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# Purification Resistance Index: a new water quality assessment method toward drinking water production

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**Abstract:** Water quality assessment plays a significant role in ensuring the availability of clean and safe water. The Water Quality Index (WQI) model method has been developed to provide a basis for assessing water quality by integrating various water quality parameters. However, existing WQIs do not "actively" consider the difficulty of water treatment from raw water to specific water use scenarios. This study proposes a novel model framework, named as Purification Resistance Index (PRI), quantitatively evaluating not only the exceedance of pollutants but also how difficult they can be removed in the water treatment process. The framework is built based on the conventional drinking water treatment processes, with sub-indices for coagulation-sedimentation (rc), filtration (rf), disinfection (rd), and advanced treatment (ra). The model considers appropriate weights assigned to each sub-index to calculate the purification resistance, resulting in a comprehensive index for water quality evaluation. Case studies on nationwide and citywide water source reservoirs demonstrated the applicability of PRI approach. PRI breakthrough the traditional water quality risk assessment paradigm and extents to engineering region and provide useful tools for water source supervision, drinking water treatment plant planning and updating, operation control, and other purposes. Water authority, water utility and municipal design institute will all benefit. It is open for more localized practices validation and discussion.

**Keywords**: Assessment; drinking water; purification resistance; raw water, water quality index (WQI); water source

## 1. Introduction

Water is an important component of the natural environment. To quantitatively reflect the level of pollution in water bodies, various water quality parameters are measured and evaluated. The Water Quality Index (WQI) model method has also been developed to integrate various water quality parameters, which provides a basis for assessing water quality. A rough WQI score may help rule out extremely unqualified water sources but fails to differentiate between marginally and moderately qualified candidates. Furthermore, single-value scores obscure details in the assessment process, especially when weights are not carefully chosen. This can lead to the categorization of high-scoring candidates that exceed crucial parameters or low-scoring ones with only moderate exceedances. Moreover, the conventional workflow for treating drinking water comprises four crucial units: coagulation, sedimentation, filtration, and disinfection. These units are meticulously designed for specific purposes, each possessing distinct removal efficiencies and challenges when it comes to various pollutants.

Therefore, the aim of this research is to include water treatment scenario to construct a novel purification resistance index (PRI) for raw water assessment, based on treatment procedure characteristics and focuses. This new index should prioritize parameters deemed most critical by experts, considering the mechanism and emphasis of each process unit. By addressing the question "*How hard is it to treat?*" comprehensively, such an index proves highly valuable in assessing water source qualification.

## 2. Methods and results

Conventional drinking water treatment processes consist of four main units: coagulation, sedimentation, filtration, and disinfection. Since the PRI aims to evaluate the challenges presented in the drinking water treatment process, selection priority is given to the primary targets of each

treatment unit. Additionally, attention is directed toward chemicals and substances that may be present in natural water bodies, especially those susceptible to exceedance under polluted conditions or in specific types of water bodies.

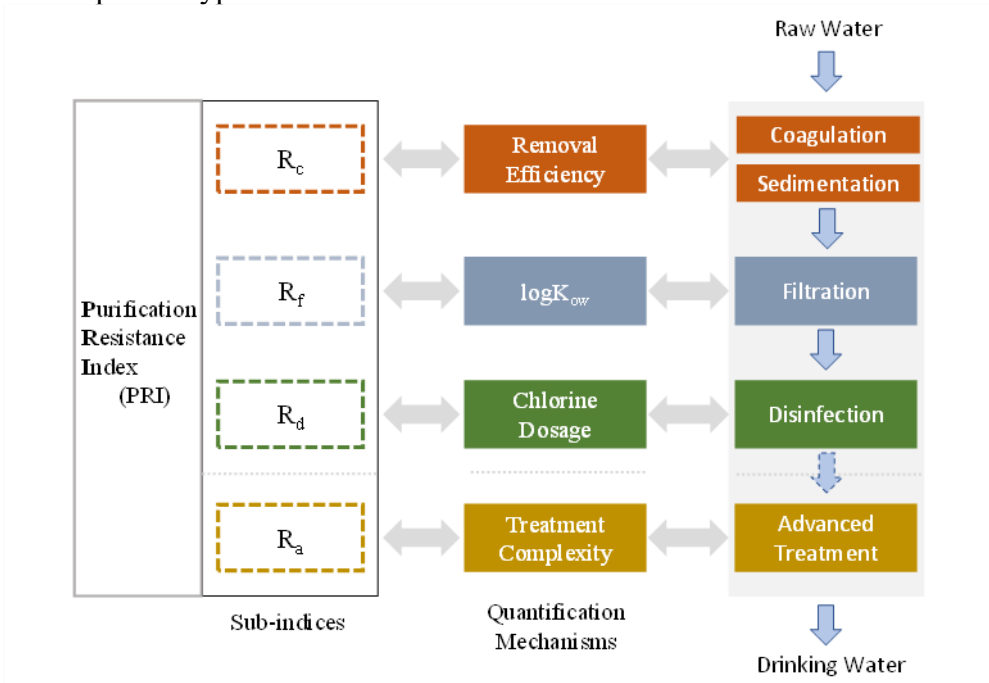


**Figure 2.1** The framework of the Purification Resistance Index (PRI) model.

Coagulation primarily targets turbidity-related substances, using coagulants to induce the flocculation process. The coagulation-sedimentation resistance can be calculated as follows, integrating environmental factors (represented by coefficient $\gamma$) while calculating the exceedance of turbidity-related substances:

$$r_c = \gamma\left(\frac{\boldsymbol{\tau}}{\tau_s} + \sum_{p=1}^{P} w_p \frac{\bar{c}_{ip}}{c_{op}}\right) \qquad \text{(Equation 1.)}$$

Filtration enhances the removal of suspended particles and also has an effect on some dissolved organic matters (DOM). Therefore, indicators such as volatile phenols, anionic surfactant, and oils (petroleum) are selected. The filtration resistance can be calculated as follows, considering the exceedance of both DOMs and the residual turbidity:

$$r_f = \frac{0.1\tau}{\tau_o} + \sum_{p=1}^{P} w_p \frac{\bar{c}_{ip}}{c_{op}} \qquad \text{(Equation 2.)}$$

Disinfection plays a crucial role in inactivating pathogenic microorganisms in water, ensuring the sanitary safety of drinking water. Fecal coliform concentration is a common indicator used to assess the levels of pathogenic microorganisms in water and is, therefore, adopted for this purpose. Additionally, ammonia nitrogen is considered due to its potential harm to human health and the ecological environment. The disinfection resistance is calculated as follows, integrated also a factor called CT value:

$$r_d = \frac{\left(\frac{c_e}{c_s} + 7.6\right) c_a}{c_r} \cdot \frac{\mathrm{CT}(T)}{\mathrm{CT}_s} \qquad \text{(Equation 3.)}$$

In addition to the above key indicators, a comprehensive evaluation is conducted for specific indicators prone to exceedance in particular water bodies. Introducing a concept of treatment complexity, the resistance for advanced treatment is calculated by the exceedance ratio for each complexity class:

$$r_a = \sum_{i=1}^{M} i\,\Delta_i \qquad \text{(Equation 4.)}$$

The sum of the above three sub-indices from the clarification stage combined with a rating based on the advanced treatment sub-index yields a dual-index as the final assessment result.

Furthermore, to demonstrate the model application in evaluating surface water quality, a case study that employs the PRI framework is conducted. It firstly assesses 14 reservoirs across China and also delves into a more detailed investigation by latest water quality monitoring dataset on 16 reservoirs in City Z located in South China.

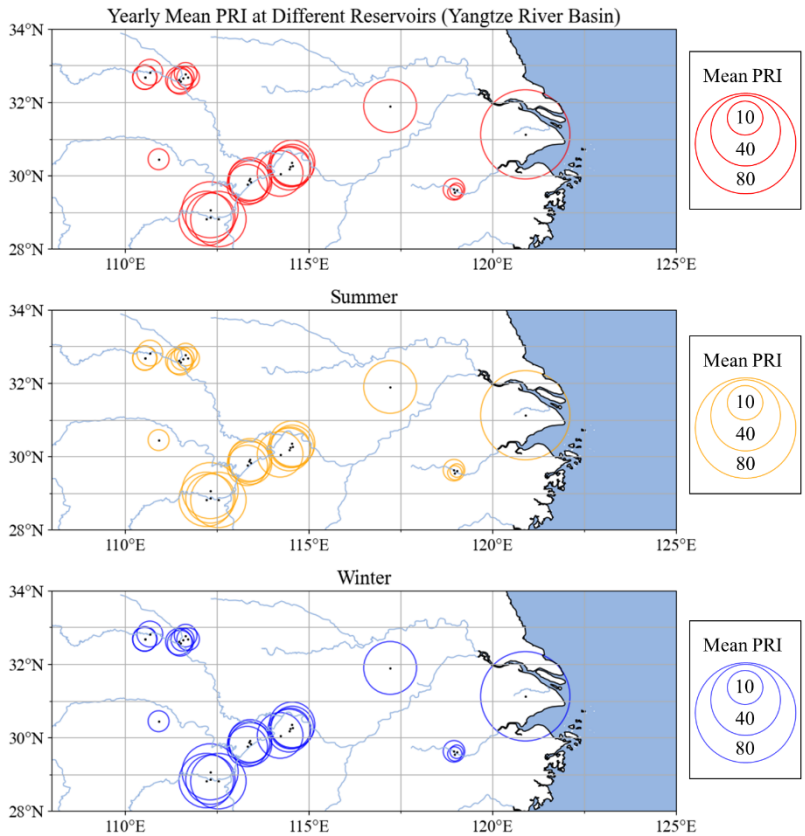


**Figure 2.2** Mean PRI (summation of $r_c, r_f$, and $r_d$) at different reservoirs located in the Yangtze River Basin.

The results show PRI's ability to identify annual variations in water quality by calculating PRI on a monthly basis, as well as its usage on water quality comparison among reservoir/rivers and abnormal exceedance identification of specific pollutants. Discussions are also presented on the topics such as sensitivity analysis of the PRI model, considerations on more water treatment technologies, adaption with local regulations, data requirements for different assessment purpose, and comparison & coupling with the existing WQI framework. Moreover, PRI's potential on over-dosing detection to assist DWTP operational assessments is also mentioned and discussed.

## 3. Conclusion

To fill the gap of active assessment on the resistance of drinking water production from raw water, this study proposes a novel framework for water quality assessment. It considers the four major processes of drinking water treatment. Based on the focus of each process, the water quality parameters are classified, and sub-indices are constructed to quantify the difficulty of treatment at each stage, referred to as purification resistance. Additionally, considering pollutants that are difficult to remove by clarification and disinfection, an advanced treatment sub-index is specially designed to provide a straightforward assessment of these pollutants' exceedance.

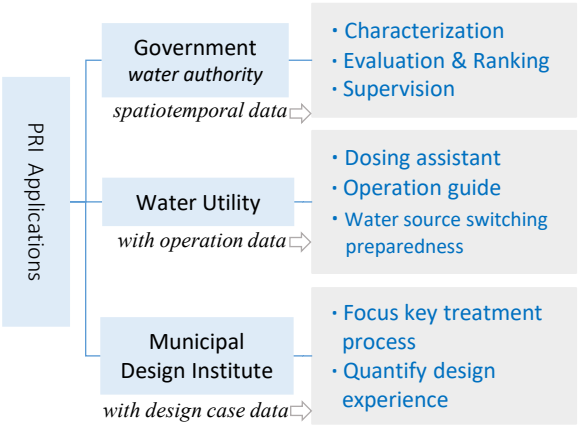


**Figure 3.1** Diagram of PRI model applications

In summary, PRI breakthroughs the traditional water quality risk assessment paradigm and extents to engineering region. It provides a clear water source portrait. Potential applications include preliminary planning of the construction of a new water plant in the water source area, seasonal changes analysis and prevention of production resistance in the water plant, rough evaluation of the difficulty of upgrading water treatment processes, dosing guide or even intelligent dosing in the water plant, analysis of the spatiotemporal evolution of water quality in the water source area and supervising the water source management, etc. More discussion, test and validation in different areas around the world are open.

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