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Environmental threats to the Three Gorges Reservoir Region: Are mutagenic and genotoxic substances important?

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The Three Gorges Dam project (TGDP), with a total static investment of 95.46 billion RMB (US$10.97 billion) based on the 1993 price level, commenced in 1994 and was completed in 2012. The creation of the Three Gorges Reservoir following the completion of the TGDP had brought about significant changes to the Three Gorges Reservoir Region (TGRR), stretching from the town of Sandouping in Hubei Province to the Jiangjin District of Chongqing Municipality. The TGDP has led to progressive urbanization and industrialization of the TGRR, accompanied by increased shipping activities, greater hydropower generation capacity, enhanced flood control and improved water supply/irrigation systems. Overall, the TGDP has brought economic benefits to China, especially in cities in and around the TGRR (Zhang, 2014). Notwithstanding, the TGDP has also caused serious environmental concerns, such as habitat destruction, siltation/sedimentation, as well as pollution and public health issues (*e.g.*, Xiao et al., 2013). In a paper entitled "Yangtze Three Gorges Reservoir, China: A holistic assessment of organic pollution, mutagenic effects of sediments and genotoxic impacts on fish" by Prof. Hollert and coworkers (Floehr et al., 2015), the authors examined one particular aspect of the environmental consequences of the TGDP namely pollution impacts, especially those associated with persistent organic pollutants. To tackle a topic as broad as this, it was necessary for the investigators to concentrate on toxicants that specifically cause mutagenic and genotoxic effects.

In the project undertaken by Prof. Hollert and coworkers, a stepwise approach integrating chemical analyses, *in vitro* studies and *in situ* investigations was used to screen for pollutants which cause significant effects in the Three Gorges Reservoir ecosystem. Furthermore, the authors, using an economically relevant indicator fish species, attempted to assess the impacts of genotoxic substances to the ecological systems in the TGRR. However, it should be noted that attempts to ascertain which chemicals or classes of chemicals are responsible for the toxicity using correlative studies can often be problematic (Ankley and Schubauer-Berigan, 1995). For example, the actual compounds causing toxicity might not have been included in the list of "target analytes", and thus will not be analyzed or quantified. As well, chemical contaminants may interact with each other antagonistically, additively, or synergistically, thereby influencing their overall toxic effects. To address these problems, toxicity identification evaluation (TIE) procedures, using toxicity-based fractionation methodologies, may help identify toxic chemicals or classes of chemicals causing observed toxicity (US, EPA (United States Environmental Protection Agency), 2007). Specifically, Phase I of TIE examines the general physico-chemical nature of sample toxicants. Phase II measures target toxicants using different analytical techniques, while Phase III confirms, or otherwise, that the suspect toxicants identified in Phases I and II of the TIE procedures are actually causing the observed toxicity. Indeed, TIE procedures have been employed to identify toxic components in water and sediments in water bodies in China (*e.g.*, Ke et al., 2015; Yi et al., 2015). Over and above this, effect-directed analysis procedures are currently being developed to deal with issues arising from mixtures of pollutants in the management of water resources (Altenburger

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et al., 2015). It is anticipated that, with suitable modification and adaptation, such effect-based tools should be applicable to a wider range of aquatic systems.

Applying the triad approach (Chapman, 1990), the study by Prof. Hollert and coworkers integrated the use of a biomarker (micronucleus induction) and a bioassay (Ames fluctuation assay), into the contaminant monitoring scheme, and the findings indicated that the observed mutagenicity and genotoxicity may at least be partly attributed to pollutants, such as polycyclic aromatic hydrocarbons (PAHs) and their derivatives (nitro- and heterocyclic PAHs). These are important results. It is worth noting, however, that although biomarkers are potentially useful (*e.g.*, Ji et al., 2010; Zheng et al., 2014), they have a number of important limitations (Lam and Gray, 2003; Lam, 2009). For example, for biomarkers to be effective in providing early warning of potential harm to biological systems, some false positives may be inevitable. On the other hand, an apparent lack of biomarker response (*i.e.*, a negative response) could either be due to the absence of harmful agents or the harmful agents occurring at levels not high enough to elicit a response. As well, certain biomarker responses, including micronucleus induction, DNA adduct levels and DNA strand breaks, can be effectively compensated or repaired by some aquatic organisms and thus making biomarker responses less observable under particular circumstances (Lam, 2009 and references therein).

The approach using a combination of both chemical analysis and bioassay has been proven useful in monitoring water quality in Chinese rivers (Rao et al., 2013). Indeed, some toxic chemicals are known to exert their toxic effect through binding to a specific site of action (receptor). Bioassays based on receptor-mediated responses can be standardized for routine use in general environmental surveillance (*e.g.*, Hecker et al., 2007), and can play an important part in revealing combined toxicities of complex mixtures in large-scale environmental monitoring programmes (Murphy et al., 2009; Hu et al., 2015). Perhaps, the possibility of incorporating a suite of receptor-based bioassays into the monitoring programme for the Three Gorges Reservoir ecosystem will assist in the assessment and prioritization of risks associated with persistent toxic substances.

Clearly, any meaningful environmental surveillance programme will need to involve a carefully thought out plan backed by a large team of qualified monitoring personnel, and the monitoring work has to be implemented consistently, systematically, and comprehensively. More importantly, the data collected will need to be analyzed appropriately and any recommendations acted upon seriously. On this basis, the work can only be realistically undertaken by government authorities, preferably Central Government Authorities. Even for Central Government Authorities, however, a comprehensive assessment of the environment impact of the TGDP will still be extremely challenging because the TGRR covers a large area and affects a large population. As well, as a consequence of the TGDP, important ecosystems may have been eliminated, altered or expanded, and new ones created (Li et al., 2013). Perhaps, separate lines of investigations will need to be undertaken to ascertain if environmental threats due to persistent toxic chemicals in general, and mutagens/genotoxicants in particular, are indeed of top priority in the overall protection and conservation of the Three Gorges Reservoir ecosystem in the future.

The Three Gorges Dam. Photo taken by Prof. Litian Zhang, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences.

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