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Evaluating the Methods for Assessing Implementation Effects of River Chief System in China

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Abstract: The newly amended *Law of the People's Republic of China on the Prevention and Control of Water Pollution*, which clarifies the liability of party or administrative heads at various levels concerning water environment rehabilitation in their respective administrative regions, stipulates the establishment of a "River Chief System." In this study, we analyze the implementation effects of the river chief system in China, current assessment methods, and deficiencies of these methods, and propose two quantitative assessment methods: (1) comprehensive water quality assessment for the cross-sections of rivers and lakes and (2) assessment using the pollutant load intercepting rate of sewer networks, aiming to improve the scientific rationality for effect assessment of the river chief system. Using the rehabilitation of Suzhou Creek in Shanghai as an example, we apply the comprehensive water quality assessment method. By analyzing the pollutant load intercepting rate of various provinces (autonomous regions or municipalities) in China, we find that, on average, 34% of wastewater is still discharged into water courses in an untreated state, leading to the repeated occurrence of water quality deterioration. Introducing comprehensive water quality assessment and the pollutant load interception rate into river chief assessment will effectively push the government at all levels to concentrate their human, material, and financial resources on urban drainage network correction and the interception of pollution sources discharged into watercourses.
Keywords: river chief system; comprehensive water quality; water environmental quality; pollutant loading; sewage collection; water pollution prevention and control

1 Introduction

Fully implementing the River Chief System (RCS) constitutes great decision-making by the Central Committee of the Communist Party of China (CPC), as it accords with the strategy of living in harmony with nature and accelerating the construction of eco-civilization. As an important form of system innovation for ensuring national water security, the RCS and the responsibilities of river chiefs were further emphasized and legally defined by the *Opinions on the Comprehensive Implementation of the River Chief System* issued by the General Office of the CPC Central Committee and the State Council in November 2016 and the amended *Law of the People's Republic of China on the Prevention and Control of Water Pollution* (hereinafter referred to as PCWP Law) issued in 2017. These documents highlight that the state shall establish a river chief system, and local governments at or above the town level shall be responsible for water environment quality in their respective regions of administration, including with regard to water resource protection, water shoreline management, water pollution control, and water environment treatment.

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The RCS—a key system innovation in the control and prevention of water pollution in China—has taken the superiority of the Chinese political system into full play and achieved remarkable results. The RCS has linked water governance with leaders' performance evaluation, nested water governance with hierarchical systems, and integrated government leadership with multi-stakeholder engagement, which has fundamentally improved the priority of water governance in local governments' daily affairs [1]. Hence, remarkable achievements have been made in water pollution prevention and control since the implementation of the RCS.

Under the support of the "Assessment of the Implementation of the PCWP Law" project of the Chinese Academy of Engineering, the authors conducted a comprehensive assessment of the implementation of the RCS in China. This paper analyzes and summarizes the implementation effects of the RCS in China, current assessment methods for RCS implementation, and current assessment methods' deficiencies. Further, this paper presents suggestions for perfecting the assessment of RCS implementation effects and the associated quantitative assessment methods, so as to provide a reference for decision-making to better promote the prevention and control of water pollution in China through the RCS.

2 Implementation effects of the RCS

Since the promulgation and implementation of the PCWP Law, the Chinese RCS has led to numerous great outcomes, which can be summarized as follows.

First, river chiefs have been appointed at different administrative levels across China. Since the implementation of the PCWP Law, as of June 2018, more than 300 000 river chiefs had been appointed in a four-tier system leveled from provincial to township in the 31 provincial regions of the Chinese mainland, establishing hierarchical management. Moreover, 29 of the 31 provincial regions have further extended the RCS in their areas to villages and expanded the coverage to all water bodies, including small rivers, lakes, reservoirs, and ponds.

Second, effective operations have been undertaken by principal officials at different administrative levels to fulfill the duties of river patrols, management, protection, and pollution control. Local governments have carried out a series of special actions to solve the prominent issues that people are concerned about, including arbitrary occupation, mining, dumping, and construction. Some local governments have explored the mechanism of "river chief–police chief–prosecutor chief" and have established the office of police chief to carry out joint law enforcement actions. Governments at different levels have also developed an information management system for river chiefs on the basis of the national digitized "one map" for water conservancy, using information technology methods such as remote sensing images at temporal scales and drones for monitoring and patrolling. Hence, the supervisory liability of the RCS has been strengthened. Through the information management system, the RCS shifted from being one of "appointing river chiefs" to one of "taking positive actions" effectively.

Third, the RCS has shown its effect in promoting the comprehensive management of the water environment in the administrative regions at all levels, where significant improvements in water quality have been identified in rivers and lakes. The resource and government efforts made for water pollution prevention and control in the last five years since the implementation of the RCS were the greatest in China, and they have brought significant payoffs. The proportions of Class I–III (excellent water quality) and inferior to Class V (without water use function) were 63.1% and nearly 1/10 (9.2%), respectively, among 968 national surface water sections in 2014 before the implementation of the RCS. According to *China's Bulletin on the Ecology and Environment in 2021*, among 3632 national surface water monitoring stations, the proportion of those falling into Class I–III was 84.9%, which was 21.8% higher than that in 2014; while the proportion of those inferior to Class V was 1.2%, which was 8% lower than that in 2014. The water quality of China's major basins continues to improve, as indicated by the excellent water quality in the Yangtze River and Pearl River Basins, obvious improvement in the Yellow River Basin, and transformation from mild pollution to good water quality in the Huaihe River and Liaohe River Basins.

However, some deficiencies remain in the implementation of the RCS. First, the illegal discharge of industrial wastewater and inappropriate discharge of domestic sewage and rural sewage are still prominent. Second, the intensity of scientific water environment rehabilitation needs to be strengthened, since the two extremities of lack of investment on the one hand and waste of investment on the other are common. Hence, it is necessary to establish scientific assessment methods to quantify the effects of the RCS.

3 Current methods for assessing the effects of the RCS

The current assessment system for the Chinese RCS can be categorized at the national and local levels.

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At the national level, the Ministry of Water Conservancy issued documents in 2021 for direct RCS assessment. From the perspectives of further implementing the RCS with great endeavor and enhancing the encouragement and support of the RCS, two types of indicators were presented: (1) the effects of river and lake management and protection and (2) work advancement. They are assigned the assessment scores of 100 and 50, respectively. Each type of indicator is further subdivided into five specific indicators for performance appraisal. Of the two types of indicators, the former clearly clarifies the requirements for the water quality and ecological improvement of rivers and lakes. In terms of quantitative assessment of the water environmental quality of rivers and lakes, the Ministry of Ecology and Environment issued the *Ranking Scheme for Water Environment Quality of National Surface Water Checking Stations in Cities at the Prefecture Level and Above (Trial Implementation)*. It proposed a ranking method for water environment quality assessment in cities at the prefecture and above level based on a comprehensive water quality index [2]. The specific process involved is as follows: (1) the water quality index for each single indicator is calculated based on the threshold concentration value of Class III as defined in the *Environmental Quality Standard for Surface Water (GB3838–2002)*; (2) the calculated water quality indices for a set of indicators are added to obtain the overall indices of assessed rivers, lakes, or reservoirs; (3) the comprehensive water quality index of a certain city is calculated by weighing the number of monitoring sections; and (4) the cities are ranked according to the magnitude of their comprehensive water quality indices.

At the local level, the governments of some provinces and prefecture cities have detailed evaluation measures to assess the effects of the RCS quantitatively. Overall, these measures include integrated river management, sewage collection and sewer network construction, and water quality assessment of river sections. In addition, key points and their associated scores are also assigned to each measure.

The effect of water quality improvement is a key factor in assessing the RCS. The new amendments to the PCWP Law, revised in 2018, introduced two new terms: “taking strategies and actions to prevent and control water pollution” and “being responsible for the quality of the water environment in respective administrative areas” to expand the responsible governments from those at the county level and above to all levels. Meanwhile, the two obligations of local governments, depicted in Clause II, were also revised. The accountability for water environment quality has been emphasized at top priority, stating that local governments at all levels bear the responsibility for water environment quality. After the implementation of the PCWP Law, the relevant rules and regulations were revised in provinces such as Liaoning, Anhui, Shandong, Henan, and Guizhou. The revised regulations clearly stipulate a target-oriented system of responsibility and performance evaluation for protecting the water environment. In areas that fail to attain the targets of water environment quality, the persons in charge are to be summoned for meetings. In provinces such as Liaoning, Zhejiang, Anhui, Sichuan, and Henan, local governments further clarified responsibilities for water environment quality and established a mechanism to ensure the accountability of local governments and responsibility investigation. Hence, despite the differences in the assessment indicators and scoring standards of the RCS across various areas, rules and regulations regarding improving water environment quality have been formulated.

To summarize the details of the assessment of RCS implementation across different locations, the methods for assessing the improvement of water environment quality include the compliance of the surface water quality with standards, the improvement of the water quality class, and the proportions of excellent water bodies (Class I–III), inferior to Class V water bodies, and black and odorous water bodies. For example, the number of monitoring stations for surface water or lake sections with improved or deteriorated water quality was used to assess the RCS in Jilin Province in 2018, and the change in water quality class was used as a scoring basis [3]. In Beijing, assessment of the RCS has considered both the compliance of water quality with the desired quality class objective and the improvement of water quality [4]. The change and elimination of the percentage of inferior Class V water bodies has been highlighted in regions such as Shanghai [5]. Additional scores have been given for water quality improvement effects in some provinces. For example, in the detailed assessment rules of Beijing, extra scores are added for every 5% decrease in the sum of annually averaged data of four primary water quality indicators, while the water quality of the mainstream sections is compliant with the designated standard [4].

Sewage interception is fundamental to the prevention and control of water pollution. Although the issue of black-odorous water bodies has been addressed since the implementation of the RCS, improvement in water quality has not been obvious in terms of repeated pollution and water quality fluctuations. The root cause is that some local governments have leveraged more investments in landscape construction and are capable of local and emergency measures to deal with water pollution, while neglecting to solve infrastructure deficits such as eliminating pollutant discharge into rivers and repairing underground pipe networks. Related terms on sewage interception and sewer network construction have been added to the detailed assessment rules of the RCS in many regions, including the elimination of direct sewage discharge outlets, sewage treatment ratios of rural and urban wastewater treatment plants (WWTPs), and correction of misconnected sewage sources. For example, the detailed assessment rules of the RCS in Shanghai have specific requirements of sewage interception, sewer network construction, attainment of water quality of WWTP discharge to the designated water quality standard, correction of sewage sources misconnected to storm drains in enterprises and public institutions and commercial and residential communities, and collection of rural sewage water [5]. In the detailed assessment rules of the RCS in Anhui Province, the construction of urban sewage treatment facilities and the sewage treatment ratios in cities and county towns are specified [6].

In addition, in terms of integrated management of the RCS, multiple indicators have been introduced into the assessment. These include the ratios of surface in rivers and lakes, clean environment and rehabilitation of illegal reclamation on riverbanks, institutional construction, and media supervision. The purpose is to achieve multiple targets of remarkable results, long-term and effective assessment mechanisms, and public engagement.

4 Major problems of the methods for assessing the effects of the RCS

In summary, water quality improvement and sewage interception are key aspects for evaluating the RCS. The following issues must be addressed in the assessment of RCS effects.

4.1 Lack of a quantitative method for assessing the improvement of water environment quality

In China, the *Environmental Quality Standard for Surface Water* (GB3838–2002) is the basis for assessing improvements in water environmental quality [7]. Specifically, water environment quality is assessed based on a single-factor assessment method (i.e., the “one-vote veto” method). In other words, among the monitored water quality indicators, the water quality grade of the worst indicator is the determinant of the overall water quality grade of the assessed water or attainment of the specified water use objective. In general, the method manifests itself as “over-protection,” making it difficult to reflect the comprehensive water quality improvement scientifically.

In 2015, the Ministry of Housing and Urban-rural Development of China issued the *Guidelines for the Rehabilitation of Urban Black and Odorous Water Bodies* (Trial Implementation) [8]. The guidelines highlighted the urgency of controlling black-odorous water bodies in urban areas and the importance of the assessment and supervision of related activities. Threshold values were defined for four indicators to characterize the occurrence of the black-odorous phenomenon. However, these four indicators are inconsistent with the *Environmental Quality Standard for Surface Water* (GB3838–2002); thus, it is difficult to continuously measure water quality improvements in practice.

In 2019, the Ministry of Ecology and Environment of China issued the *Ranking Scheme for Water Environment Quality of National Surface Water Checking Stations in Cities at the Prefecture Level and Above* (Trial Implementation). The scheme proposed a ranking method based on a comprehensive water quality index composed of a set of indicators intended to represent the change in water environment quality in terms of comprehensive water quality and solve the over-protection problem of the single-factor assessment method [6]. The comprehensive index based on the concentration limit of Class III water can measure consecutive water quality changes; however, this method cannot intuitively represent (1) the overall water quality class, (2) the continuous change in water quality within the same water quality class, and (3) the black-odorous occurrence. Therefore, a more reasonable assessment method is required to address these problems.

Accordingly, it is necessary to establish a more scientific and reasonable assessment method for water environmental quality improvement, so that the water quality assessment of rivers in the jurisdiction of the RCS is practical instead of over-protected. Meanwhile, the developed method should be capable of assessing continuous water quality change within one water quality class, as water quality improvement does not necessarily indicate a change in the water quality class. Additionally, the developed assessment should be able to discriminate between black and odorous water bodies.

4.2 Lack of a scientific assessment method for actual sewage collection ratio

As of 2018, China had built 4332 WWTPs, with a treatment capacity of 1.95×10^8 m^3/d. Based on *China’s Urban–Rural Construction Statistical Yearbook*, the sewage collection ratio measured by the WWTP inflow volume divided by total sewage discharge reached more than 90%, similar to the levels in Europe and the United States. A similar method is also used in the detailed assessment rule of the RCS. However, due to sewer-related problems such as sewage misconnection into storm drains, rainwater misconnection into sewer pipes, damaged sewer pipes, and

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surface water intrusion into sewer pipes, WWTP inflow comprises sewage and clean water including rainwater, river water, and groundwater, which overestimates the wastewater treatment rate of China's urban WWTPs. On the other hand, this calculation method does not reflect the fact that much untreated wastewater is still discharged into rivers and lakes, leading to worse water quality in urban rivers and lakes in China than in Europe and the United States [9].

Therefore, in the assessment of sewage interception, local governments must address both the WWTP inflow volume and inflow water quality, avoiding miscalculations due to sewer network problems, and making substantial achievements in sewage interception. Accordingly, a scientific and reasonable method for assessing sewage interception should be developed to assist river chiefs at all levels to effectively promote sewage collection in their jurisdictions and fundamentally improve the water quality.

5 Quantitative methods for assessing the effects of the RCS

5.1 Establishment of an assessment method based on the comprehensive water quality of rivers and lakes

To avoid the over-protection caused by a single-factor assessment method, and considering the non-synchronous changes of water quality indicators on a spatial and temporal scale, a new assessment method based on a comprehensive set of water quality indices should be established for rivers and lakes, so as to assess the achievements and improvements of water environment quality by the RCS reasonably.

By measuring the average value of a group of water quality indicators, we can assess (1) the comprehensive water quality change of a monitoring station over time and (2) the change in comprehensive water quality between upstream and downstream monitoring stations. In this way, uncertainty in comparing water quality due to the above-mentioned non-synchronous changes of water quality indicators in spatial and temporal scales could be eliminated, highlighting the actual water quality change of rivers and lakes by river chiefs and strengthening a river chief's responsibilities.

5.1.1 Water quality identification index (WQI)

A WQI is used to determine the comprehensive water quality of water cross-sections. The structure of the WQI is expressed as follows:

$$\mathrm{WQI} = X_1 \cdot X_2 \qquad (1)$$

where X_1 is the water quality class for assessing the water quality qualitatively and X_2 is the proportion of the measured value in the range of X_1. The WQI is calculated using a set of water quality indicators (detailed calculation procedures are described in the relevant literature [10–12]).

The WQI has the following characteristics:

(1) The integer digit represents the water quality class; 1–5 indicate Class I–V, respectively, and greater than 6.0 indicates inferior to Class V.

(2) The larger the WQI value, the worse the water quality.

(3) A value of 6.5–7.0 and above represents the occurrence of a black and odorous water body.

(4) The index can evaluate the effects of both the elimination of a black and odorous water body and the continuous temporal and spatial changes in water quality.

Therefore, the WQI can be used to determine the comprehensive water quality of water cross-sections.

Overall water quality variation based on the WQI is expressed as follows:

$$V = \frac{WQI_s - WQI_e}{WQI_s} \qquad (2)$$

where V is the overall water quality variation, $V > 0$ indicates an improvement in the overall water quality, and $V<0$ indicates a deterioration of the overall water quality. For spatial variations, the WQI_s and WQI_e are the comprehensive water quality indices of the upstream and downstream sections, respectively. For temporal variations, the WQI_s and WQI_e are the comprehensive water quality indices of the beginning and end, respectively.

The criteria for overall river water quality based on the WQI are shown in Table 1.

5.1.2 Case study: comprehensive water quality assessment of Suzhou Creek in Shanghai

Suzhou Creek, also known as the Wusong River, spanning 125 km long in total, is a very important water body in Shanghai. The segment of the river in Shanghai is approximately 53.1 km long, 23.8 km of which lies in Shanghai's urbanized area. Black-odorous water bodies have occurred in some segments of the river since 1920 owing to increased population and industrial development. This black-odorous phenomenon gradually worsened and stayed year-round in the segments ranging from the Waibaidu Bridge to Caojiadu by the founding of the People's

Republic of China in 1949, and expanded to the entire urban segments in 1978. The severely polluted Suzhou Creek disgraced the reputation of the Shanghai metropolitan area as a center of the international economy, trading, and finance.

Table 1. Criteria of the overall river water quality based on the WQI.

WQI	Overall river water quality
1.0≤*WQI*≤2.0	Class I
2.0< *WQI*≤3.0	Class II
3.0< *WQI*≤4.0	Class III
4.0< *WQI*≤5.0	Class IV
5.0< *WQI*≤6.0	Class V
6.0< *WQI*≤7.0	Inferior to Class V without opacity and odor
WQI >7.0	Inferior to Class V with opacity and odor

Note: In the water environment rehabilitation of Suzhou Creek in Shanghai, the comprehensive water quality threshold for eliminating black odor occurrence is WQI=7.0 [11,12]; while in small- and medium-sized rivers, the reported threshold is WQI=6.5 [13].

To reduce sewage discharge into the urban section of Suzhou Creek, Shanghai started the Confluence Sewage Project I in 1988, which was completed by December 1993. As a result, the pollution level of Suzhou Creek's mainstream had gradually decreased since 1994. However, black-odorous occurrence still arose because of the large amounts of untreated sewage discharge into Suzhou Creek's tributaries and the unfavorable back-and-forth tide flow in Suzhou Creek's mainstream. In response, Shanghai launched a large-scale project, the Suzhou Creek Rehabilitation Stage I (1998–2000). This project emphasized the interception of the pollution sources of Suzhou Creek tributaries and the change in water flow direction of Suzhou Creek's mainstream from a back-and-forth movement to a single-direction flow (i.e., west to east), in order to improve the water quality of Suzhou Creek gradually. As a result, black odorous occurrence was nearly eliminated by 1999 (WQI≤7.0). The comprehensive water quality of Suzhou Creek was ameliorated to Class V in 2001 and further improved to Class IV and Class III in 2015 and 2018, respectively, without repeated black and odorous occurrence or water quality deterioration during the rehabilitation process. The water quality has steadily improved over the years for the cross-sections in both the upstream and downstream regions, indicating remarkable results (Fig. 1).

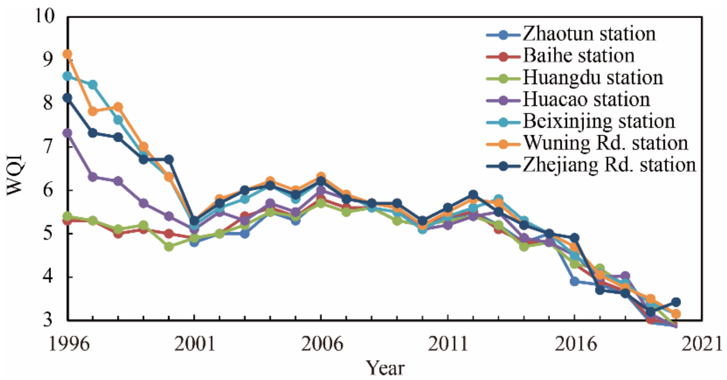

Fig.1. WQI changes of Suzhou Creek in Shanghai (1996–2021).

During the rehabilitation process of Suzhou Creek, the WQI was used for periodic analysis of the spatial and temporal variations in comprehensive water quality across different districts. As a result, pollution control was prioritized by governments responsible for the rehabilitation of Suzhou Creek tributaries.

For example, the comprehensive water quality of cross-district monitoring stations in one year of the Zoumatang River, a tributary of Suzhou Creek, is shown in Fig. 2. Its WQIs are shown in Table 2, indicating (1) the quantitative overall water quality variations across different cross-district stations of tributaries and (2) the gap between the current water quality and the water use objective. The results can effectively promote the responsibility of river chiefs at all levels of water pollution control.

The remarkable achievement of the Suzhou Creek rehabilitation project benefited from the establishment of an assessment system targeting quantitative improvement in water quality. In this system, the temporal and spatial

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changes in the comprehensive water quality of river stations were routinely monitored, compared, and analyzed. Thus, governments along the tributaries of Suzhou Creek can implement measures to control water pollution actively. A comprehensive water quality identification index calculated using averaged data of sets of water quality indicators was developed to evaluate the rehabilitation effect of Suzhou Creek. The comprehensive water quality identification index can assess water quality in terms of both water quality classes and continuous water quality changes within the same class. Meanwhile, it can determine the occurrence and degree of black odorous water. Based on this method, we can not only assess the rehabilitation effect of black-odorous waters but also assess the continuous water quality improvement over a spatial scale (i.e., between upstream and downstream stations) and temporal scale (i.e., water quality change of the same station with time), which plays an important role in assisting responsible officers of districts in river pollution control and management.

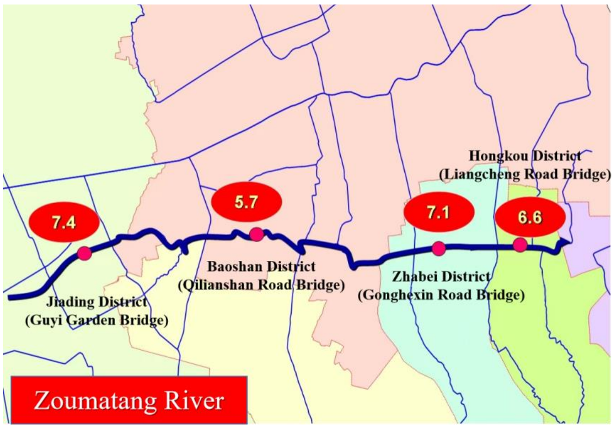

Fig. 2. The WQI of monitoring stations in one year of the Zoumatang River.

Table 2. Water quality evaluation of cross-district monitoring stations based on the WQI.

District	Monitoring Station	Associated water function	WQI	Overall river water quality	*V* (%)
Jiading District	Guyi garden bridge	Class V	7.4	inferior to Class V with opacity and odor	–
Baoshan District	Qilianshan road bridge	Class V	5.7	Class V	−23%
Zhabei District	Gonghexin road bridge	Class V	7.1	inferior to Class V with opacity and odor	24.6%
Hongkou District	Liangcheng road bridge	Class V	6.6	inferior to Class V without opacity and odor	−7.0%

Note: $V < 0$ and $V>0$ reflect the improvement and deterioration of the overall water quality, respectively.

5.2 Establishment of an assessment method based on pollutant interception ratio

To address the overestimated sewage collection or sewage interception ratio, an assessment method is needed to consider both the volume and quality of inflow into a WWTP and scientifically reflect the actual achievements in sewage collection.

5.2.1 Pollutant interception ratio of the urban sewer networks

The pollutant interception ratio of sewer networks is expressed as the ratio of the pollutant loading entering the WWTP to that of the sewage discharge in its service area as follows:

$$R = \frac{L_{\mathrm{WWTP}}}{L_{\mathrm{sewage\ discharge}}} \quad (3)$$

where R is the pollutant interception ratio and L_{WWTP} is the pollutant loading entering the WWTP, calculated as follows:

$$L_{\mathrm{WWTP}} = C_i \times Q_i - C_e \times Q_e \quad (4)$$

where C_i is the concentration of the WWTP inflow in the dry-weather period, Q_i is the WWTP inflow volume in the dry-weather period, C_e is the concentration of external water (including groundwater and river water), and Q_e is the volume of external water. Considering that the concentration of external water is much lower than that of dry-weather WWTP inflow, the pollutant loading of external water can be ignored, and equation (4) is further simplified as

$$L_{\mathrm{WWTP}} = C_i \times Q_i \quad (5)$$

$L_{\text{sewage discharge}}$ is the pollutant loading of the sewage discharge in the service area of the WWTP, which is calculated as follows:

$$L_{\text{sewage discharge}} = C_s \times Q_s \quad (6)$$

where C_s is the concentration of sewage discharge in the service area of the WWTP and Q_s is the volume of sewage discharge in the service area of the WWTP.

5.2.2 Calculation case

A quantitative analysis is conducted to justify the difference of the volume-based interception ratio and pollutant-based interception ratio using data from 30 provinces (autonomous regions, municipalities) in China. Given the unavailable data on the volume of groundwater and river water entering the sewer networks, these impacts are not considered in this calculation from a conservative estimation.

Accordingly, the interception ratio of chemical oxygen demand (COD) mass is calculated and analyzed in 30 provinces (autonomous regions, municipalities) in China, except the Tibet Autonomous Region. The discharge and inflow data of the WWTPs were obtained from *China's Urban Construction Yearbook 2020* [14]. The COD concentrations of sewage discharges were based on the theoretical values of inflow into WWTPs across China [15]. The actual water qualities of sewage inflow are referred to in the figures in the *China Environmental Yearbook*, which were essentially in agreement with the COD concentrations from the relevant literature [15]. On this basis, the sewage collection ratios in sewer networks throughout the country were calculated, as shown in Fig. 3.

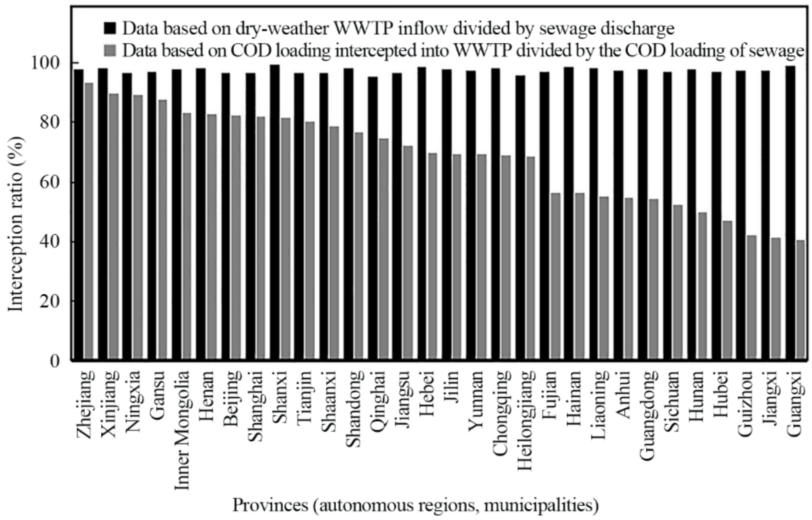

Fig. 3. Volume-based and pollutant-based interception ratio in 30 provinces (autonomous regions, municipalities)

As shown in Fig. 3, the statistical sewage collection ratios of sewage are as high as 97% if measured by the volume of dry-weather WWTP inflow divided by the volume of sewage discharge. However, when considering the sewage collection ratio measured by COD loading intercepted into the WWTP divided by the COD loading of sewage, the actual sewage collection ratio is only 66% on average. Thus, approximately 34% of untreated sewage is still discharged into water bodies in China. These data are consistent with the pollution situation in urban rivers in China.

A comparison of the interception ratios of COD mass among China, Germany, and Singapore is presented in Table 3. Evidently, Germany and Singapore perform much better than China, with a ratio of over 90%. This further indicates that the actual sewage collection ratio in sewer networks in China is relatively low. The black-odorous phenomenon still exists because of overflows in urban sewer networks, especially on rainy days. Therefore, the pollutant interception ratio should be taken as an index in the evaluation of river chiefs' performance to leverage more resources and efforts to solve the problem of sewage collection.

All in all, to fully embody the effectiveness of the RCS, comprehensive water quality improvement and a pollutant interception ratio should be included to the existing assessment in addition to routine activities such as patrolling. Furthermore, relevant technical specifications of assessments should be formulated. By doing so, it would be feasible

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to accurately learn about the current situation of pollution management in rivers and lakes, evaluate river chiefs' performance, and set reasonable stage objectives for sewage interception and water pollution control.

Table 3. Comparison of COD loading interception ratio between China, Germany, and Singapore.

Country	Sewage discharge (× 10^4 $m^3 \cdot a^{-1}$)	WWTP inflow volume (× 10^4 $m^3 \cdot a^{-1}$)	COD concentration ($mg \cdot L^{-1}$)		Pollutant interception ratio (%)
			Domestic sewage	WWTP inflow	
China	5 693 152	5 552 733	377	256	66
Germany	520 000	661 300	808	577	92
Singapore	32 448	40 150	772	565	90

Note: The water quality of WWTP inflow in Germany is referred to in the literature [16,17].

6 Conclusion

Pollution in water bodies is associated with untreated sewage discharge due to sewer-related problems. Therefore, pollution management for rivers and lakes constitutes a systematic effort from many stakeholders, which highlights the necessity of the RCS. In the future, assessment of the RCS should place more emphasis on resolving sewer-related problems. With the improvement of comprehensive water quality of rivers and lakes as the constraint condition and pollutant interception ratio of sewer networks as the driving factor, river chiefs at all levels can make great efforts to truly allocate investments to improve sewage collection and existing pipe network correction. In this way, limited investments can produce maximum profits while setting lake and river pollution control on the correct technical path. Accordingly, substantial achievements in water pollution control are expected.

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