete spectrum of different types of reservoir found in the world. Some are located in a tropic climate which can release a significant amount of GHG and some in arid environments, where sequestration probably dominates over release of carbon (Kansal, 2014). Between these extremes are reservoirs located in wet, humid or dry tropical environments. Their performance in terms of emission of GHGs is more difficult to trace out. The data of the four Indian reservoirs which are located in different regions shown in the Figure 2have been collected according to the latitude and longitude basics, the mean annual daily air temperature and Mean annual precipitation from 2 meters above the located surface has been analyzed by collecting the data from 1997-2013 from NASA Prediction of Worldwide Energy Resource (POWER). Run-off data are obtained from UNH/GRDC composite run-off fields V 1.0. And the analyzed values are shown in the Table 2. The predicted values of that particular year as well as the expected lower and upper range of CO_2 and CH_4 with a confidence interval of 67 percent are listed in the Table 4. And mean emissions over reservoir life time (100 years) is shown in the Table 3

Table 2: Details of parameters which are required for estimating diffusive fluxes by using GHG risk

S. NO	STATIONS	Age	DMAP (mm/yr) (1997-2013)	R (mm/yr)	DMAT (°C) (1997-12)	Lat.	Long.
1	Srisailam	31	919	200	25	16°05'13'' N	78°53'50' 'E
2	Tehri	7	980	405	14.57	30°22'40'' N	78°28'50' 'E
3	RanaPratapSagar	43	852	315	26	24°55'04'' N	75°34'53' 'E
4	Subansiri Lower	1	1766.5	500	9	27°33'13'' N	94°15'31' 'E

DMAP and DMAT - Daily Mean Annual Precipitation and Temp., R – Runoff, Lat. - Latitude, Long. – Longitude

Figure 2: location of reservoirs studied



H-High, M- Medium, CI- Confidence Interval

Table 3: Estimated Diffusive Flux during 2013 with 67% confidence interval

S. NO.	STATIONS	Predicted gross* annual CO_2 diffusive flux (mg C-CO_2 m^{-2} d^{-1}) Predicted value	67% CI Lower limit	67% CI Upper limit	Predicted gross* annual CH_4 diffusive flux (mg C-CH_4 m^{-2} d^{-1}) Predicted value	67% CI Lower limit	67% CI Upper limit	REMARKS CO_2 emission	REMARKS CH_4 emission
1	Srisailam	410	178	943	118	33	420	M	H
2	Tehri	812	353	1868	114	32	404	H	H
3	RanaPratapSagar	397	173	913	146	41	518	M	H
4	Subansari	1223	532	2814	55	15	194	H	H

Table 4: Average Diffusive Flux over 100 years with 67% confidence interval

H-High, M- Medium, CI- Confidence Interval

5 CONCLUSIONS

S.No	STATIONS	Predicted gross* annual CO_2 diffusive flux (mg C-CO_2 m^{-2} d^{-1}) Predicted value	67% CI Lower limit	67% CI Upper limit	Predicted gross* annual CH_4 diffusive flux (mg C-CH_4 m^{-2} d^{-1}) Predicted value	67% CI Lower limit	67% CI Upper limit	REMARKS CO_2 emission	REMARKS CH_4 emission
1	Srisailam	413	381	449	130	114	147	H	H
2	Tehri	372	342	404	82	72	93	M	H
3	RanaPratap Sagar	479	441	521	160	141	182	M	H
4	Subansari	400	369	435	31	28	36	M	M

In this case study, four reservoirs from different regions of India have been selected and the emission through diffusive flux has been estimated. According to the study, CH_4 emissions are high for all the reservoirs and CO_2 emissions are high for Tehri, Subansari and moderate for Srisailam and RanaPrathapSagar when compared with threshold limits of the model. While considering throughout the life time assessment of the reservoir (100 years), the emission of CH_4 is high for all reservoirs except Subansari and CO_2 emissions are in a limit and medium except Srisailam. Even though these are predicted values, the CH_4 emissions is high for all the reservoirs and hence mitigation measures must be taken to reduce the emission since GWP of CH_4 is 25 times higher than the CO_2. Water bodies have the potential to emit large amounts of CO_2 and CH_4 and contribute to global warming. The decomposition of organic matter is the main reason for the production of these GHGs so we have to control the entrance of OM into water bodies, maybe upto some extent. Another possibility is logging trees before starting the flooding process so that less organic matter is available for decomposition. Due to the fact that the oxidation of CH_4through Methanotrophic bacteria seems to be a key factor to decrease the amount of CH_4 released into the atmosphere, this mechanism should be supported somehow to minimize the emissions from water bodies. There is still a need for lot of research to understand all the important processes.

REFERENCES

[1] Abril, G., Guérin, F., Richard, S., Delmas, R., Galy-Lacaux, C., Gosse, P., &Matvienko, B. (2005). Carbon dioxide and methane emissions and the carbon budget of a 10-year old tropical reservoir (Petit Saut, French Guiana). Global Biogeochemical Cycles, 19(4).

[2] Barros, N., Cole, J. J., Tranvik, L. J., Prairie, Y. T., Bastviken, D., Huszar, V. L., Roland, F. (2011). Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude. Nature Geoscience, 4(9), 593-596.

[3] Farrèr, C., Senn, D., 2007. Hydroelectric Reservoirs-the Carbon Dioxide and Methane Emissions of a "Carbon Free" Energy Source. Master's thesis, ETH EidgenössischeTechnischeHochschule Zürich.

[4] Fearnside, Philip M. "Greenhouse gas emissions from hydroelectric dams: controversies provide a springboard for rethinking a supposedly 'clean'energy source. An editorial comment." Climatic Change 66, no. 1 (2004): 1-8.

[5] Goldenfum, J.A., 2009. UNESCO/IHA Greenhouse Gas (GHG) Research Project. UNESCO/IHA measurement specification guidance for evaluating the GHG status of man-made freshwater reservoirs.

[6] Houghton, J.T., 1996. Climate change 1995: The science of climate change: contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

[7] Kansal, M.L., 2013. Impact of water bodies on Green House Gas Emission, National seminar on green chemistry, 5-6.

[8] Mishra, U., 2004. Environmental impact of coal industry and thermal power plants in India. Journal of environmental radioactivity 72, 35-40.

[9] Tortajada, C., Altinbilek, D., & Biswas, A. K. (2012). Impacts of Large Dams: A Global Assessment. Springer.

[10] Tremblay, A., 2005. Greenhouse gas Emissions-Fluxes and Processes: hydroelectric reservoirs and natural environments. Springer.