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# Assessing water quality of five typical reservoirs in lower reaches of Yellow River, China: Using a water quality index method

Wei Hou, Shaohua Sun, Mingquan Wang, Xiang Li, Nuo Zhang, Xiaodong Xin, Li Sun, Wei Li, Ruibao Jia*

*Urban Water Monitoring Center of Shandong Province, Shandong Province 250021, China*

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ABSTRACT

To assess water quality of reservoirs in lower reaches of Yellow River using the water quality index (WQI) method and try to compare water quality and main contaminations of mountain and Yellow River reservoirs, water samples were carried out over 6 years. Nine water variables were selected to participate WQI calculation by Principal Component Analysis (PCA). WQI values ranged from 17.8 to 77.8 in five reservoirs, which indicated "good" to "very poor" water quality of reservoirs. No significant differences in WQIs were found between mountain and Yellow River reservoirs. A major finding from our study is that mercury was the main contamination in 5 reservoirs, while TP (total phosphorus) and $SO_4$ were another main contaminations in mountain and Yellow River reservoirs, respectively. Application of the WQI is suggested to be a helpful tool that enables the public and decision makers to evaluate water quality of drinking reservoirs in lower reaches of Yellow River.



## 1. Introduction

Yellow River is one of most seriously affected rivers by human activities and has the largest sediment concentration in world rivers (Wang et al., 2007). Urban and agricultural areas are widespread in the basin, and many non-point and point source pollutants input into the river (Hao et al., 2004; Xing et al., 2005). Total discharge of wastewater in Yellow River was as high as $4.474 \times 10^9$ t in 2012, including $2.803 \times 10^9$ t industrial wastewater and domestic wastewater of $1.671 \times 10^9$ t (Yellow River Conservancy Commission of the Ministry Water Resources, 2012). Jinan City, located in the lower reaches of Yellow River (Fig. 1), is an important city receiving water from east route of the South to North Water Transfer (SNWT) Project. Reservoirs in Jinan City are composed of Yellow River reservoirs and mountain reservoirs. Water in mountain reservoirs is contributed by rainfall and runoff. While Yellow River water – pre-precipitated by grit removal tanks before pumped into reservoirs – is the only water source of Yellow River reservoirs. Reservoirs water as the main source of drinking and industrial water plays an important role in urban water systems, accounting for 90% of total urban water supply. In the past 20 years, vegetable planting bases and recreation facilities have developed, and these reservoirs have faced many water quality problems, such as high nitrogen and phosphorus concentrations (Li et al., 2012), cyanobacteria blooms (Xu et al., 2012), dissolved oxygen deficit. Concentrations of major ions in much of the Yellow River basin, especially in downstream of the major irrigation areas, have increased significantly between 1960 and 2000 (Chen et al., 2003). Wang et al. (2006) found that water quality of water receiving lakes was better than that of rivers in the east route of SNWT Project, where water quality was influenced by point and non-point pollutions. Ni (1991) firstly reported the mesotrophic water body of Wohushan Reservoir during 1980s, one of mountain reservoirs in Jinan City. Previous works mostly focused on trophic state assessment for individual waterbody; however, few studies have paid attention to comprehensive water quality for multiple reservoirs in lower reaches of Yellow River. Furthermore, Jinan City located in temperate zone of North China, usually burn coal to keep indoor warm for four months a year, and vegetable bases have rapidly developed around mountain reservoirs in recent ten years. These non-point pollution sources may impact water quality of drinking reservoirs.

Water quality index (WQI) model developed in 1965 based National Sanitation Foundation (NSF) is a mathematical method, transforming large quantities of water quality data into a single number that represents general quality of surface water quality (Srebotnjak et al., 2012; Lumb et al., 2011). The WQI method has

* Corresponding author at: 68 Weiwu Road, Jinan City, Shandong Province, China. Tel.: +86 531 55589607; fax: +86 531 55589607.
*E-mail address:* jiaruibao1968@163.com (R. Jia).

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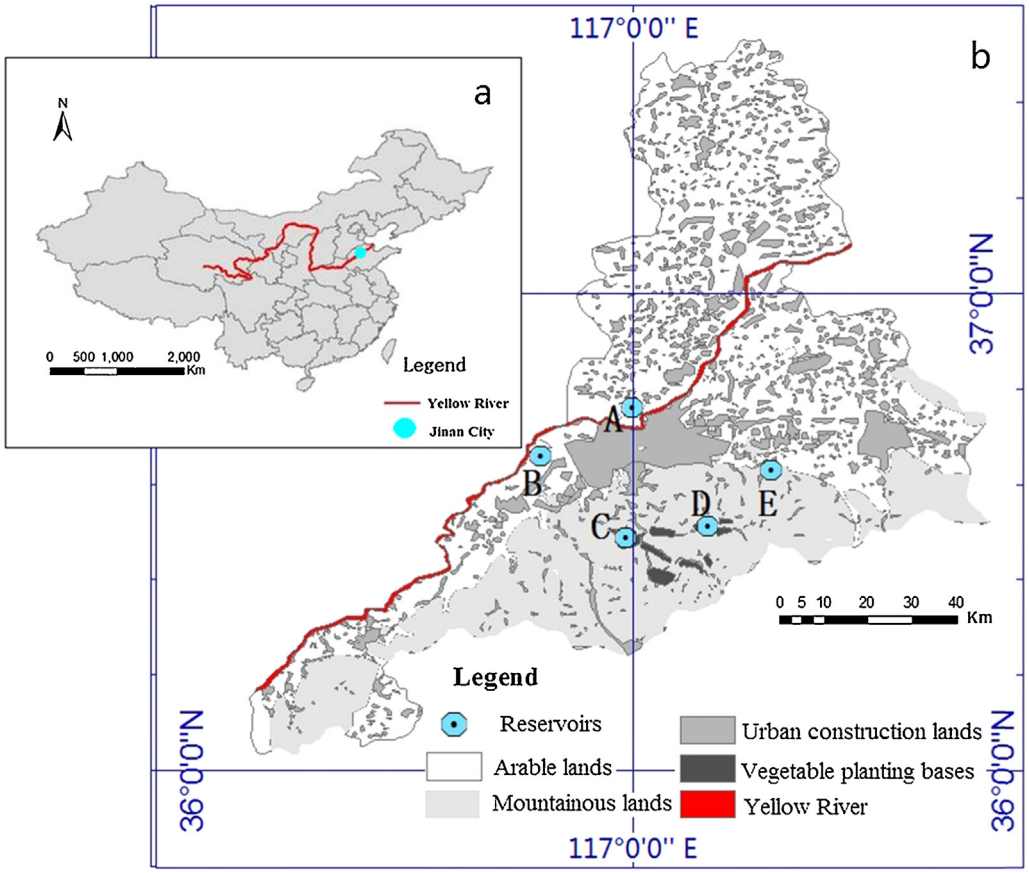


**Fig. 1.** Map of China (a) and land utilization in Jinan City showing the locations of five reservoirs and Yellow River (b). English letters represent the names of reservoirs. A: Yuqing; B: Queshan; C: Wohushan; D: Jinxiuchuan; E: Langmaoshan.

been widely applied to assess water quality in America (Chow-Fraser, 2006), China (Liu et al., 2012a,b), India (Kumar and Dua, 2010) and Spain (Bordalo et al., 2006). The comprehensive pollution index was firstly proposed in 1974 in China. Sánchez et al. (2007) reported a classification from "good" to "medium" quality in Pairs Park in the Municipality of Las Rozas in Spain by using WQI method. Simões et al. (2008) also found the degradation in Macuco and Queixada Rivers from aquaculture activity can be easily inferred with WQI. Li and Zhang (2008) found that Danjiangkou Reservoir, water source area of the Middle Route of SNWT Project, had been heavily polluted by heavy metals (mercury and selenium) assessed by WQI method.

In this study, we selected three mountain reservoirs and two Yellow River reservoirs to use WQI as indicators of the water quality of drinking reservoirs in coal-burning and agricultural watersheds, and compare main contaminations and water quality in mountain reservoirs with that in Yellow River reservoirs, as a particular case in lower reaches of Yellow River. The monitoring data over 6 years could also help to compare water quality of water sources for human consumption before and after completion of east route of SNWT Project in future.

## 2. Methods and materials

### 2.1. Background and study sites

Jinan City with a total population of 6,810,000 inhabitants is the capital of Shandong Province where reservoirs are composed of Yellow River and mountain reservoirs. Mountain and Yellow River reservoirs supplied 10% and 80% of total urban water, respectively. These reservoirs possess different basin features and human activities, which affects nutrient loading and pollution sources that define reservoirs' water quality. Catchments of Yellow River reservoirs are mainly occupied by cities and towns and agricultural farming, with much nutrient and pollutants input into reservoirs. While vegetable planting bases, recreation and entertainment settings (e.g. sports stadia, wildlife park, restaurant business, hotels) distributed in catchments of mountain reservoirs. Three mountain reservoirs (Langmaoshan, Wohushan and Jinxiuchuan Reservoir) and two Yellow River reservoirs (Yuqing and Queshan Reservoir) were selected for this study (Fig. 1). The five reservoirs are located in temperate zone in Northern China, and constructed between 1958 and 2000, spanning a large catchment area gradient. Wohushan Reservoir has the largest capacity; the others are medium scale reservoirs (Table 1). All of reservoirs served multiple purpose-water supplies for drinking, agriculture, industry and fish farming, which could stand for most of reservoirs water quality in lower reaches of Yellow River. Yuqing Reservoir is an important water receiving reservoir of east route of SNWT Project that is the largest project over centuries to solve water shortage problem in vast areas of northern China.

### 2.2. Field sampling

Sample collection, stabilization, and transportation to laboratory as well as storage were conducted according to the recommendations of Chinese National Standard Methods (Jin and Tu, 1990). All water samples were taken at 0.5 m below the surface from three pelagic sites in each reservoir on three occasions over 6 years (2007–2012), covering four seasons. Water temperature,

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