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Effects of damming on the distribution and methylation of mercury in Wujiang River, Southwest China

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HIGHLIGHTS

- Total Hg concentrations decreased from upstream to downstream of the Wujiangriver as the result of the intercepted particulate Hg.
- Net Hg methylation and the output of MeHgfrom reservoirs increased with progressive increase of trophic stage in reservoir.
- Net Hg methylation and discharge of MeHgfrom hypolimnion resulted in the elevation of MeHgin several sections of the river.

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ABSTRACT

Newly built reservoirs are regarded as sensitive ecosystem for mercury (Hg) methylation. A comprehensive study was conducted to understand the influence of damming on the distribution and methylation of Hg within a river-reservoir ecosystem in Wujiang River Basin (WRB), Southwest China. Hg species in inflow-outflow rivers of six cascade reservoirs were analyzed each month during 2006. Mean concentrations of total Hg (THg) and methylmercury (MeHg) in river water in WRB were 3.41 ± 1.98 ng L^{-1} and 0.15 ± 0.06 ng L^{-1}, respectively. THg and particulate Hg (PHg) concentrations in outflow rivers of reservoirs significantly decreased after dam construction, suggesting that a considerable amount of PHg was intercepted by way of sedimentation. However, the influence of damming on the distributions of dissolved Hg (DHg) and reactive Hg (RHg) in rivers was less pronounced. MeHg concentrations in outflow rivers of the older reservoirs significantly increased compared to inflow rivers with the maximum increasing factor of 92%, indicating the active net Hg methylation in the reservoirs. However, the difference between MeHg in inflow rivers and outflow rivers were less pronounced in the newly constructed reservoirs, indicating that these reservoirs were not active sites of Hg methylation. The construction of the cascade reservoirs resulted in the elevation of MeHg in several sections of the Wujiang River, which attributed to the net Hg methylation in reservoirs and discharge of MeHg from hypolimnion. MeHg-enriched water in outflow rivers from hypolimnetic water could be transported to downstream, posing potential threat to the aquatic food web and human health.

1. Introduction

Mercury (Hg) as an extremely persistent, bioaccumulative, and toxic pollutant, has received considerable attention in the past decades (Lindqvist et al., 1991; Stein et al., 1996). Inorganic Hg (IHg) can undergo chemical and microbial transformations to methylmercury (MeHg), which can be accumulated by aquatic biota and biomagnified along the food chains (Watras et al., 1995), posing a potential threat to wildlife and human health (Hammerschmidt et al., 2006). Consequently, fish consumption is regarded as the main route of MeHg exposure to humans (Clarkson, 1993).

It is generally accepted that reservoirs are sensitive ecosystems for Hg methylation and subsequent contamination of MeHg to food web of aquatic ecosystem (Lucotte et al., 1999; St. Louis et al., 2004). The risk of elevated MeHg concentrations in fish is one of the most important concerns in newly constructed reservoirs. With the rapid development of dams in river systems over the world, the scientific communities are paying more and more attention to the impacts of dam construction on transportation and transformation of Hg in

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river-reservoir systems (Kelly et al., 1997; Heyes et al., 2000).

Elevated levels of MeHg in fish have been widely reported in recently impounded hydroelectric reservoirs in North American and North Europe, where fish consumption advisories were commonly issued by local health departments (Lucotte et al., 1999; Abernathy and Cumbie, 1977; Bodaly et al., 1984). In China, Hg concentrations in fish from reservoirs along the Wujiang River and the Yangze River were also significantly elevated (Jin and Xu, 1997; Li et al., 2013). Enhanced MeHg production in water from newly built reservoirs following impoundment may persist for up to 10 years (St. Louis et al., 2004; Kelly et al., 1997). Hg methylation is largely facilitated by a subset of sulfate-reducing bacteria (SRB), iron-reducing bacteria (IRB), methanogens, and firmicutes in natural environment (Gilmour and Henry, 1991; Gilmour et al., 2013; Schaefer et al., 2014). Recently, Bravo et al. (2014) explored that both SRB and IRB are potential methylators for MeHg production in reservoirs. Furthermore, the decomposition of flooded vegetation and organic matter in soils may stimulate the Hg methylation (Lucotte et al., 1999). The net Hg methylation rate decreases with the increase of the reservoir age as the result of the continual decomposition of organic matter in submerged soil (Lucotte et al., 1999; St. Louis et al., 2004). Active Hg methylation were also observed in old reservoirs in North America and Europe (e.g. Falls Creek Reservoir in Idaho, USA and Babeni Reservoir in Romanian) (Gray and Hines, 2009; Bravo et al., 2014).

The total amount of large dams in China accounted for more than 50% of the total globally since 1982, and many more new dams are being created rapidly (The World Commission on Dams, 2000). The Wujiang River is the largest tributary of the upper Yangtze River. Since 1970s, numerous large cascade reservoirs have been or are being constructed along Wujiang River Basin (WRB), Southwest China (Fig. 1), such as Wujiangdu Reservoir (WJD, impoundment in 1979), Dongfeng Reservoir (DF, 1994), Puding Reservoir (PD, 1994), Yingzidu Reservoir (YZD, 2003), Suofengying Reservoir (SFY, 2003), Hongjiadu Reservoir (HJD, 2004). In addition, a number of reservoirs were also built in the tributaries of Wujiang River, such as Baihua Reservoir (BH, 1966), Hongfeng Reservoir (HF, 1966), and Aha Reservoir (AH, 1960).

Numerous studies were conducted to investigate the biogeochemical cycling of Hg in river-reservoir ecosystem in WRB, Southwest China. Early studies have confirmed that the newly constructed reservoirs, such as the YZD, SFY, and HJD, within WRB were not active sites for Hg methylation given the low organic matter content in submerged soil (Meng et al., 2010; Yao et al., 2011). However, the older reservoirs within WRB, such as the WJD, PD, and DF, were characterized by a much more active net Hg methylation compared to the newly constructed reservoirs (Meng et al., 2010, 2016; Yao et al., 2011; Feng et al., 2009a, b). These observations implied that Hg methylation will be promoted with the increase of trophic stage in reservoir. Unfortunately, most of the research related to Hg cycling in river-reservoir system have focused on the unique biogeochemistry within reservoirs, while

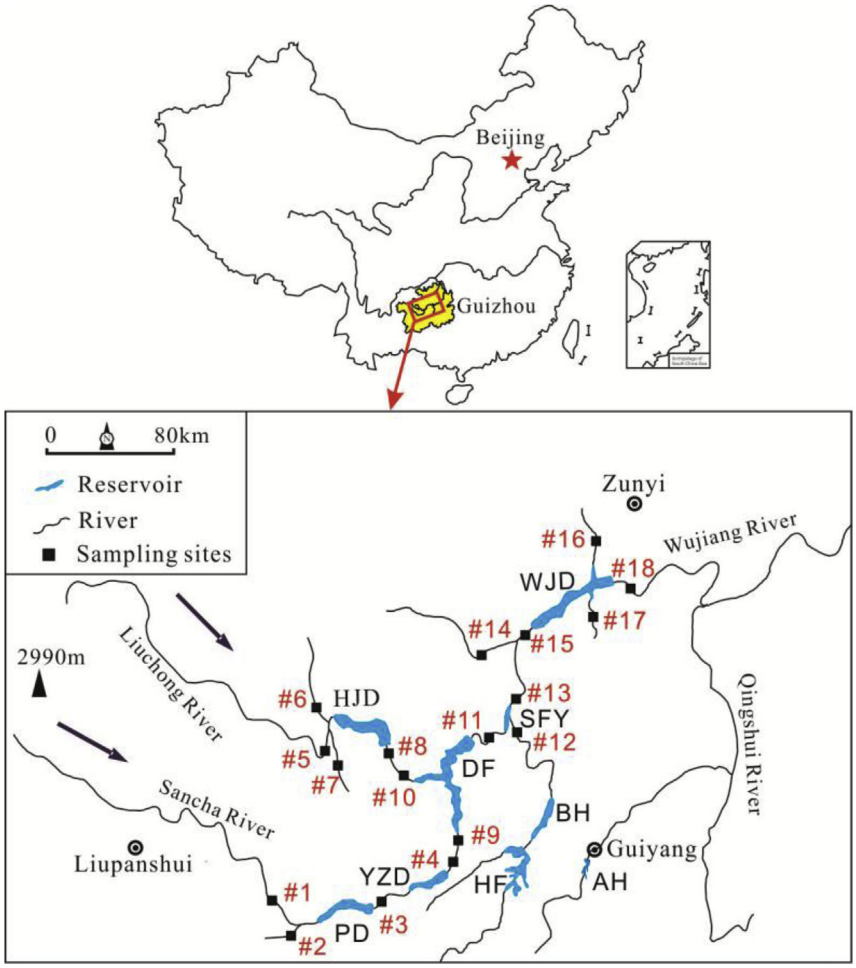

Fig. 1. Map of the study area and sampling sites of inflow-outflow rivers of reservoirs in Wujiang River Basin, Guizhou Province, China. (Hongjiadu Reservoir, HJD; Yinzidu Reservoir, YZD; Suofengying Reservoir, SFY; Puding Reservoir, PD; Dongfeng Reservoir, DF; Wujiangdu Reservoir, WJD; Aha Reservoir, AH; Hongfeng Reservoir, HF; Baihua Reservoir, BH).