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Long-term prediction of greenhouse gas risk to the Chinese hydropower reservoirs

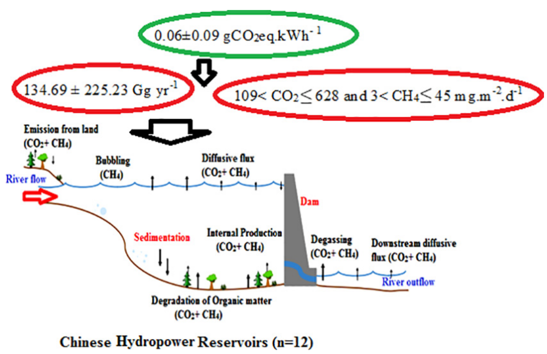
Amit Kumar [a,*], Tao Yang [a,*], M.P. Sharma [b]

[a] *College of Hydrology and Water Resources, Hohai University, Nanjing 210098, China*
[b] *Alternate Hydro Energy Center, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand 247667, India*

HIGHLIGHTS

- Electricity generation from hydropower is a challenging issue when it comes to sustainable development.
- This study predict long-term GHG risk to the Chinese hydropower reservoirs and its associated life cycle emissions.
- The carbon emissions as CO_2eq of the studied reservoirs are found as 134.69 ± 225.23 Gg yr^{-1}, with large share from CH_4 emission.
- The associated life cycle GHG emissions are also estimated as 0.06±0.09 $gCO_2eq.kWh^{-1}$.

GRAPHICAL ABSTRACT



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ABSTRACT

China is undergoing an extensive hydropower development, but the magnitude of greenhouse gas (GHG) emissions risk to reservoirs is not well known. Electricity generation from hydropower is a challenging issue when it comes to sustainable development. In this study, the data on Chinese hydropower reservoirs (n = 12) were collected from the literature and is used as in input to Greenhouse Gas Risk Assessment Tool (GRAT) to predict long-term GHG (CO_2 & CH_4) risk to the hydropower reservoirs and its associated lifecycle GHG emissions (GHG-LCA). The model predicted that till recently (i.e., year 2018) the hydropower reservoirs found under medium risk (i.e., $109 < CO_2 \leq 628$ and $3 < CH_4 \leq 45$ $mg \cdot m^{-2} \cdot d^{-1}$) which will reduce slowly over a period of 100 years. Out of 12 hydropower reservoirs studied, TGR presently under high risk of CH_4 (i.e., 47 $mg \cdot m^{-2} \cdot d^{-1}$) and medium CO_2 risk. Therefore, assessment is required to know the magnitude of CH_4 and its effect on regional climate so that mitigation measures could be taken in advance. The carbon emissions as CO_2eq of the studied reservoirs are found as 134.69 ± 225.23 Gg yr^{-1}, with a large share from CH_4 emission. The associated life cycle GHG emissions are also estimated as 0.06 ± 0.09 $gCO_2eq \cdot kWh^{-1}$, which is higher than the global estimates (i.e. 0.015 $gCO_2eq \cdot kWh^{-1}$).

1. Introduction

Hydropower reservoirs besides providing multiple benefits (flood control, irrigation, water supply etc.) (Chen et al., 2018). Decomposition of flooded vegetation produce significant source of greenhouse gas (GHG) emissions under certain conditions and underlying soil are the

* Corresponding authors.
E-mail addresses: amitkdah@hhu.edu.cn (A. Kumar), tao.yang@hhu.edu.cn (T. Yang).

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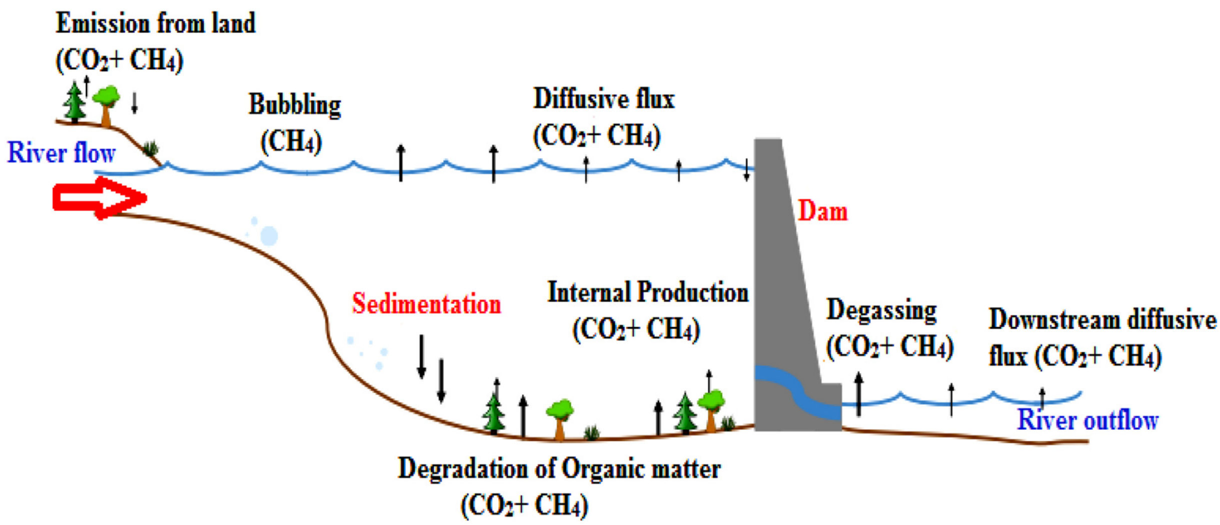

Fig. 1. GHG emission pathways from hydropower reservoir (Kumar and Sharma, 2016a).

potential source of GHG from the reservoirs. GHGs released from reservoirs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (IPCC, 2013). IPCC (2006) reported that contribution of CO_2, CH_4 to the total GHG emissions are more compared to N_2O unless significant sources of nitrogen are available which flow to the reservoir by anthropogenic activities. The global warming potential (GWP) of these gases are different e.g. CH_4 has a GWP of 34 times higher than CO_2, whereas N_2O has a GWP 298 times that of CO_2 on a per molecule basis over a period of 100-year time horizon (IPCC, 2013; Demarty and Bastien, 2011; Fearnside, 2012). Factors contributing to the supply, generation, and release of GHG from the reservoirs include: the age of reservoir, eco-region, vegetation covers, organic matter and nutrient inflows (Barros et al., 2011; Kumar and Sharma, 2016a, 2016b, 2016c, 2017; Kumar et al., 2017). Emissions tend to decline with aging process; exponentially at initial stages (>10 years) and slower over a period of 100 years (Kumar and Sharma, 2016a, 2016b). Besides, the external climatic factors like shape & location of the reservoir in the watershed, the temperature, precipitation, wind speed, and direction are the major stressors increasing the risk of GHG released from the reservoir (UNESCO/IHA, 2012; Kumar and Sharma, 2016a, 2016b). The risk is a threat of damage, injury or any other negative impact caused by external or internal obligation. The vulnerability of the risk can help predict the long-term fate of GHG from freshwater reservoirs and assess the potential impact of both the short and long-term and allows to adopt suitable measures to reduce the impacts. It is reported that the reservoirs located in tropical and/or subtropical eco-regions are found to have higher risk than located in temperate eco-regions as evidenced by higher GHG emission per kWh of electricity production from tropical reservoirs compared to Renewable Energies Technologies (RETs). Modeling studies help to plan appropriate and timely so that the short/long-term impacts of climate charges may be minimized (Yang et al., 2010, 2015, 2017; Zhong et al., 2018). The models available for estimating GHG emission from freshwater reservoirs on a regional scale are limited, particularly, when GHG measurements facilities are scarce or not available. UNESCO/IHA (2012) developed a GHG Risk Assessment Tool (GRAT) to estimate the vulnerability of a reservoir to GHG

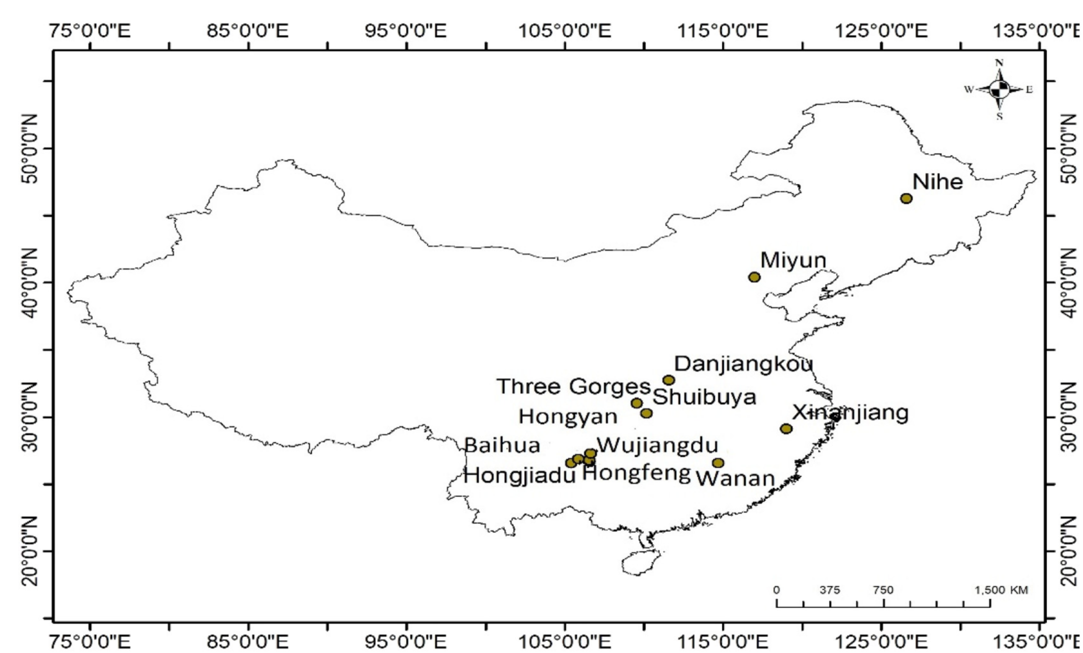

Fig. 2. Locations of the hydropower reservoirs in China.