Potential Impacts and Challenges of Climate Change on Water Quality and Ecosystem: Case Studies in Representative Rivers in China

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Abstract: Potential impacts of climate change on water quality and ecosystem, as a newly emerged problem and challenge, is of great concern by scientists and governments. However, scientific researches and practices are still facing big challenges in these issues because of their complexity and uncertainty. This paper reviews the most recent literatures on this topic at first, and proposes some research gaps between published results and what needs to be known in practice. Additionally, basing on our knowledge and results of some recent case studies of the two representative rivers which are Huai River and Hanjiang River in China, it should be addressed that if the impact of climate change on the water quality and ecosystem has been taken concern, water pollution and related water environmental problem caused by human activities and economic development must be addressed firstly. It has also been recognized that water quality and ecosystem can be significantly impacted by climate change under the condition of human activities. Climate change can alter water temperature and hydrological regimes and thus influence the water quality and ecosystem. Then, the contents and principles of adaptation options and adaptability construction are discussed. The present study is expected to make clear of conceptions and to give directions for further relevant researches.

Key words: potential impact; challenge; climate change; water quality and ecosystem

1 Introduction

With the development of economy and industry, “greenhouse gases” especially CO₂ are emitted continuously to the atmosphere, which leads to global climate change (Rundgren et al. 2005; Lenihan et al. 2008). Global climate change is likely to have significant effects on the hydrological cycle (IPCC 1996). The hydrological cycle will be intensified, with more evaporation and more precipitation, but the extra precipitation will be unequally distributed around the globe. Some parts of the world may see significant reductions in precipitation, or major alterations in the timing of wet and dry seasons (Arnell 1999). Climate change can have far reaching consequences for water resources (Arnell 2003), water quality (Hejzlar et al. 2003; Webb et al. 2003) and ecosystem (Beaugrand and Reid 2003; EA 2005; Hiscock et al. 2004; Moss et al. 2003; Sommer et al. 2004; Wilby et al. 2006). Strong climate-water quality relationship was found between air and water temperatures and nutrient concentrations. Effective precipitation also appeared to exert a significant influence on water quality. This influence is, by contrast with the influence of air temperature, less direct (Tibby and Tiller 2007). Changes in water quality during storms, snowmelt, and periods of elevated air temperature or drought may exceed the thresholds of ecosystem tolerance, and thus lead to aquatic ecosystem degradation. Continued climate stress would increase the frequency with which ecosystem thresholds are exceeded and thus lead to chronic water quality changes (Murdoch et al. 2000).

However, besides climate change impacts on water
availability and hydrological risks, the consequences on water quality and ecosystem is just beginning to be studied (Delpla et al. 2009). Fortunately, climate change is increasingly recognized as an important regulatory factor, capable of influencing water quality and the structural properties of aquatic ecosystems (Law et al. 2009). But the impact mechanisms of climate change on water quality and ecosystem are still not fully understood. Moreover, the challenges of water resources management also include that how to solve the impact of climate change on the water resource and what feasible adaptations should be taken to keep the economic and social developments from adverse effects. The present paper provides a review of potential impacts of climate change on water quality and ecosystem, mainly including the overview of international researches on this issue, our opinions are based on two case studies we have done before and the implications and adaptations of water resource management.

2 Perspective on climate change impact on water quality and ecosystem

The impacts of climate change on hydrology have been studied widely (Pfister et al. 2004; Middelkoop et al. 2001; Xia and Zhang 2005; Xia and Zhang 2008). However, the focus of past works has been on water quantity impacts (e.g., flooding and droughts) rather than on changes in water quality (Drago et al. 2005). Recently, also the potential impacts of climate change on surface water quality and ecosystem have been increasingly acknowledged (Murdoch et al. 2000, Whitehead et al. 2009). The IPCC Fourth Assessment Report (Kundzewicz et al. 2007) was beginning to consider the impacts of climate change on water quality although not in great detail. And the EU Euro-limpacs Project, a multi-partner, €20-million research project, is investigating the impacts on water quality and ecosystem of rivers, lakes and wetlands across Europe (Battarbee et al. 2008). Also in China, one project funded by the Ministry of Water Resources is to analyze the impacts of climate change on Chinese water resources, one topic of which is to investigate its impacts on water quality and ecosystem.

Results of previous studies have indicated that water quality can be directly affected through several climate-related mechanisms on both short and long term (Tu 2009; Park et al. 2009). These include impacts of air temperature increase, as well as changes in hydrological factors and others (Murdoch et al. 2000). The most immediate reaction to climate change is expected to be in river and lake water temperatures (Hammond and Pryce 2007). Due to river and lake water temperatures are in close equilibrium with air temperature, air temperature is a key variable affecting water temperature in most biological systems, strongly influencing water chemistry, biochemical reactions and growth/death of biota (Blenckner et al. 2007; Malmaeus et al. 2006). Tibby and Tillier (2007) analyzed over 15 years of water quality monitoring data from three lakes from Western Victoria, Australia, and their relationship to climate change. They found that there are strong relationships between climate change and water quality in these lakes of varied size and salinity.

The extreme events (floods and droughts), the frequency of which is predicted to increase, also modify water quality through direct impacts of dilution or concentration of dissolved substances. More intense rainfall and flooding could result in increased loads of suspended solids (Lane et al. 2007) and contaminant fluxes (Longfield and Macklin 1999) associated with soil erosion and fine sediment transport from the land (Leemans and Kleidon 2002). Lower minimum flows imply smaller volume for dilution and higher nutrients concentrations. Reduced dilution will increase organic pollutant concentrations, with increased biological oxygen demand (BOD), and hence lower dissolved oxygen (DO) concentrations in rivers (Prathumratana et al. 2008; Van and Zwolsman 2008). And drought – rewetting cycles may impact water quality as it enhances decomposition and flushing of organic matter into streams (Evans et al. 2005).

The impacts of climate change on water quality and ecosystem are getting more attention. However, there are still some problems need to be improved in the future. There is a lack of studies differentiating the impacts of climate change and human activities, and the impacts of climate change on water quality and ecosystem through changing water regimes are still unclear, and most adaptations proposed before are idealistic or impracticable.

3 Major challenge of climate change altering water quality and ecosystem in China

Due to huge population and booming economy, water resource is relatively scarce in China. The scarcity is aggravated by unequal spatial and temporal distribution. Recently, the deterioration of water quality and ecosystem has become increasingly prominent, it is mainly influenced by human activities. Changes in land use alter biological, physical, and chemical processes in watersheds and thus significantly affect the quality of adjacent surface waters. In addition, sewage linked to human activities can directly destroy water quality and ecosystem. Besides sewage, climate change can both mitigate and exacerbate the degradation of water quality and ecosystem.
Moreover, when point source pollution is reduced in China, climate change is expected to result in increasing impacts in the future. The Huai River Basin and Han River Basin are just such two cases where water quality and ecosystem are significantly impacted by both human activities and climate change.

3.1 The case study in Huai River Basin
Huai River is one of the seven largest rivers in China, which lies about mid-way between the Yellow River and the Yangtze River. Originating in the Tongbai Mountains in Henan Province, it flows through Henan, Anhui, Shandong and Jiangsu provinces and into the Hongze Lake in Jiangsu province. Due to sustained, rapid growth of industrial, agricultural and municipal pollutants, the rate of water quality deterioration of the River increased over the past 20 years (Hua et al. 2007).

Two representative stations along the Huai River, Bengbu Watergate (BW) and Luohu Rubber Dam (LRD), were chosen recently for one of our projects. The effect of climate change on water quality is given (Figs. 1 & 2). It is shown that water quality variation significantly correlated with precipitation at BW but was strongly affected by air temperature at LRD. The contribution rates of climate change (precipitation and air temperature) to water quality parameters were calculated and compared. The results suggested that 3.5% and 1.5% of water quality variation were caused by precipitation and air temperature changes, respectively, at BW, and 3.3% and 10.5%, respectively, at LRD. It is concluded that there was a significant impact of climate change on water quality sometimes, and a warming climate may influence water quality through increased water temperatures and modification of regional patterns of precipitation. However, climate change was not the main factor affecting water quality compared to pollution caused by human activities.

3.2 The case study in Han River Basin
Han River, the largest tributary of the Yangtze River, originates from Ningqiang County of Shaanxi province, and covers approximately 151,000 km² with a total length of 1577 km (Yang et al. 1997; Shen and Liu 1998). The rapid processes of urbanization and economic development brought about a swift deterioration of river water quality during the 1990s. The environmental capacity of the river is expected to decrease further and the water quality problem in the basin will be more prominent (Zhu et al. 2008).

Mechanisms and main factors causing algal bloom in Han River have been studied, based on monitoring data, collected information and investigation work. Reasons and key factors for the Han River’s water bloom are also analyzed by using the hydrodynamic model and dynamic model of eutrophication (Xie et al. 2004). The results showed that polluted drainage along the lower section of Han River is the predominate factor. Additionally, water
velocity is also an important factor affecting algal bloom. Han River is characterized by slow water flow like that in lakes when its water level gets lower than the Yangtze River. When the two factors happen coincidentally with higher temperature in spring, algae grow quickly. The result of this case study indicates that hydrological regime can be a key factor influencing water quality and ecosystem (Fig. 3). Climate change is expected to affect water quality and ecosystem through influencing hydrological regimes. Consequently, the transfer and transformation mechanisms of contaminants in aquatic systems go differently. As a result, these changes lead to alteration of water quality and ecosystem. Therefore, it is necessary and urgent to make clear the alteration of hydrological processes in response to climate change.

4 Implications and adaptations for water quality and ecosystem management

Even though it is a fact and inevitable that climate change can significantly alter water quality and ecosystem, it is still no doubt that human activities contribute much more than climate change. This implies that positive management can minimize some climate-change impacts on aquatic ecosystems. In order to deal with the climate changes that are taking place now and to prepare for those that are likely to happen in the future, a certain tool required is water quality and ecosystem management plan. This should contain all significant pressures and impact of human activities on the aquatic environment. Specific and practical management options should be chosen for different regions.

In order to avoid adverse impacts of climate change on aquatic ecosystems, two aspects (adaptation options and adaptability) should be taken into account simultaneously. Certainly the most important and well known method to protect aquatic ecosystems is to reduce contaminant levels. Therefore, it is vital that both point and nonpoint pollution sources should be restricted strongly. Adaptation options should also improve the ability to moderate, cope with and take advantage of the consequences of climate change. Moreover, because of uncertainty of future climate variability, management responses should be built in flexibility to ensure that current coping strategies are consistent with future climate change. Meanwhile, adaptability is also an increasing important work, which requires the environmental change monitoring and modeling, and strengthening basic research and practice. Management innovation is also necessary for better adaptability. In addition, relevant education and training can raise awareness and encourage more people to pay attention to this issue, which will greatly enhance the adaptability regarding about climate change.

5 Conclusion Remarks

It is well proved that water quality and ecosystem can be impacted significantly by climate change. However, scientific works on this important issue are very limited. More and deeper scientific researches and practices should be conducted in the near future.

Basing on the two case studies in China, it is concluded that the degradation of water quality and ecosystem is mainly influenced by human activities, and can be exacerbated by climate change. Climate change can affect water quality and ecosystem through not only working on water temperature but also altering hydrological regimes.

For further studies, long time continuous monitoring in different regions is still required to support basic data. More efforts should be taken to separate the impacts of climate change from human activities based on the data, although it is complicated. Meanwhile, to get a better understanding of the issue, it is suggested to give more information about the alteration mechanisms of hydrological regimes by climate change.

Finally, specific and practical adaptation options and positive ways to enhance adaptability should be proposed to decision-makers.

References


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气候变化对水质与水生态系统的潜在影响与挑战:以中国典型河流为例

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摘要：气候变化对水质与水生态的潜在影响已经成为当前必须面对的新问题和新挑战，这也引起了世界各国科学家和政府的高度关注。但是，由于它的复杂性和不确定性，目前针对该问题的科学研究和科学实践仍然十分有限。本文首先回顾了近年来国内外相关研究成果，并指出了研究现状与实际需求之间的差距。另外，基于作者在淮河和汉江的相关研究成果，我们认为，人类活动和经济发展带来的污染是造成水质与水生态恶化的最重要的原因，同时，气候变化在此基础上具有推波助澜的增益作用，气候变化主要通过改变水温和水文情势从而影响水质和水生系统。本文最后讨论了适应性对策的内涵，认为适应性对策应该包括适应方式和适应能力建设两个主要方面，适应性对策应该尽可能地具有针对性和可操作性。本文对今后的相关研究可起澄清概念和指明方向的作用。

关键词：气候变化;潜在影响;水质;水生态