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# PROGRESS IN RESEARCH ON RIVER WATER CHEMISTRY IN CHINA

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**ABSTRACT:** River water resource is the most important component of water resources in China. This paper reviews the progress in the research on river water chemistry in China. It includes three parts: 1) the development of river water quality monitoring in China (at present, there exist three water quality monitoring networks in China: near 3000 water quality monitoring stations under the Ministry of Water Resources, several thousands water quality monitoring sites under the State Environmental Protection Administration and four sites under the China's GEMS/Water Program); 2) progress in the research on chemical characteristics of river water chemistry in China and their geographical roles on nation-wide and region-wide scales; and 3) progress in the research on river quality changes in the last 40 years (the long-term monitoring data reveals that the water quality of the Changjiang River has acidification trend, the Songhuajiang River had alkalization trend, and the Huanghe River has concentration trend in the last 4 decades).

**KEY WORDS:** China's; river; water chemistry; water quality change

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River water resource is the most important component of water resources in China. Comprehensive and specific researches on river water chemistry in China have been carried out since the 1950s. The objective of this paper is to review the progress in the research on river water chemistry in China, especially on river water chemistry geography and water quality change in the last forty years.

## 1 THE DEVELOPMENT OF RIVER WATER QUALITY MONITORING IN CHINA

Water quality monitoring record is the basis of the research on river water-chemical characteristics and river water quality changes. The water quality monitoring of rivers started in about 1890 on a few European rivers such as the Thames and the Seine. The descriptions of water quality were very simple at that time: dissovlved oxygen, pH and faecal coliforms. Following the rapidly expanded uses and the related descriptors of water quality and pollution, the type and number of descriptors has exponentially increased during the last one hundred years. Development and increasing sophistication of water quality monitoring program occurred not only in response to newly emerging pollution issues, but also due to continuous improvement of analytical methods. As a result, the official list of desriptors of water quality exceeds 100 items in the European Economic Community or the U. S. Environmental Protection Agency. The global freshwater quality monitoring project, in short GEMS/WATER, launched in 1976 by four

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United Nations agencies —UPEP, WHO, UNESCO and WMO —is a long term project. One of its aims is to assess the quality of rivers, lakes and groundwaters on a global scale (GEMS, 1983, 1988) based upon the monitoring data from voluntary contributions of 59 countries (including China's mainland) from all continents except parts of Africa and Eastern Europe.

Water quality monitoring of rivers in China started at the end of the 1950s, but it has been developing quickly. At present, there exist three water-quality monitoring networks.

1) The water quality monitoring network under the China's Ministry of Water Resources. More than 900 national water quality monitoring stations over 500 rivers were established in 1956. The monitoring items included the main physical properties, gases, ions and nutritious elements of river water, and common pollutants were added to the monitoring items after the 1970s. The network was renewed in 1986. At present, total 2799 monitoring stations are put into use covering all the main rivers and lakes in China. Combined with the hydrometric stations, 65 percent of the water quality monitoring stations can monitor the water quality and hydrological parameters synchronously.

2) Water quality monitoring network under the State Environmental Protection Administration. More than 300 stations were established over 6 major rivers in 1979, monitoring 17 water quality parameters which reflect the trends of water pollution. Monitoring stations have been greatly increasing in recent years.

3) China's GEMS/WATER Program monitoring stations. Four monitoring stations (Wuhan Changjiang, Jinan Huanghe, Zhaoqing Xijiang and Wuxi Taihu) have been established since 1979. More than 40 water quality parameters have been monitored in accordance with the demands and regulations of the GEMS/WATER Program.

China's perfected river water quality monitoring networks are beneficial to the research on river water chemistry and river water quality change.

## 2 RESEARCH ON WATER CHEMISTRY OF CHINESE RIVERS

### 2.1 The Research on Nation-wide Scale

In the early 1960s, YUE Jia-xiang and WANG De-chun analyzed the water quality data of over 900 stations in 500 rivers from 1957 to 1960, conducting the research on spatial variation of hydro-chemistry of Chinese rivers for the first time. They compiled and drew *The Map of Water-Chemistry of Chinese Rivers* and *Map of Total Hardness of Chinese Rivers* (YUE *et al.*, 1963). In the early 1970s, LIU Pei-tong, WANG Hua-dong and XUE Ji-yu compiled *The Map of Total Dissolved Solids in Chinese Rivers* and *The Map of Chemical Flow Modulus of Chinese Rivers* based on water chemistry data of over 700 stations in whole China.

There was very little information available in the western literature on the chemical composition of the major rivers of China. Since they include the largest in terms of sediment transport (the Huanghe (Yellow) River), the third largest in terms of flow (the Changjiang (Yangtze) River) and major streams draining the Xizang Plateau, this lack of data represents a significant gap in the knowledge of the chemical denudation rates of the continents as a whole and of South, Central and East Asia in particular. To begin to rectify this situation, HU Ming-hui, R. F. STALLARD & J. M. EDMOND collected suitable samples from major Chinese rivers for analysis. It was found that the chemistry of such rivers in China is dominated by the weathering of carbonates and evaporites, with no pronounced effects of the degradation of aluminosilicates (HU *et al.*, 1982).

In the middle 1980s, based on the water chemistry data of 30 major Chinese rivers, XU Yue-xian estimated the chemical flow of Chinese rivers and the discharge of each major ion into different China's seas. In addition, he calculated chemical flow and its modulus of each major river, probing into the temporal and spatial variation features of chemical flow of major rivers and analyzing its causes (XU, 1984). In the same period, CHEN Jing-sheng and LI Yuan-hui studied the physical and chemical denudation rates of the river drainage areas in China and their spatial trends based on the water chemistry data of 90 hydrometric stations in the mainland and over 30 hydrometric stations in Taiwan Island (CHEN *et al.*, 1984).

In the book "*Evaluation of Chinese Water Resources*" edited by China Ministry of Water Resources, the spatial trends of total dissolved solids, total hardness, and water chemistry type of the Chinese rivers were systematically studied and the seasonal and yearly variation of water chemistry and chemical flows of the Chinese major rivers were discussed (CMWR 1987).

In the early 1990s, ZHANG Li-cheng and DONG Wen-jiang (1990) studied the neutralization capacity of river water in China for acid and alkalinity, and pointed out that the neutralization capacity of river water for acid is bigger than that for alkalinity. They discussed the geo-chemical factors controlling the neutralization capacity of river water and its spatial variation. If the total dissolved solid of river water is relatively high (> 200– 500 mg/L), the total hardness is high (8°– 16°), the neutralization capacity for acidity is also high (1.0 meq/L) and the neutralization capacity for alkalinity is correspondingly relatively low (< 0.1 meq/L).

XU Jong-xin (1994) studied the chemical denudation rates of river drainage area in the different natural zones according to the water quality data from 70 representative hydrometric stations over the 7 Chinese major river systems including the Songhua, Liaohe, Haihe, Huanghe, Huaihe, Changjiang and Zhujiang rivers. They found that the chemical denudation modulus is the highest in the subtropical and tropical zones in central and southern China; the lowest chemical denudation modulus is in the semi-arid regions of warm Temperate Zone in northern China.

In most recent years, CHEN Jing-sheng, XIA Xing-hui and ZHANG Li-tian (1998) once again studied the water chemistry of the Chinese four largest rivers including the Changjiang, Huanghe, Songhua and Zhujiang (peat) based on the long-term data since the late 1950s to 1990 with statistical methods and GIS techniques, revealing that: 1) the total ion contents of the main streams of these rivers are higher than the average of the world rivers; 2) the water chemistry of these river systems is controlled by the rock type in the river basin; 3) the total ion contents of each river system are negatively correlated with regional rainfall and positively correlated with regional aridity.

## 2.2 The Research on Regional Scale

In the beginning of the 1960s, LIU Pei-tong and WANG Hua-dong (1965) conducted a research on water chemistry of the rain water, river water, lake water and groundwater of Daihai Basin. ZHU Qi-jiang and WANG Jia-xin (1963) carried out a comparative research of water chemistry between Hutuo River and Fuyang River in North China. In the 1970s, ZHANG Shen and YU Wei-xin analyzed the water chemistry of Mount Qomolangma area. In the early 1980s, ZHU Yan-ming (1981) conducted a research on river water chemical characteristics and its causes of Tianchi Lake in the Changbai Mountain, northeast China, discovering that the water chemistry of Tianchi Lake is dominated by $HCO_3^- - Na^+$ with low total dissolved solid, which is different from other lakes. No significant horizontal variation of water chemistry is found while the contents of most ions increase with the increase of depth. In the middle 1980s, LIU Ya-chuan (1986) probed into the water chemistry of rain water, surface water and groundwater of the Shiyang River Basin of Hexi Corridor in Gansu Province, and pointed out that the total dissolved solid in water bodies increases along with the reduction of latitude. GUO Chang-lin (1987) analyzed the water chemistry of the Huanghe River based on the water quality data from 69 stations. The main results obtained are as follows. 1) The dominant ions of the water chemistry are different from on place to another, and the content of total disolved solid is in a very large range (200 – 5000 mg/L). The water chemistry type depends on the total dissolved solid, and the water chemistry type is dominated by chloride or sulphate if the total dissolved solid is high while the water chemistry type is dominated by carbonate if the total dissolved solid is low. 2) The total dissolved solid is about 400 mg/L in the upper and lower reaches of the Huanghe River. 3) The hydro chemical characteristics of the middle reaches show zonality, which is in accordance with the distribution trend of physical geographical conditions.

LI Jing-bao (1988, 1989) studied water chemistry of the Xiangjiang River Basin and chemical flow, as well as the chemical denudation of Dongting Lake catchment. In the 1990s, based on water sample collection and analy from the Hainan Island, CHEN Jing-sheng *et al*. (1991, 1992) studied the following three aspects: 1) the chemical components of the river water in different regions of the Hainan Island, and the establishment of quantity model for determining the rock weathering source and rain source of major ions in the river water; 2) the distribution of stable isotopes of oxygen and hydrogen in the river water as well as its latitude effect, heighe effect and mountain mass shield effect; 3) the difference of river hydro-chemistry between the Hainan Island and Taiwan Island as well as Hawaiian and its controlling factors.

## 3 RESEARCH ON RIVER WATER QUALITY CHANGES DURING THE LATE 40 YEARS

The water quality change mentioned here neither to the seasonal fluctuation of the contents of major ions, nor refers to the random change of some water quality parameters caused by water pollutants, but refers to the water quality change with a trend in a large area or a large river basin resulting from the lasting influences by human activities under a certain social-economic level. The research on water quality change of a large area or a large river basin is an important aspect of the glboal change research. According to GERT Knutsson's idea (1994), a long-term monitoring data as least 15 years must be needed for this kind of research so as to distinguish the influences by human activities from the natural fluctuation of water quality.

The research on river wter quality change began at the end of the 1970s in China. According to HSU Yuin-piau's research (1978), the conductance rate of many rivers greatly increased from the beginning of the 1960s to the middle 1970s because of the influence of human activities such as the discharge of irrigation water from farmland, industrial waste water and municipal waste water discharge. For example, the conductivity of the Jilong River increased from 150– 300 micro-mhos/cm in 1962– 1963 to 330– 890 micro-mhos/cm in 1975– 1976. HAN Qing revealed (1980) that the distinct increase of the total dissolved solid of the Tarim River was mainly caused by the influence of large quantity of irrigation water and the increase of evaporation resulted from the construction of reservoirs. WANG Ming-yuan and ZHANG Shen (1990) reported that the nitrogen content of the Changjiang River at the Datong station increased from the end of 1950's to the middle of 1980's, and the increase of the nitrogen discharge was closely related to the increase of the nitrogen fertilizer application in the basin.

The Institute of Environmental Hygiene, The Chinese Academy of Preventive Medicine (1990) was responsible for the first stage plan of GEMS/WATER in China. CHEN Chang-jie studied water quality changes of the Changjiang, Huanghe and Zhujiang rivers and Taihui Lake based on the monthly monitoring data from 1980 to 1989, discovering that the water quality changes of these four waters systems showed the following trends. 1) The conductivity of the four stations all had increasing trends, and the Huanghe River was especially distinct. 2) The chloride contents in the Changjiang and Huanghe rivers and Taihu Lake all had increasing trend. 3) The contents of $Na^{+}$ and $Cl^{-}$ in the Huanghe River increased year after year, and they are interrelated. 4) The nitrogen content of the four studied water bodies all had distinct increasing trend.

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China's Ministry of Water Resource have conducted a research on the trend of contents and fluxes of several water quality parameters (such as COD, $NH_3-N$, $NO_2-N$, $NO_3-N$, volatile phenol and total hardness) in 140 rivers of the Chinese nine large river system based on the monitoring data from 1986 to 1991, indicating that COD had clear increasing trend in these five years (CMWR, 1995).

CHEN Jing-sheng and XIA Xing-hui have collected the water quality data of the Changjiang, Huanghe and Songhua rivers from the Water Year Book published from the end of the 1950s to the middle 1980s. According to statistical analysis of the major ion contents, they have found that the water quality of the Changjiang River had acidification trend, the Songhua River had alkalization trend and the Huanghe River had concentration trend (CHEN *et al.*, 1998a, 1998b, 1998c, XIA *et al.*, 1999).

Among the 50 stations with the duration of the time series no less than 15 years in the upper and middle reaches of the Changjiang River system, total of 40 stations (80%) showed the identical water quality trend from 1958 to 1985: the contents of $SO_4^{2-}$ and $Ca^{2+}$ increased, and the content of $HCO_3^-$ decreased in some stations (pH value decreased in very few stations), consequently, the ratios of total hardness to total alkalinity increased. The main cause of the acidification trend were serious acid deposition resulted from the increasing sulfur emission from coal combustion and the oxidation process of nitrogen fertilizer run off from farmland in the area. Th increased acidity of the precipitation intensified the corrosion of carbonate mineral in the limestone and the carbonate-contained rocks widely distributed in the basin, leading to the above mentioned water quality trend.

Among the 24 sations with the duration of the time series no less than 15 years in the main stream and the tributary (Nenjiang River) of the Songhua River system, total of 16 stations (67%) showed the same water quality trend from 1958 to 1985: the alkalinity ($HCO_3^-$) and $Na^+$ content increased, and pH value increased in some stations, as a result, the ratio of total hardness to total alkalinity decreased. The water quality trend was related to the quick development of papermaking in Heilongjiang Province and the application of groundwater dominated by $HCO_3^- - Na^+$ to farmland irrigation.

Among the 36 stations with the duration of the time series no less than 15 years in the middle reaches of the Huanghe River system, total of 26 stations (72%) showed the same water quality trend from 1958 to 1985: the contents of all the major ions increased somewhat, and the ratios between ions showed no distinct change. The water quality trend was related to the decrease of the natural runoff and the increase of irrigation water to farmland in the area.

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