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## Bibliometric Analysis of Research on the Water and Sediment Environment in the Middle Lower Changjiang River Basin

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# Bibliometric Analysis of Research on the Water and Sediment Environment in the Middle & Lower Changjiang River Basin

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**Abstract.** To elucidate research progress, hotspots, and trends regarding the water and sediment environment in the Changjiang River Basin, a bibliometric analysis of research published on the water and sediment in the middle-lower reaches of the Changjiang River, from 1991 to 2020, was conducted, according to the Web of Science Core database. With regard to the number of papers, distribution of research institutions, tracking of research hotspots, related disciplines, highly cited literature, etc., a comprehensive statistical analysis was conducted to investigate the research characteristics, research status, and development trends of the water & sediment environment in the middle-lower section of the Changjiang River. Combined with the latest trends in water and sediment environment research, important future research directions were investigated. The results indicated that, among the literature, the Chinese Academy of Sciences(CAS) was the largest contributor to study on the water and sediment environment of the Changjiang River, followed by universities along the Changjiang River. Chinese scientific research institutes paid the most attention to changes in the water and sediment environment of the Changjiang River and cooperated on an international level with other countries. From the perspective of discipline distribution, the number of papers on ecological environment was the highest, followed by that on geological environment, water resources, engineering, and oceanography. The amount of research conducted on water and sediment transport, riverbed change, water pollution, and other issues was relatively high. According to the highly cited literature, water contamination and sediment were the main concerns. Combined with high-frequency keywords — and by consulting the relevant literature — this paper presented the hot spots of the water and sediment environment in the middle-lower reaches of the Changjiang River. It is determined that the implementation of water conservancy projects in the upper reaches of the Changjiang River has changed the path, release mechanism, and role of phosphorus, as well as the ecological environment of the Changjiang River Basin and its estuary. Change of phosphorus flux and its effect on environment are one of the most important directions for future water and sediment environment research.

**Keywords:** bibliometric; Changjiang River; Web of Science; water and sediment environment; phosphorus flux



## 1. Introduction

The Changjiang River Basin is an important cultural birthplace of the Chinese nation, a "golden waterway" that crosses southwest, central and east China, and an important support point for the improvement of ecology and environment in the north [1]. Faced with the new era of the Changjiang River Basin (i.e., implementing a major protection strategy and requirements of the high-quality development of the Changjiang River Economic Zone), recent research on the Changjiang River has increased in China and other countries and the results have been fruitful. The literature metrics analysis is based on the existing literature and, through analysis of the number of articles published in related disciplines — including structural distribution, quantitative relationships, change rules, etc. — to accurately understand research progress in a certain field in different periods and to quantitatively, objectively, and comprehensively evaluate and predict the developmental trend of the discipline. As it can reveal the development pattern of the discipline in question from many aspects, bibliometrics is highly recommended by researchers and has been applied in many disciplines. According to Qiu, measuring the quantity and quality of research outputs has a guiding effect on research, to some extent [2]. To objectively evaluate research institutions and understand the research trends in a certain field, Tang [3] constructed the method of depicting research institutions through bibliometric methods.

To understand the current status and development trend of sediment and water environment research in the middle & lower reaches of the Changjiang River Basin over past 30 years, in this paper, bibliometric analysis was used to reveal the history, hotspots, and development trends of sediment and water environment research from the perspective of scientific literature output, which will provide some reference for future related research.

## 2. Methods

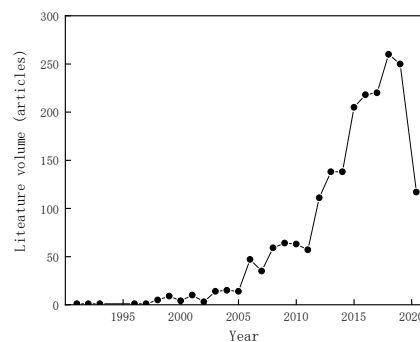
How to objectively reflect the content and results of scientific research and scientifically evaluate the level and efficiency of scientific research is a challenge that countries around the world are committed to solving [4]. The number of publications and citation frequency play an extremely important role in revealing the level of disciplinary or professional research, objectively reflecting the value of the literature and grade of the journal, and evaluating individuals' academic achievements, etc.; these are the criteria for evaluating the scientific and technological influences of countries, institutions, and individuals [5–6]. In this paper, the Web of Science Core Collection was chosen as the database and bibliometric theories and methods were applied to search for keywords with strong correlations to be used as the subject terms, such as sediment, water environment, and middle-lower reaches of the Changjiang River, with the search period of 1991 – 2020 and data retrieval time of April 30, 2020. Based on the search results, after data merging, deduplication, and other data cleaning processes, index comparison analysis was conducted and 2061 pieces of literature were obtained as the research objects. Among them, 1865 were journal articles, accounting for 90.49 %, and 196 were in other forms — such as conference proceedings or reviews — accounting for 9.51 %. The research contents include publication years, main publication countries/regions, research institutions, journal distribution, current research hotspots, etc., to understand the current research status of the sediment and water environment, other countries/regions, and to reveal the distribution and developmental trend of papers in related research fields, from 1991 to 2020.

## 3. Results and Analysis

### 3.1. Characteristics of Changes in the Number of Published Articles in the Time Dimension

The trend of article publication from 1991 to 2020 is shown in figure 1. According to Price's "four-stage theory" of literature growth [7], with reference to the data in figure 1, the literature on water and sediment environment research is divided into three stages of development, i.e., the budding stage of research in the 1990s, the growth and development stage in the early 2000s, and the rapid (mature) development stage in recent years, since 2012. From 2 articles in 1991 to 4 articles in 2000, which belonged to the budding stage of water and sediment environment research, with the

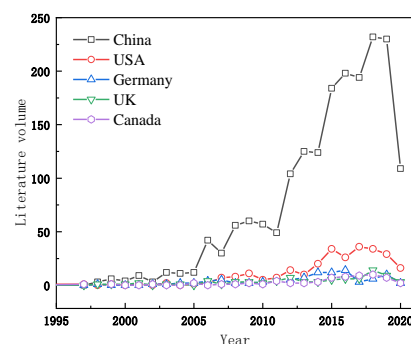
fluctuations in literature volume in 1999 caused by the extreme floods in 1998; from 10 articles in 2001 to 57 articles in 2011, which belonged to the growth and development stage of water and sediment environment research; from 111 articles in 2012 to 117 articles in 2020, which belonged to the rapid development stage of water & sediment environment research, in which the 2020 statistics are updated to April and are expected to reach 250 – 300 articles by the end of 2020.



**Figure 1.** Number of research papers on water & sediment environment from 1991 to 2020.

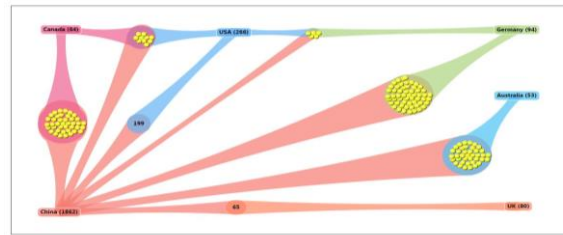
### 3.2. Distribution of the Number of Articles by Country

The top five countries with respect to the number of articles retrieved were analyzed (figure 2). Figure 2 shows that China published the most, with 1862 articles published in related fields, followed by the USA, Germany, UK, and Canada, with 266, 94, 80, and 64 articles published in related fields, respectively. The trend of figure 2 is approximately consistent with the overall trend of figure 1, indicating that Chinese scholars have paid attention to the water&sediment environment in recent years and that, except for the United States, where there have been slight changes in recent years, the attention of other countries to the water&sediment environment in the middle-lower reaches of the Changjiang River has not significantly changed in the past 30 years.



**Figure 2.** Top five countries regarding the number of articles.

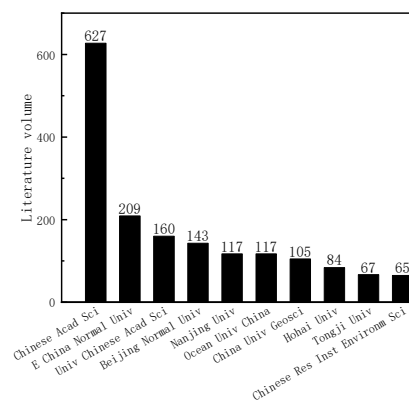
The results of analyzing the relationship between countries with more than five collaborative publications are shown in figure 3. The results show that the other five countries have mainly collaborated with China and, even though the United States has collaborated with Canada and Germany in collaborative publications, there have still been Chinese scholars involved in the study of the Changjiang River Basin, which is dominated by China.



**Figure 3.** Analysis of cooperation between countries.

### 3.3. Number of Articles Published by Different Research Institutions

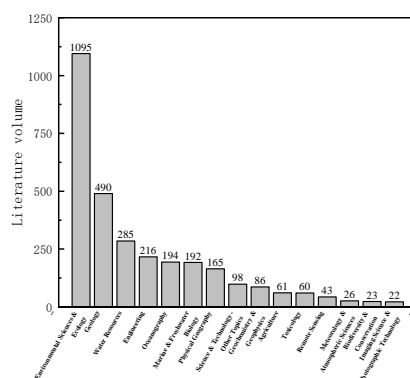
The search of major institutions is a method of conducting an academic evaluation that can reflect the research level of the entire research team. Figure 4 lists the top 10 research institutions in the study of water and sediment environment in the middle & lower reaches of the Changjiang River Basin, all of which are Chinese institutions. The Chinese Academy of Sciences (CAS) is the largest contributor to the research, with 627 publications, followed by the East China Normal University, with 209 publications, and the University of Chinese Academy of Sciences, Beijing Normal University, Nanjing University and Ocean University of China, with 160, 143, 117, and 117 publications, respectively. This is due to the "geographical advantage" of the colleges and universities along the Changjiang River and the CAS distributed in the provinces and cities of the Changjiang River Basin, which have done a lot of work on the economic development, rational use of water and sediment resources, and ecological environment construction of the Changjiang River Basin. It is also closely related to the fact that Beijing and Shanghai are the cultural, scientific, and educational centers of the country, with a large number of colleges and universities and scientific research institutions with strong scientific research strength. This shows that the colleges and universities along the river and the CAS are the main institutions involved in research in China.



**Figure 4.** Top 10 research institutions by the number of articles.

### 3.4. Distribution of Different Disciplines

Figure 5 lists the statistical results of the top 15 disciplines in the Changjiang River Basin in terms of the number of published research papers on the water and sediment environment. The results show that the discipline of ecology and environment ranks first, with 1095 papers published, accounting for 53.13 % of the retrieved papers, and the disciplines ranked second to fifth are geology, water resources, engineering, and oceanography, accounting for 23.78 %, 13.83 %, 10.48 %, and 9.41 % respectively. The comparison shows that current research on the water&sediment environment is mainly focused on water ecology, water and sediment movement, riverbed evolution, and waterway remediation.



**Figure 5.** Statistics of papers published by disciplines.

### 3.5. Hotspot Keyword Analysis

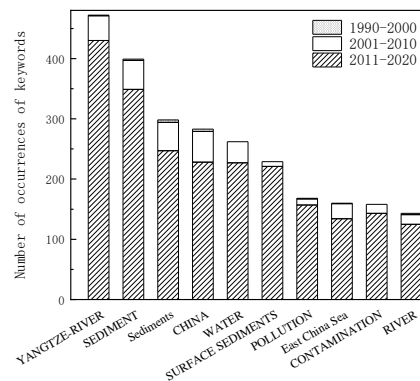
Keywords are a high-level summary of the main content, usage methods, and research objects of the literature. Through a statistical analysis of the keywords, the focus and hotspots of a certain field of research can be determined and the keywords that appear frequently in a certain period may be the hotspots, development trends, or key research areas of the discipline. In this paper, the keywords retrieved from the literature are divided into three stages according to time (1990 – 2000, 2001 – 2010, and 2011 – 2020) and the top 10 keywords appearing frequently are shown in figure 6. It can be concluded that.

(1) "SEDIMENT" has ranked first in the past 30 years, indicating that there have been a lot of new changes in water and sediment research and the attention to water and sediment problems in the region of the Changjiang River has increased rather than decreased. Moreover, heavy rainfall in the summer of 2020 in the entire basin of the Changjiang River caused the outbreak of large-scale floods; hence, water&sediment studies of the Changjiang River will receive more attention in the future.

(2) "POLLUTION" and "CONTAMINATION," which ranked fourth and fifth, were not of high interest in 2001 – 2010 but the appearance of such keywords increased sharply in the following decade, indicating that the issue of pollution in the region has received a great deal of attention from scholars.

(3) The third-ranked term "SURFACE SEDIMENTS" was at the bottom of the top ten rankings of keywords from 1991 to 2010 and its frequency increased sharply after 2011, reflecting the hotspot related to the coupling of sedimentary rocks and silt with the water&sediment environment in this basin.

(4) "Water," which was second most common, had not appeared before 2000 but has been growing steadily since 2001. Combined with the sub-keywords "NITROGEN," "PHOSPHORUS," "ORGANIC-MATTER," and "HEAVY-METALS," it can be seen that, in addition to sediment problems, nitrogen, phosphorus, organic matter, heavy metals, etc., have also gradually been gaining more attention.



**Figure 6.** Statistical results of the top 10 keywords frequency.

### 3.6. Analysis of Highly Cited Literature

Highly cited literature usually reflects the latest scientific discoveries and research progress in the related fields and is a bellwether for the frontiers of scientific research, which often has a wide and far-reaching academic impact in the long term. Table 1 presents the top 10 cited papers from 1991 to 2020 concerning water and sediment environment research in China. The top 10 hot papers have been cited more than 300 times. Two papers related to water and sediments ranked second and sixth, published in 2007 and 2006, respectively, and two studies on trace heavy metal pollution in sediments in the Changjiang River ranked first and fourth, published in 2011 and 2012, respectively, indicating that the issue of water and sediments has continued receiving attention from the academic community while the water environment pollution of the Changjiang River has only attracted the attention of scholars in recent years. The increasing number of research results is consistent with previous analyses on the frequency of keyword occurrences.

**Table 1.** Top 10 highly cited papers.

| Serial No. | First author | Title  | Publications                     | Total number of citations | Year of publication |
|------------|--------------|--|----------------------------------|---------------------------|---------------------|
| 1          | Yi, Yujun    | Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River Basin | ENVIRONMENTAL POLLUTION          | 583                       | 2011                |
| 2          | Liu, J. P.   | Flux and fate of Yangtze River sediment delivered to the East China Sea  | GEOMORPHOLOGY                    | 521                       | 2007                |
| 3          | Wang, Houjie | Stepwise decreases of the Huanghe (Yellow River) sediment load (1950-2005): Impacts of climate change and human activities   | GLOBAL AND PLANETARY CHANGE      | 409                       | 2007                |
| 4          | Pan, Ke      | Trace metal contamination in estuarine and coastal environments in China   | SCIENCE OF THE TOTAL ENVIRONMENT | 403                       | 2012                |

|    |                                |  |  |     |      |
|----|--------------------------------|--|--|-----|------|
| 5  | Cai, Wei-Jun                   | Estuarine and Coastal Ocean Carbon Paradox: CO <sub>2</sub> Sinks or Sites of Terrestrial Carbon Incineration?   | ANNUAL REVIEW OF MARINE SCIENCE, VOL 3   | 366 | 2011 |
| 6  | Liu, J. P.                     | Sedimentary features of the Yangtze River-derived along-shelf clinoform deposit in the East China Sea  | CONTINENTAL SHELF RESEARCH   | 317 | 2006 |
| 7  | Ip, Carman C. M.               | Trace metal distribution in sediments of the Pearl River Estuary and the surrounding coastal area, South China   | ENVIRONMENTAL POLLUTION  | 308 | 2007 |
| 8  | Bianchi, Thomas S.             | Large-river delta-front estuaries as natural recorders" of global environmental change   | Proceedings of the national awareness of the science of the United States of America | 293 | 2009 |
| 9  | Zhao, Shiye                    | Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observations on occurrence, distribution  | MARINE POLLUTION BULLETIN  | 239 | 2014 |
| 10 | Zareitalab ad, P.; Siemens, J. | Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) in surface waters, sediments, soils, and wastewater - A review on concentrations and distribution coefficients | CHEMOSPHERE  | 234 | 2013 |

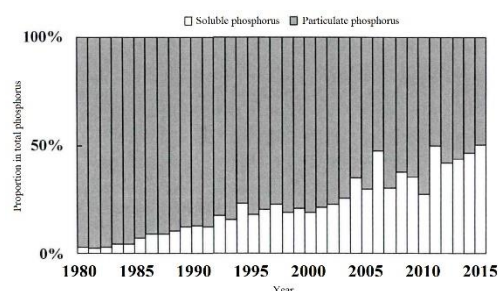
#### 4. Discussions

The Chinese government has taken great protection as the guidance for the Changjiang River economic belt and ecological environment restoration as the overriding task. From the above analysis, it can be seen that more and more attention has been given to problems concerning the water environment. Phosphorus, as an important biogenic element in the water environment, has good "particle adsorption properties" and an affinity with sediment particles. The construction and use of reservoirs in the upper reaches of the Changjiang River has significantly changed the process of water and sediment transport downstream, significantly altering the cycling path and action law of phosphorus in the river basin. Phosphorus, an important substance in water, has a significant impact on the ecology and water quality of the river basin. Particulate phosphorus is the major form of phosphorus in river water, suspended sediments are the main carrier of particulate phosphorus transport and the concentration of particulate phosphorus is greatly influenced by sediment concentration.

In an experiment on phosphate adsorption by sediments in the Three Gorges reservoir area, Yang [8] investigated the effects of sediment particle size, sediment concentration, and overlying water phosphorus concentration on sediment adsorption and desorption; the results demonstrated that sediment particle size is an important factor influencing phosphorus adsorption and that the smaller the sediment particle size, the larger the specific surface area and the stronger the adsorption capacity for phosphorus. Fine sediments with a particle size of less than 8  $\mu\text{m}$ , which are closely related to the transport of phosphorus and other pollutants, as well as the ecological environment, also decreased significantly, and the flux of such fine sediments from 2009 to 2016 was 94.8 % less than that before



1990 [9]. Chen [10] took the Yichang River section as an example, where the phosphorus flux in the Yichang River section increased before impounding and the phosphorus flux in the Yichang River section was greatly reduced after impounding. The transport flux of particulate phosphorus is mainly concentrated in the high-water period, accounting for more than 80 % of the annual transport flux [11]. The increase in dam storage capacity intercepts more and more suspended sediments, which significantly reduces the output flux of suspended solids (SS); the lower SS flux leads to an increase in dissolved phosphorus (DP) concentration, which is mainly due to an increase in the number of freely moving phosphorus ions in water, with relatively few particulates [12]. The above analysis indicates that the particulate phosphorus in the upper reaches of the Changjiang River is trapped in the reservoir and the flux of particulate phosphorus downstream has been greatly reduced after the reservoir started to operate (as shown in figure 7).



**Figure 7.** Proportion of particulate phosphorus output to total phosphorus output in soluble phosphorus river of Changjiang River from 1980 to 2015 [13].

From the phosphorus output pattern, the increase in precipitation and flow promoted the loss of phosphorus from soil and sediment and the flux of phosphorus output from river particles was positively correlated with precipitation and river flow — this was the main driving force of non-point source phosphorus pollution in the river basin — while the DP output was less driven by precipitation and flow and there was no correlation between the DP output flux and precipitation and flow; the impact on DP pollution in the Changjiang River was significant [13]. The background concentration of DP in flood season and non-flood season increased significantly, especially in non-flood seasons, due to reservoir siltation and sediment reduction. The elevated environmental background values of DP led to an underestimation of the environmental impact of water conservancy projects.

Under natural conditions, phosphorus flux in the Changjiang River Basin has little environmental impact on freshwater systems. However, when the particulate phosphorus enters the estuarine brackish water system, it displaces iron-bound phosphorus (BAP), etc., as seawater promotes iron transfer [14–15]. Upstream reservoirs significantly reduce the BAP supply to the estuary. In addition, since most of the nitrogen-containing substances are soluble in water, the upstream reservoirs have little influence on the nitrogen transport. As a result, nitrogen transport is constant while the phosphorus transport is reduced so the nitrogen-to-phosphorus ratio increases significantly. The changes in nutrient salt concentration and structure in the Changjiang estuary sea area also show the same pattern. The increase in the nitrogen-to-phosphorus ratio will lead to changes in the composition of dominant phytoplankton species, which may cause changes in the structure of the ecosystem in the Changjiang river and estuary. Therefore, we should focus on the changes in phosphorus flux and its effects.

## 5. Conclusion

In this paper, relevant literature from the ISI Web of Science Core Collection was used as a data source and the distribution of literature output year, keyword distribution, important research institutions, major countries and institutions, and highly cited literature were statistically analyzed using bibliometric methods. The following conclusions were obtained.

- (1) The literature output was very low before 2000 but has increased rapidly since 2002. On the one

hand, the attention of the academic community has increased owing to frequent floods in the basin and the impact of the Three Gorges Project, with huge investment from the government on the downstream. On the other hand, this was due to the increase in national investment in scientific research and the level of scientific research in China.

(2) Research on the water&sediment environmental issues of the Changjiang River Basin has received a lot of attention from scholars, with the CAS conducting the largest number of studies(627 articles), followed by colleges and universities along the Changjiang River, which have also paid great attention to research on the subject.

(3) From international cooperation, it can be seen that Chinese research institutes are most concerned about the environmental changes and they have abundant research contents and cooperation with other countries.

(4) Regarding the disciplinary distribution of water&sediment environment research, there were most articles in the ecological environment, followed by the geological environment, water resources, engineering, and oceanography, with relatively high attention to water and sediment transport, riverbed changes, channel dredging, water quality pollution, and other issues in water and sediment environment research. With the 2020 outbreak of flooding in the middle-lower reaches of the Changjiang River Basin, remote sensing imaging (in the 15th place) may increase.

(5) The construction of upstream water conservancy projects for the Changjiang River has changed the path, release mechanism, and role of the phosphorus cycle in the river basin, as well as the ecological environment of the Changjiang River Basin and estuary. It is necessary to strengthen the in-depth study of the water&sediment environment in the river basin and combine it with the operation of the Three Gorges to realize joint water-sediment-phosphorus regulation in the basin; hence, providing a reference with regard to the impact of Three Gorges and other water conservancy projects on the water and sediment environment.

The water and sediment environment in the middle-lower reaches of the Changjiang River Basin remains a key issue at present and for a considerable period in the future, under the influence of Changjiang River protection and utilization, as well as climate change. A quantitative analysis of the research literature on the water&sediment environment has, to some extent, guided research on the water and sediment environment in the basin.

### Acknowledgments

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