Green House Gas Emissions from Hydropower Reservoirs: Policy and Challenges

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Received: 16.02.2016 Accepted: 11.04.2016

Abstract -The Greenhouse gas (GHG) emissions turns out to be one of the most important factor contributing to global warming significantly. Literature revealed that reservoirs too can be an important source of emissions, especially in tropical areas. A lot of efforts have undergone in determining the GHG from reservoirs, however, due to various uncertainties like lack of standardized measurement tools and techniques, till date the determination has been little difficult. Some of the international organization like United Nations Educational, Scientific, and Cultural Organization (UNESCO), International Energy Agency (IHA), and International Hydropower Association (IEA) has been making a lot of effort to know the contribution that reservoirs make in GHG emissions. The key objective of this paper is to find policy and challenges at different scales that could help to address the GHG emissions from reservoirs and its impact on climate change.

Keywords-GHG, Policy, Challenges, Reservoirs, global impact

1. Introduction

With continuous pressure on controlling environmental pollution, there is also a continuous focus on greenhouse gas emission (GHG) arising out of hydropower reservoir which is leading to global warming (GW). The reservoirs located in tropical areas are noted to emit a significant amount of carbon dioxide (CO_2) and methane (CH_4) when compared to the reservoirs located in other eco-regions [1]. The gasses like CO_2, CH_4 and nitrous oxide (N_2O)from natural sources like rivers, lakes, estuaries, wetlands, forest, and soils as well as from anthropogenic activities are noted to be major GHG contributor that effect GW [2]. The Intergovernmental Panel on Climate Change (IPCC) reported thatCH_4 is 21 times higher global warming potential (GWP) than CO_2 over a period of 100 years [3]. It shows that CH_4 is considerably more potent to the population than CO_2. The processes related to the source and sink of GHGs from hydropower dams is similar, irrespective of their usages [4]. The issue of emissions from the reservoirs is relevant to sustainable development besides the production of energy, urban water supply, and food production, with across-the-board implications on reservoirs. Lemperiere and Lafitte [9] estimated that 40% of the world's population get their food supply from irrigated land whereas, 30-40% of agricultural areas get irrigated using water supplied from reservoirs.

Heterotrophic bacteria (aerobic and anaerobic) facilitate degradation of organic matter (OM) available in the reservoirs as well as on its sediment water-interface, thereby causing GHG emission. There are four methods by which GHG emission from the reservoirs gets transported to the atmosphere: [1, 5, 7]: a) Diffusive flux:GHG emissions from the air-water interface; b) Ebullition or Bubbling: GHG emitting in the form of bubbles from water interface. It observed mainly in shallow water, where depth is less than 20m; c) Degassing: an emission during the discharge from turbine outlets induced by a dramatic change in hydrostatic pressure; d) Diffusive fluxes along the downstream of a reservoir. The quantity of GHG emission primarily depends on the amount of OM, age, depth, shape of the reservoir, C: N, N: P, C: P ratio and climatic conditions of the reservoirs [6-7]. Research studies reveal that the hydropower reservoirs contribute low GHG emissions compare to fossil fuels, but higher than solar or wind power. Tropical reservoirs have been found to give higher emission levels compared to reservoirs located in temperate regions [8].

Lima et al., [10] observed that the dams located in tropical countries like India, China and Brazil contribute significantly to

the climate change because of the high amount of GHG emission. Clean Development Mechanism (CDM), United Nations Framework Convention on Climate Change (UNFCCC) and IPCC [3, 11] have recognized emission from the reservoir as important issues both at national as well as international level. With the passage of time and continuous focus on the area, there is also a continuous increase in the scientific knowledge base on hydropower reservoir and its inclusion in climate policy framework [12, 13]. The issue on reservoir emission comes out to be a challenging topic both from policy making or from the management point of view on account of its nature which involve multiple stakeholders linked with water flow & storage and a variety of scales where interventions may occur. To predict the vulnerability of any reservoirs is connected to GHG-emitting from the reservoir, and to the stages (pre and post-impoundment) at which the impact accrues. Greenhousegasses (GHGs) generated within a reservoir by degradation of OM by aerobically & anaerobically. However, there is some OM, which originates in the upstream during various processes undergone degradation aerobically and anaerobically in the reservoir. Particularly for older reservoirs (<10 years), for which the initially flooded biomass has largely been used up, continuing emission levels can be attributed to inflows of OM through runoff. Land use and management practices in upstream areas of the reservoir can thus considerably affect the runoff of organic carbon and finally reaching into a reservoir, where degradation occurs to emit GHG to the atmosphere. A lot of work has performed in the literature on the measurement of GHG fluxes from reservoirs located in temperate, sub-tropical and tropical reservoirs in Canada, China, Finland, Iceland, Norway, Switzerland and the USA [1]. Results of measurements in tropical/subtropical regions areparticularly concentrated in Brazil, with a few isolated published studies in Panama, French Guyana, Laos and India. The key objectives of this paper include (a) pathways leading to appropriate data collection and accounting mechanisms for GHG emissions from individual reservoirs, b) to develop policy and challenges at appropriate scales.

2. Challenges with GHG Emission from Reservoirs

Several studies on GHG emissions from reservoirs have shown that the formation/ development of reservoir changes the pattern of emissions in the watershed because of its nature of acting both as a sink and sources which sometimes is seen in the same reservoir as well [14-18]. The changing pattern of GHG fluxes of any river basin can be analyzed by measuring fluxes before and after the construction. Some studies are carried out to estimate GHG emissions from reservoirs by prediction without the use of field measurements [19-21].

Features associated with various forms of electricity in the field of GHG emanations demands adequate exploration. Direct GHG emissions, namely CO_2, CH_4 and N_2O, are obtained from power generation plants owing to combustion of fuels like coal, wood, crude-oil-based products, coke, natural gas, peat, and other biomass fuels. As per the World Energy Council report [22], lifecycle GHGs emission (CO_2-eq/kWh) are estimated as 7-22g for wind energy, 5-90g for hydroelectric power, 13-104g for solar and 3-40g for nuclear. Since there are a lot of uncertainties in a specific reservoir because of various site-specific factors, it is very difficult to use such technique for determining the percentage emission of GHGs from a particular reservoir. The main concerns regarding the existing stage of knowledge have given in Table 1.

Table 1. Challenges and consequences of GHG emissions from reservoirs

S. No	Challenges	Consequence
1.	The available literature data on gross GHG emissions from young (<10 years), shallow, warm-water reservoirs, is not the representative of the majority of reservoirs globally.	Overestimation of the GHG emission from hydroelectric reservoirs and a sinful acknowledgment of the despotic province of freshwater reservoirs in climate change.
2.	Data related to GHGs emission not acquired through standard procedures and methods.	Comparisons of available results require intense interpretation of the data.
3.	The proper technique is not available for the estimation of net GHG emissions from the reservoir.	Divergent interpretations of GHG emissions are required from reservoirs.
4.	Difficult to get representative sample of existing and planned reservoirs.	Large uncertainties at the global scale have found in regarding GHG emissions from reservoirs.
5.	There are many physicochemical factors that can influence the GHG emission potential from a reservoir, and the exact environmental conditions and physical characteristics of any two reservoirs are never the same.	Applying results of one reservoir on another is not applicable because of climatic conditions and reservoir characteristics.

3. Dam GHG Controversy

Every anthropogenic activity and freshwater reservoirs give a GHG footprint. Since when the first studies reported on GHG emissions (considerably CO_2 and CH_4) from reservoirs [23-25], are now being reported as a serious concern on a global scale under discussion by several policymakers and environmental is still today [26-30]. Report by World Commission on Dams (WCD) in the year 2000 although being a significant achievement on reservoir emissions has yet not discussed at the

global stage. Reports also suggest that if the reservoirs are contributing a significant amount of emissions than it has to investigate further to the reservoirs characteristic and implement the catchment area treatment plan to mitigate the effect of GHG on climate change. Researchers from the hydropower industry have contributed a lot to the researchers published till date. However, there can be other factors as well which also needs to be considered and hence, it is necessary that the topic studied in depth by independent bodies. Therefore, IPCC has been asked to take the lead in the research.

The main attention has been the debate on hydroelectric power's climate-friendliness and comparison of GHGs emission to other energy sources, like fossil fuels, a type of non-renewable source. Emissions from reservoirs made for drinking water supply, agriculture, and flood control has been ignoring.Due to its little awareness, it has not come into ordinary discussions of GHG emissions. This feature has been further confirmed in the study conducted by Makinen [31]. Asdrubali et al., [32] has used geographic information system (GIS) based tool for the accounting of GHG, which provides valuable data to decision-makers in an appropriately conservative manner other than outdated inventories.

4. GHG Controversy and Policy Formulation

The discussion on reservoir emissions has been highly one-sided and biased due to lack of independent research. It resulted in the prevalence of research sponsored by the hydropower industry [33].For example, studies adopting a lifecycle approach viz. construction, operation and decommissioning of medium and large dams have so far not considered emissions from them after impoundment of reservoirs. Policy formulation on the GHGs has hampered due to lack of sufficient data and uncertainties in the measurement of GHG emissions. Existing information on the issue can be use for taking actions through detailed accounting mechanisms are not easily available. Available mitigation measures are not coming into the picture during the discussion to overcome the adverse effects of GHG emissions at different levels. Hence, to address the existing knowledge gap in scientific research and policy, there is an urgent need to consider existing and future reservoirs in discrete ways.

For making future reservoirs, issues like topography, soil organic carbon and types of vegetation & its density should be taken into account for site selection [2, 34]. Clearing the land biomass (vegetation) before impoundment of the reservoir and managing the land around the reservoir can considerably influence the amount of OM in a reservoir and its further degradation causing GHG emissions to the atmosphere [34]. In future, features of spillway and design of turbine inlet deal a variety of prospects to minimize GHG emissions. The amount of OM coming from the river through runoff and confluence to the reservoir controlled by a combination of land management and removal of allochthonous OM as part of catchment area treatment plans. Another prospect is to regulate the water level of the reservoir and the release of water from their conduits because the fluctuations in the water level affect the rate at GHG emission through ebullition and the size of drawdown areas as well.

5. Discussions

Improvement in coverage is a tough task as it is inevitable that there would be a conflict of interests of hydropower industry and nations whose only source of energy is hydropower. Just like GHG emissions from different anthropogenic sources, an urgent need to take care of emissions coming out from reservoirs is required. It could stabilize GHG concentrations in the atmosphere to a level that could prevent risky implications arising out of global warming from its emissions.

This study offers options for possible coverage interventions at the reservoir, river, and catchment, nearby, countrywide and international stages, which can become a part of IWRM (Integrated Water Resources Management) plans, also in the reduction of GHG emission plans under climate exchange regulations.

Formulation and implementation of worldwide policies related to climate change could have an extensive effect even at lower degrees. Tier 1 problem will come out from the range of country-level climate policies, with an aim to affect within the regions of GHG reporting and reducing emissions. Tier 2problem will come at the extent of regulations of water and control practices at different ranges. Urgent need of practical efforts is required to mitigate the adverse effect of GHG emissions from the water resources like reservoirs, lakes, wetlands, etc. IWRM guidelines and frameworks do not include climate change impact policies related to dams. However, it is needed in view of coming risks possessed by climate change.

With the help of the information's provided in this paper and the data presented, it can be concluded that though there is not many comprehensive data available but still, it offers a strong indication of the type of emissions and its potential impact. In due course of time there will be more data and research work in the area and hence, there will be more amount of knowledge which would have been gainshortly. This knowledge may lead to the adoption of stringent measures in the national and global domain for an accounting of GHG emissions from water reservoirs.

6. Conclusion

Even though scientific researchers carried out till now doesn't solve many technical issues related to measurement and reporting, present knowledge about reservoir emissions gives significant information regarding types of emissions (mainly N_2O, CH_4, CO_2) and eco-region where they are significantly important. The full picture of GHG emissions at worldwide is still unknown because of many uncertainties present inaccurate measurement and unavailability of reservoir emissions data on a large scale. In the making of policies and related actions on reservoir emissions, research studies should be motivated and encouraged for the betterment of scientific background. Looking at the impact of dams and its catchments at different scales, an urgent need of making policies on the global scale to deal with GHG. Better communication between scientific and policy-making groups urgently needed for successful mitigation of

adverse effect of climate change due to reservoir emissions. UNFCCC guidelines to be follow on a large scale before constructing any hydropower reservoirs.

Standardized techniques for measuring are needed to be implemented to quantify the net GHG emissions from hydropower reservoirs before and after the construction of reservoirs for better policy formulation. CO_2 capture and storage are not a priority for the Indian Government because, while an agreement to the Kyoto Protocol and UNFCCC, presently there are no such GHG emission reduction targets. Further, research and development are required to predict the potential of GHG storage in geological reservoirs in India. International bodies have to play the important part in cultivating such research.

Acknowledgement

One of the authors (AK*) acknowledges the financial support from Ministry of Human Resource Development (MHRD), Govt. of India in the form of Ph.D. scholarship to carry out research work.

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