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Improving the Water Quality Monitoring System in the Yangtze River Basin—Legal Suggestions to the Implementation of the Yangtze River Protection Law

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Abstract: The Yangtze River Basin is the largest river basin in China and has the most complex trans-boundary problems. The water quality monitoring system of the provincial boundary sections in the basin is the typical go-to system to show the interaction between administrative regions and basins. In this article, we discuss the water quality monitoring system in the basin from a legal perspective, explore the achievements and deficiencies of the system, and identify the main elements that constrain the effective operation of the system in the basin, including the fragmented competencies of monitoring institutions, the different monitoring techniques, the overlapping monitoring contents and scopes, the different data releasing channels, and the different applications of the data. We provide legislative suggestions to implement the newly enacted Yangtze River Protection Law and valuable lessons for the design of monitoring systems in other countries or (trans-boundary) basins that face a similar situation.

Keywords: water quality monitoring; provincial boundary sections; Yangtze River Protection Law; Yangtze River Basin; monitoring; effectiveness

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1. Introduction

The Yangtze River Basin is the largest river basin in China and the third largest in the world, covering around 1,800,000 square kilometers. It is 6300 km long, crossing 19 provincial administrative regions, and is the most complex river basin in China (State Council 2014). There are 5 steel fields, 7 oil refineries, and more than 400,000 chemical enterprises, as well as over 6000 medium and large sewage outlets along the Yangtze River that discharge nearly 40 billion tons of wastewater to the river every year, accounting for more than half of the national wastewater discharge and forming a coastal pollution zone of nearly 600 km (IAP2 n.d.). As a result, this worsens the ecosystem degradation and creates pressure on the safety of the drinking water (Xin 2016); however, due to the great disparities of the economic and social development in the upper and lower reaches of the basin, the conflicts arising from basin management and (administrative) regional management have become increasingly prominent. This has become a serious conflict in the Yangtze River Basin and a major obstacle to the implementation of the combination of basin management with administrative regional management required by the Chinese Water Law. The application of the combination approach considers both the physical and hydrological boundaries and the administrative boundaries of a river basin. It is different from many places in the world, for example, from the Integrated River Basin Management approach applied in the EU, which is required by the Water Framework Directive (WFD) and considers river basins as the basic management units, and aims for cooperation regarding planning, goal and standard-setting, management, and monitoring by all river basin

authorities within the whole, often transboundary river basin, including cooperation with States that are not part of the European Union (WFD 2000).

Water monitoring is a support system that provides facts and figures to address water quality challenges. Taking EU as a reference, one can see that there are three different types of monitoring elaborated by the EU Water Framework Directive: (1) surveillance monitoring, which detects the actual situation or environmental status of a water body at a certain time, the results of which can be compared throughout the whole river basin; (2) operational monitoring, which obtains information on the trends in water quality over time and compares them against the throughput of the basin; (3) investigative monitoring, the aim of which is to learn about the effects of measures that have been taken to improve water quality or the status of waters and to investigate and understand why certain measures are effective or not. (Beijen et al. 2014; Ferreira et al. 2007; Gourbesville 2008).

Compared to the EU, there are only two types of monitoring for surface water in China. The first is water quality monitoring, which compares the data obtained to the surveillance monitoring of the WFD (WFD 2000). It monitors the parameters indicative of physico-chemical quality elements detailed in the Environmental Quality Standards for Surface Water (GB3838-2002) (Section 2.2.2). The second is special monitoring, like the investigative monitoring of the WFD. It is only carried out when a water body fails to achieve the environmental objectives and the causes are unknown. Our study was focused on China's water quality monitoring in the Yangtze River Basin. The monitoring system in this research refers to the Chinese legal system of setting up monitoring sites in river basin sections across provincial administrative jurisdictions to monitor the physico-chemical quality elements of incoming water from upstream provinces and those of water flowing downstream. We focused only on surface water, although surface water and groundwater are now monitored by the same agencies. In the past, deep groundwater was treated as a mineral resource and managed by a different agency. Groundwater deserves more sophisticated research.

Current research mostly focuses on the engineering and modeling aspects in the field of water monitoring (Chen et al. 2020; Di et al. 2019; Huan et al. 2020; Xu and Liu 2017). To address this imbalance, in this article, we discuss the issue from a legal perspective. We chose to investigate the monitoring system in the Yangtze River Basin for several reasons. First, monitoring is crucial to determine whether water quality standards are being complied with, whether additional measures are necessary, and to assess which measures are effective (Beijen et al. 2014; Gourbesville 2008). Second, a monitoring system is a representative model of combining basin management with administrative management, as required by the Water Law. It delimits the boundary of basin management and administrative management by introducing additional corresponding responsibilities to form interactive relationships between basin authorities and regional authorities. Third, the water quality monitoring system has a long history of practice in the Yangtze River Basin; the problems exposed therein are the most prominent, and the experience accumulated in the basin is the most comprehensive in China.

The purpose of this study was to improve the water quality monitoring system in the Yangtze River Basin, as well as to provide legislative recommendations for the implementation of the Yangtze River Protection Law, which was enacted on 1 March 2021. It is specific national legislation on the protection of the Yangtze River Basin.

The method applied in this research was the combination of desk research and empirical research. The research scope covers the provincial boundary sections (points) of the whole Yangtze River Basin (including the mainstream, tributaries, lakes, etc.), including 78 state-controlled provincial boundary sections monitored and managed by competent national authorities in the basin, as well as 170 provincial boundary sections supervised and managed by the local governments in the basin. The research data come from the Weekly Report of Surface Water Automatic Monitoring, the National Surface Water Quality Report (monthly), and the Bulletin of China's Ecological Environment (annual, (issued by the Ministry of Ecological Environment and the China National Environmental Monitoring

Center), the Yangtze River and Southwest Rivers Water Resources Bulletin and the Water Resources Bulletin of the Yangtze River Basin (monthly, published by the Yangtze River Commission). The data were sourced from 2011–2017. Empirical data were collected through panel discussions organized by the Yangtze River Commission (Water Resources Protection Bureau) in December 2015, April 2016, December 2017, and May 2017. A survey was conducted in the Hubei Environmental Protection Department of Hubei Province Government in October 2015 to further understand the problems and institutional requirements of the environmental protection authorities in implementing the water quality monitoring system for the provincial boundary sections of the Yangtze River Basin.

2. The Water Quality Monitoring System for Provincial Boundary Sections in the Yangtze River Basin

The water quality monitoring system, one of the major monitoring systems of the national water resources monitoring capacity-building project, was established to prevent water pollution and control the total amount of major pollutants in large water systems in China, and to meet the needs of environmental management of water pollution prevention and control across provincial boundaries. The monitoring system in China is a three-tiered system composed of the national, provincial, and municipal levels. There are 1931 surface water sections (sites) under the national monitoring program covering 7 large river basins of the Yangtze River (509 monitoring sections), the Yellow River, the Pearl River, the Songhua River, the Huaihe River, the Haihe River, and the Liaohe River, according to the 2019 Report on the State of the Ecology and Environment (Ministry of Ecology and Environment 2020). Environment protection authorities at the central, provincial, city, and county levels are in charge of the general environment monitoring work, including water quality monitoring within their administrative jurisdictions. The provincial environment protection authority bears the overall responsibility for environmental quality monitoring, surveying, assessment, and examination within the province, and its subordinate cities and counties (Zhou 2020). There were seven Water Resources Protection Bureaus established in 2019, subordinated to the Ministry of Ecology and Environment, and responsible for water quality monitoring in provincial boundary sections in the seven major river basins, respectively. However, in the Yangtze River Basin, the Yangtze River Commission, while mainly in charge of water quantity monitoring, its newly established Water Quality Monitoring Center in December 2020 also performs water quality monitoring. These monitoring results, however, are not made public (Section 2.2).

Monitoring the water quality at departure and entry points of provincial river administrative boundaries is effective. It reflects the impact of upstream water quality on downstream water quality and even the ecological status of the water. Although the monitoring system was established in the 1990s, the problems related to the design of the system in the provincial boundary sections became prominent after a long period of practice. This section discusses the achievements and deficiencies of the system.

2.1. Achievements

Water quality evaluation in China is based on national water environment standards, that is, the Environmental Quality Standards for Surface Water (GB3838-2002), which measures the quality of surface water according to six grades, with the highest three grades suitable for human consumption and the lowest "Inferior Grade V" level considered without function and unfit even for agricultural or industrial use (Dai 2019).

In the period from 2011 to 2017, the water quality in the provincial sections of the Yangtze River Basin generally improved, with the number of sections with water quality of Grades I–III increasing (Table 1). The monitoring system, according to our panel discussions, plays a positive role in improving the relationship between competent authorities in the upstream and downstream parts of the basin in general, since the monitoring data can provide vital information on the water status in dispute.

Table 1. Overview of water status in the Yangtze River Basin (2011–2017).

Year	2011	2012	2013	2014	2015	2016	2017
Provincial boundary sections	162	177	182	164	164	164	164
Grade I water quality	11	8	16	19	16	17	16
Grade II water quality	61	101	93	92	93	94	99
Grade III water quality	54	48	54	36	37	36	32
Grade IV water quality	9	11	10	7	10	8	11
Grade V water quality	14	3	5	5	7	5	4
Inferior Grade V water quality	13	6	5	5	1	4	2
Proportion of Grade I–III water quality	77.8%	88.7%	89%	90.6%	89.0%	90.6%	89.6%

2.2. Deficiencies

Despite the above-mentioned achievements, the monitoring system in provincial boundary sections of the Yangtze River Basin also has some severe deficiencies, amongst others, regarding the overlap of monitoring institutions, the differences in monitoring scope, the varied data releasing channels, and the usage of the monitoring results, which are demonstrated below, in Table 2.

Table 2. Overview of the monitoring systems in provincial boundary sections of the Yangtze River Basin.

Monitoring Institutions	The Center, The Bureau (Section 2.2.1)
Monitoring Content	Environmental quality standards for surface water (GB3838-2002), but with different techniques to measure water quality.
Monitoring Scope	The Center: 648 state-controlled water quality sections. The Bureau: 164 provincial boundary water quality monitoring sections.
Monitoring Results	The Center: Real-time, monthly, and annual reports. The Bureau: Monthly and annual reports.
Application of Results	The Center: Design of water and environmental protection objectives. The Bureau: Inspecting, reporting, and supervising water quality (by Ministry of Water Resources)
Legal Basis	Environmental Protection Law (2015); Water Pollution Prevention Law (2008); Water Law (2002)

2.2.1. Various Institutions of Water Quality Monitoring in the Provincial Boundary Sections of the Yangtze River Basin

Two institutions monitor the water quality in the provincial boundary sections of the Yangtze River Basin according to the existing law—the China National Environmental Monitoring Center (the Center) and the Administration Bureau of the Ministry of Ecology and Environment (the Bureau), both of which are subordinate to the Ministry of Ecology and Environment (Figure 1). The Environmental Protection Law and the Water Pollution Prevention and Control Law authorize the monitoring right to the former Ministry of Environmental Protection, which was incorporated into the newly established Ministry of Ecology and Environment during the 2018 institutional reform of the State Council. The water monitoring function was then transferred from the former Ministry of Environmental Protection to the current Ministry of Ecology and Environment and is now performed by the Center. As a national environmental monitoring center, the Center is responsible for the management and operation of the national environmental monitoring network covering not only water but also air, ecology, soil, noise, and so forth. The Ministry of Ecology and Environment, as stated above, has established seven Water Resources Protection Bureaus to monitor water quality in provincial boundary sections in seven national major river basins.

According to the Water Law, river basin authorities also have the right to monitor water quality. In the case of the Yangtze River Basin, the monitoring was performed by the Water Resources Protection Bureau of the Yangtze River Commission under the leadership of the Ministry of Water Resources before the 2018 institutional reform. During the reform,

the water monitoring function of the Ministry of Water Resources was assigned to the Ministry of Ecology and Environment (to the Bureau, more specifically). The function of monitoring in practice is performed as usual, the only change is that the Bureau is currently under the dual leadership of the Ministry of Ecology and Environment and the Ministry of Water Resources.

Both the former Ministry of Environmental Protection and the Ministry of Water Resources monitor the water quality based on the Environmental Quality Standards for Surface Water (GB3838-2002) (Section 2.2.2). The original design was that each Ministry had its own monitoring network; however, over time, the overlap became a problem, which often resulted in conflicting monitoring data, which are further analyzed in Section 3.

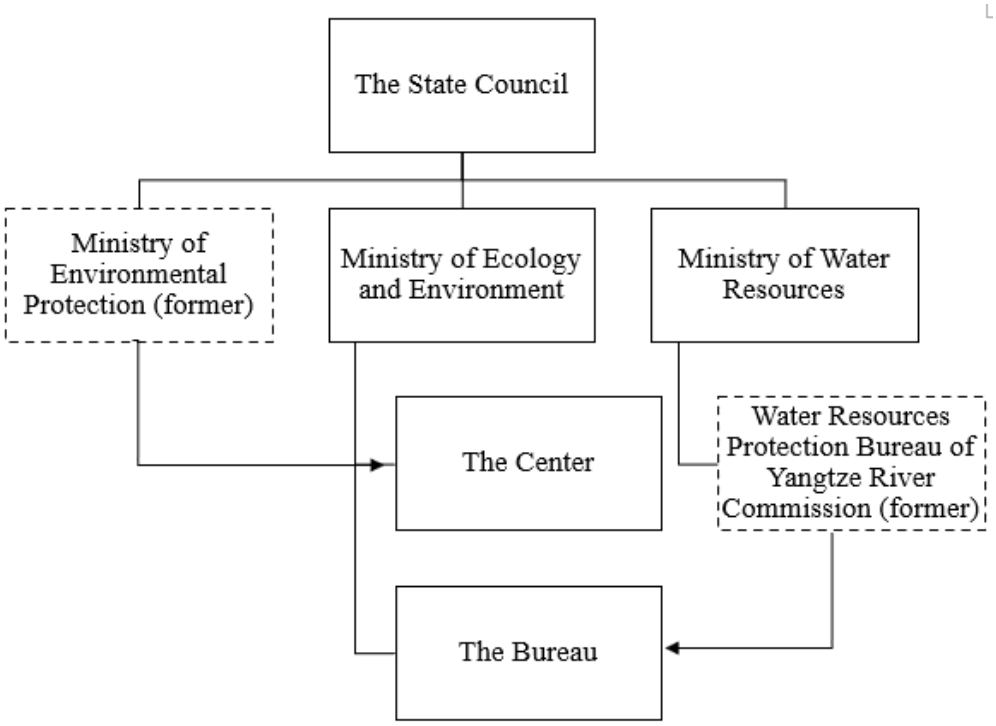

Figure 1. Institutions competent to monitor the water quality in the provincial boundary sections of the Yangtze River Basin (the institutes in the dotted boxes ceased to exist after the 2018 institutional reform).

2.2.2. Varied Techniques and Scope of Water Quality Monitoring in the Provincial Boundary Sections of the Yangtze River Basin

According to Environmental Quality Standards for Surface Water (GB3838-2002), the content of water quality monitoring for surface water in China includes 109 monitoring indexes (24 basic items, 5 supplementary items for the centralized drinking water source, and 80 special items). Key water quality parameters, such as suspended solids, pH value, dissolved oxygen, electrical conductivity, biochemical oxygen demand, ammonium nitrogen, oils, volatile phenols, sulfate, residual chlorine, mercury, and lead, have generally been sampled and measured twice per month (Zuo et al. 2013). The monitoring contents at the provincial boundary sections of the Yangtze River Basin includes 24 basic items, which are divided into Grades I–V, referring to national nature reserves, key zones for the protection of surface drinking water, surface drinking water sources, industrial/recreational water, and agricultural/landscape water, respectively (Zhao et al. 2018). To determine the water quality category, 21 items were investigated, not including water temperature, total nitrogen, and fecal coliform bacteria. The highest value of these 21 items was employed to establish the water quality category at the cross-sections. On 22 December 2020, the Ministry of Ecology and Environment issued a "Guideline on Setting National Monitoring Network Cross Sections for Surface Water Environment Quality Monitoring during "14th

Five-year Plan" Period" ([2020] No. 714), specifying that during the "14th Five-Year Plan" (2021–2025), national surface water will be monitored by the "9+X" mode and evaluated by the "5+X" mode. "9" refers to the nine basic monitoring indicators including water temperature, pH value, turbidity, electrical conductivity, dissolved oxygen, ammonia nitrogen, permanganate index, total phosphorus, and total nitrogen. "5" is for pH value, dissolved oxygen, ammonia nitrogen, permanganate index, and total phosphorus. "X" is for, in addition to the nine basic indicators, the other indicators in the Surface Water Environmental Quality Standards" (GB3838-2002). "X" indicators will be carried out manually and measured separately. According to the Ministry of Ecology and Environment, the "5+X" mode has good consistency with the "21 items evaluation" and will be feasible.

The scope of water quality monitoring in the provincial boundary sections of the Yangtze River Basin varies among the two different monitoring institutions as well because, firstly, as stated above, the former Ministry of Environmental Protection and the Ministry of Water Resources set up their own water quality monitoring sections at the provincial boundaries in the Yangtze River Basin. In 2016, the former Ministry of Environmental Protection set up 648 monitoring sites at state-controlled sections in the Yangtze River Basin, across 15 provinces. Among them, 78 are provincial boundaries that are now monitored and managed by the Center. In 2014, the Yangtze River Water Commission of the Ministry of Water Resources set up 164 monitoring sites at the provincial boundary sections in the Yangtze River Basin, which are monitored and managed by the former Yangtze River Water Resources Commission—now the Bureau (Yangtze River Water Resources Network 2016). Although the scope of water quality monitoring in the provincial boundary sections of the Yangtze River Basin differs between the Center and the Bureau, there are overlaps and conflicts. For example, both the Center and the Bureau have set up monitoring sites at the border area between Jiangxi Province and Hunan Province of Pingshui River but named them differently—"Fengtouzhou" by the Center and "Jinyushi" by the Bureau (Tian 2013). Both of them represent the water quality of Pingshui River in the provincial boundary sections; however, the monitoring results are often different because the two monitoring sites are not located on the same point. Another example is that, according to the data issued by the Ministry of Water Resources, the total amount of wastewater discharged into the Yangtze River was nearly 40 billion tons in 2012; whereas the data issued by the (former) Ministry of Environmental Protection in the same period shows that the total amount of wastewater discharged into the Yangtze River was less than 30 billion tons (Ministry of Water Resources 2012). Furthermore, the data inconsistency also resulted from the evaluation methods. For example, when monitoring the water quality, the Bureau took the natural background into account; the Center, however, did not. After the integration, the Environmental Quality Standards for Surface Water (GB3838-2002) has been mandatory as the reference for evaluating water quality. Because the natural background is not considered in these Standards, the problem of data inconsistency in this regard is solved.

For the reason behind these overlaps and conflicts, see Section 3.

2.2.3. Varied Releasing Data Channels of Water Quality Monitoring Results of Provincial Boundary Sections in the Yangtze River Basin

At present, the monitoring results of the water quality in the provincial boundary sections of the Yangtze River Basin are made public by the Ministry of Ecology and Environment but through different channels. The Center publishes monitoring data in three categories: real-time, monthly, and annually. The monitoring results of the nationally controlled provincial boundary monitoring section in the "national automatic surface water quality monitoring system" are published via real-time publication on the official website of the Ministry of Ecology and Environment; however, the real-time data contain only four main indicators: pH, dissolved oxygen (DO), permanganate index (CODMn), and ammonia nitrogen (NH3–N) (Di et al. 2019). These four indicators are the main pollutants defined by the central government. The rest of the data are published through the National Surface Water Quality Report (monthly) as well as through the Bulletin of

China's Ecological Environment (annual). The monitoring data from the Bureau were made public through the Water Resources Bulletin of the Yangtze River Basin (monthly) and the Yangtze River and Southwest Rivers Water Resources Bulletin (annual). Since 2019, due to the reform of institutional functions, the Yangtze River Commission has published "Reports of Water Resources Monitoring for Important Control Sections of the Yangtze River Basin" monthly, which only includes water level and water flow information of 93 important provincial boundary sections of the Yangtze River Basin, but without the release of monitoring data and conclusions of specific provincial boundary sections as it did before the institutional reform.

2.2.4. Varied Application Approaches of Water Quality Monitoring Results in the Provincial Boundary Sections of the Yangtze River Basin

Currently, the objective setting, assessment, and inspection related to the protection of the Yangtze River Basin by the Ministry of Ecology and Environment are all based on the monitoring results of the national surface water quality control sections (including the provincial boundary sections), which are monitored by the Center. The results of water quality monitoring published by the Center are widely used to facilitate the design of water and environmental protection objectives, water and environmental quality improvement objectives, and water pollution prevention and control objectives. These objectives are usually set in the form of corresponding programs, plans, and responsibility agreements for water pollution prevention and control objectives. For example, the objective of surface water and environmental protection in the Yangtze River Economic Zone reads as follows: "by 2020, the proportion of state-controlled sections (points) reaching or surpassing Grade III water quality is more than 75% and the proportion of Inferior Grade V sections is less than 2.5%" (Ministry of Environmental Protection, Development and Reform Commission, and Ministry of Water Resources 2017b). The aim of improving the water and environmental quality in the Yangtze River Basin reads "by 2020, the proportion of sections whose water quality reaches or surpasses Grade III is more than 76%, and the proportion of sections with Inferior Grade V is less than 3%" (Ministry of Environmental Protection, Development and Reform Commission, and Ministry of Water Resources 2017a). The objectives of protection and restoration of the Yangtze River are as follows: by the end of 2020, the proportion of state-controlled sections with favorable water quality (up to or better than Grade III) in the Yangtze River Basin will reach more than 85%; the proportion of state-controlled sections losing water use functions (Inferior to Grade V) will be less than 2% (Ministry of Ecology and Environment, and Development and Reform Commission 2019).

The monitoring results issued by the Bureau are not used to set water quality objectives but are instead mainly used by the Ministry of Water Resources to report, supervise, and inspect the water quality. There is no law to stipulate the different functions of the monitoring results, leading the Center and the Bureau to act according to their own wills and interests. The Bureau carries out special monitoring every year; it selects monitoring sections of the provincial boundaries with serious water pollution for special investigations, sends briefings to the provincial and municipal governments and provincial river chief offices accordingly, and puts forward suggestions and requirements for water resources protection within provincial boundaries (Dai 2015b). There is no mutual use between the two sets of data collected by the Center and the Bureau, which has led to a great amount of wasted administrative resources.

3. Discussion

After studying different water quality monitoring bulletins of provincial boundary sections in the Yangtze River Basin, we found that the monitoring data were inconsistent. Taking the data in December 2018 as an example, the Water Resources Bulletin of the Yangtze River Basin (monthly) issued by the Center and the National Surface Water Quality Report (monthly) issued by the Bureau, we see differences in not only the number of monitoring sections but also the proportion of water quality of different grades (Table 3).

Table 3. Comparison of water quality monitoring at provincial boundary sections in the Yangtze River Basin in December 2018 (Bureau of Ecological and Environmental Supervision of the Yangtze River Basin of the Ministry of Ecological Environment 2018).

Monitoring Institutions	Number of Monitoring Sections/Total	Proportion of Grade I–III/Unit	Proportion of Grade IV/Unit	Proportion of Grade V/Unit	Proportion of Inferior Grade V/Unit
The Center	60/78	96.6% (58)	1.7% (1)	1.7% (1)	0
The Bureau	148/164	88.5% (131)	8.1% (12)	2.7% (4)	0.7% (1)

Table 3 shows that the monitoring results of the Center suggest better water quality when compared to the results of the Bureau—that is, there is no Inferior Grade V and only one Grade V water body at provincial boundary sections in the Yangtze River Basin according to the Center, compared to one Inferior Grade V and four Grade V by the Bureau. There are several reasons for this discrepancy. First, the number of provincial boundary sections monitored by the Center (60) is far less than those monitored by the Bureau (148), which means that the data collected by the Center is likely to be less representative of the actual water quality compared to the data collected by the Bureau. Furthermore, the Center has fewer monitoring sites at the provincial sections of the tributaries of the Yangtze River than the Bureau. According to the data published by the Bureau, all four Grade V and the one Grade Inferior V water bodies are located in tributaries. This misclassification of a water body can sometimes have serious consequences. If the lower grade quality of a water body is misclassified as higher quality, water pollution can be neglected and further aggravated. Conversely, if a higher grade is misclassified as a lower grade, an improvement plan is required, which results in unnecessary extra costs (László et al. 2007).

The underlying reasons for the inconsistency of monitoring data are that the current monitoring institutions and monitoring networks over the provincial boundary sections in the Yangtze River Basin are too fragmented. This fragmentation is a result of the current legal system. As stated in Section 2.2, different laws have authorized the monitoring rights to different monitoring institutions, that is, the Center and the Bureau. The fragmentation exists not only in the field of monitoring but in general water management in China (Dai 2019). Before the 2018 institutional reform, the former Ministry of Environmental Protection and the Ministry of Water Resources played the most important roles in water management at the central level. Each Ministry had its own interests. Cooperation and coordination were low since there were neither clear inter-agency lines of communication between the two ministries nor a higher-level authority that could facilitate cooperation (Dai 2015a); therefore, when considering the whole monitoring system, it is not difficult to understand why the two ministries set up their own monitoring networks. The 2018 institutional reform was supposed to mitigate the fragmentation; however, it is too early to determine whether they have succeeded.

Before the institutional reform, the Water Law tried to rectify the fragmentation by proposing a combination approach that combines the river basin management with administrative region management in 2002. The reason behind the approach is that the fragmentation does not only exist at the central level but across the whole country; corresponding to the distribution of powers between the former Ministry of Environmental Protection and the Ministry of Water Resources, the local environmental protection agencies and water resource authorities (which are situated under the local governments), as well as the River Basin Commissions (which are under the Ministry of Water Resources), all have the same institutional arrangements, and thus, face the same fragmentation problem (Dai 2012); however, after almost two decades, the current river basin management system in China is still dominated by the local governments through which the river flows, with the relevant administrative departments (mainly environmental protection agencies and water resource authorities) acting independently (Liu 2011; Lv and Chen 2016; Yu 2011).

Before the Yangtze River Protection Law was enacted, the rules that were applied to the river basins were of low legal status and with a narrow scope. For example, the Interim

Regulations on the Prevention and Control of Water Pollution in the Huaihe River Basin (1995) and Taihu Lake Basin Management Regulation (2011) were limited to the sub-basins of the Yangtze River Basin. They were unable to manage problems in the water quality from a holistic point of view. The Yangtze River Protection Law requires the establishment of "a Yangtze River Basin Coordination Mechanism" (Article 4) and the improvement of "the monitoring network system and monitoring information-sharing mechanism" (Article 9) but leaves the implementation work to the relevant departments of the State Council and the provincial governments in the Yangtze River Basin. The next section provides legal advice on how to implement the coordination mechanism in terms of water quality monitoring in the Yangtze River Basin.

4. Legislative Suggestions to Improve the Water Quality Monitoring System of Provincial Boundary Sections

Before going further on how to implement the River Basin Coordination Mechanism, we would like to explain the current constraints on such a mechanism. The water monitoring of the Yangtze River Basin involves different upstream and downstream provinces and different provinces on the left and right banks. At this moment, the data collected by the different administrative regions are often different due to different monitoring means or technologies applied, which often creates misleading water quality indicator data. This further affects the protection of the basin. Currently, the water quality of the Yangtze River Basin is managed by the provincial governments and Yangtze River Commission, with the former playing the main role (this corresponds to the distribution of powers between the former Ministry of Environmental Protection and the Ministry of Water Resources; see Section 3). The cause of this is that the Central Government assigns national emission quotas of major pollutants to the provinces but not to the basins; consequently, the provincial governments are the authorities who bear the responsibility of achieving suitable water quality standards, not the basins. Under such pressure, provincial governments focus more on their own jurisdictions, and the Yangtze River Commission has no say. This has contributed to the conflicts between governments who share boundaries and the provinces and the Yangtze River Commission, and thus, has led to trans-boundary water pollution problems. The coordination between different monitoring authorities is essential.

4.1. Clarifying Watershed Monitoring Authorities

In light of the monitoring institutions, though the 2018 institutional reform of the State Council has initially touched the unification of monitoring authorities by making the Bureau (a water resources administrative department) responsible for water resources monitoring, and the Center (an ecological environmental administrative department) responsible for water environment monitoring, the division of responsibilities and the difference between water resources and water environment (including water quality) is not clear. At the central authority level, the State Council should clarify the role of the basin monitoring authorities in the different departments. The responsibilities of various departments in water monitoring of Yangtze River Basin, especially the Center and the Bureau, should be defined as far as possible by listing their respective responsibilities in detail. Furthermore, special river basin monitoring clauses should be formulated to clarify the legal definition of water environmental monitoring (including water quality) and water resource monitoring, especially the legal boundaries between them.

At the basin level, the following may serve as an example. The Regulations on the Management of Taihu Lake Basin divides the responsibility of Taihu Basin Bureau and the provincial governments within the basin—that is, the Taihu Basin Bureau is responsible for monitoring the water quality of the boundary waters of the administrative regions and the control sections of the main rivers entering the lake; the provincial governments are responsible for monitoring the quality of water bodies in their administrative regions, and the data collected by the different authorities are required to be shared on the same platform. In the same way, the Yangtze River Commission, after increasing the water quality monitoring capacity, can be responsible for the monitoring of water quality in the

provincial sections, inflows and estuaries of important tributaries, and key water functional areas. The provincial governments monitor the water quality of water bodies within their jurisdictions. Both of them should collect data by unified means and technologies and publish and share the data based on the same platform.

4.2. Merging the Monitoring Network and Establishing a Data Sharing Platform in the Yangtze River Basin

Article 9 of the Yangtze River Protection Law requires the improvement of a monitoring network in the Yangtze River Basin. The monitoring scope of the Center in the Yangtze River Basin, as stated in Section 3, currently is restricted in the setting of provincial boundary sections. The total number of monitoring sites is far less than that from the monitoring network of the Bureau, which makes it difficult to reflect the real status of the water quality in the provincial boundaries of the Yangtze River Basin (Liu 2011). Under the Yangtze River Protection Law, the State Council can authorize the Ministry of Ecology and Environment to integrate the monitoring network of the Bureau or the function of water quality monitoring of the Bureau into the network of the Center. Because, first, currently both of the Bureau and the Center perform water quality monitoring based on the same standards, there is no substantial difference in terms of the monitoring contents, only in scope. Second, the Center, as the national environmental monitoring authority, has the obligation to formulate monitoring norms, organize monitoring networks in conjunction with relevant departments, unify planning for the establishment of national environmental quality monitoring stations (sites), and establish sharing mechanisms of monitoring data. Third, as stated above, since the Center has fewer monitoring sites at the tribunals of the Yangtze River than the Bureau, incorporating the monitoring sites of the Bureau could realize the full coverage of the Yangtze River Basin. At the same time, the problem of overlapping monitoring, for example, two nearby monitoring sites representing the same water body, should be solved as well, for example, by merging the different sites into one. Furthermore, measurement frequency and a period of record of historical data collection should also be unified when designing the new monitoring network.

In addition, as Article 9 of the Yangtze River Protection Law states, the platform for exchanging and sharing the monitoring data should be also improved. Regarding this, the Center can establish an office under the Yangtze River Commission in conjunction with other departments, such as hydrology, natural resources, meteorology, and agriculture of the provincial governments across the basin, to establish a data-sharing mechanism for exchanging and sharing water quality monitoring data in the basin. This is because, in addition to the Center and Bureau, the above departments at the central level also have their own environmental monitoring networks related to the monitoring of water quality nationwide. Exchanging and sharing relevant monitoring data and information with these departments could provide more comprehensive, real, and objective data for the status of a given water body. Furthermore, a coordinated mechanism in the networks of measuring water quality, quantity, surface water, and groundwater, and so forth, should be established as well, since the water system is a whole system and different elements affect each other (Borden and Roy 2015).

4.3. Clarifying the Legal Validity of Monitoring Results in the Yangtze River Basin

To implement the River Basin Coordination Mechanism, the legal effect of the existing two sets of river basin monitoring results from the Center and the Bureau should be clarified. Instead of using the data separately according to the specific sector's needs, we suggest that the two sets of data (there should be only one set of data after merging the two networks) are uniformly applicable to the following areas. First, the data can serve as the legal basis for assisting water authorities in real-time operations and decision-making (Borden and Roy 2015). Second, the unified data can serve as the foundation for the central government and local governments to evaluate the baselines of water quality, the goals of water pollution prevention and control, and facilitate the competent authorities to make long-term plans in the Yangtze River Basin. Third, this data merger allows the Ministry of

Ecology and Environment to send alerts and enforcement orders to local governments of the basin promptly when an abnormality occurs.

4.4. Involving Stakeholders in Monitoring Data Collection and Release in River Basin

Article 79 of the Yangtze River Protection Law also requires the government at all levels to "improve the public participation procedure". In fact, while public and stakeholder participation has been increasingly acknowledged as important in natural resource management (Franzén et al. 2015; Human and Davies 2010), the environmental laws in China have promoted a change of water governance towards increased stakeholder participation in the last decade (Dai 2019). The government, however, still plays the main role in collecting and releasing the monitoring information in the current water quality monitoring system. To implement Article 79 of the Yangtze River Protection Law, besides allowing the public to access the monitoring information, the governments should also encourage research institutions to participate in real-time water quality research and share data with government monitoring institutions, which could thereby aid in the transparency of decision-making (Borden and Roy 2015; Nare et al. 2006). Such environmental detection institutions in provinces of Zhejiang, Shanghai, and Guangdong are now taking shape. For example, to integrate various government official monitoring data and scientific research test data (which is collected by research institutions based on research needs) to form an intelligent decision-making platform, the Chinese Academy of Environmental Sciences established the national Yangtze River Ecological Environment Protection and Restoration Joint Research Center in April 2018 (Implementation Plan on Pilots of Sponge City Programme in Wuhan City 2016).

Furthermore, the general public should also be encouraged to participate in water quality supervision and reporting. The public has taken action in this regard. For example, in April 2015, the China Public Environment Research Center, together with the Foundation of Society of Entrepreneurs and Ecology and the Alibaba Foundation, officially released the BlueMap APP in Beijing (Deng 2015). The public can use mobile phones to obtain the government's monitoring data and can also report water pollution events to government departments. The Yangtze River Protection Law and its bylaws should further develop these kinds of reporting channels and tools.

5. Conclusions

In this study, we analyzed the important functions and various drawbacks of the water quality monitoring system for provincial boundary sections of the Yangtze River Basin from a legal perspective and provided legislative suggestions for the implementation of the Yangtze River Protection Law regarding the River Basin Coordination Mechanism. We suggest that the governments at the central and local levels clarify the monitoring responsibilities among different departments, merge the current monitoring institutions and networks, improve the data-sharing platform by establishing a subordinate office under the Yangtze River Commission, and at the same time, clarify the legal validity of monitoring results and involve stakeholders in the monitoring activities.

This study also provides valuable insights for the design of monitoring systems in other countries and (trans-boundary) basins. The identified factors that hamper effective monitoring systems in the Yangtze River Basin—the fragmented competences of monitoring institutions, the different monitoring techniques, the overlapping monitoring contents and scopes, the different data releasing channels, and the different applications of the data—might constrain the monitoring systems in other countries or basins as well; therefore, the suggestions made in this article may be useful for countries or basins who need to further improve their water monitoring systems.

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