Monitoring and Assessment of Youshui River Water Quality in Youyang

Xue-qin WANG¹, Juan WEN¹, Ping-hua CHEN², Na-na LIU¹
¹ Chongqing Real Estate College, Chongqing 401331, China
² Youyang County Environmental Protection Bureau of Chongqing, Youyang 409800, China
The author’s e-mail address, 471981660@qq.com

Abstract: By monitoring the water quality of Youshui River from January 2016 to December 2016, according to the indicator grading and the assessment standard of water quality, the formulas for 3 types water quality indexes are established. These 3 types water quality indexes, the single indicator index $A_i$, single moment index $A_k$ and the comprehensive water quality index $A$, were used to quantitatively evaluate the quality of single indicator, the water quality and the change of water quality with time. The results show that, both total phosphorus and fecal coliform indicators exceeded the standard, while the other 16 indicators measured up to the standard. The water quality index of Youshui River is 0.93 and the grade of water quality comprehensive assessment is level 2, which indicated that the water quality of Youshui River is good, and there is room for further improvement. To this end, several protection measures for Youshui River environmental management and pollution treatment are proposed.

1. Introduction
The Youshui River is the largest tributary of the Yuanshui River, and originates from two sources, the North source and the South source. It flows through Xuanen (Hubei), Longshan (Hunan), Laifeng (Hubei), Youyang (Chongqing), Xiushan (Chongqing), Gaoqiao (Hunan), Yongshun (Hunan), Guzhang (Hunan), and Yuanling County (Hunan). It is 477 kilometers in length, in which 81km is in the Youyang area, and its watershed area is 18530km², and average width is 12.5m.

The Youshui River is an important surface water and drinking water in Youyang County. Once the water was contaminated, it would produce great negative impacts on the local water environment, industrial production and drinking water. However, with the development of social economy, the Youshui River was once polluted. In recent years, Youyang County implemented the Youshui River centralized pollution remediation projects to control the pollution, such as constructing sewage treatment facilities, closing down or relocating the pollution of industrial enterprises and livestock farms on both sides of the river, strict controlling the pollution emission of general industrial enterprises, and so on. And now, it is time to monitor the water quality status of Youshui River and determine whether they meet the drinking water requirements, and whether long-term consuming Youshui River water will affect residents' health [1-2]. This will provide a reference for the further management of water environment in the Youshui River.

2. Materials and methods
2.1. Monitoring sites and water sampling
According to the ‘water environmental monitoring standards(SL219-98)’ and other relevant standards, the water quality monitoring site of the Youshui River is set at Laozhai, Wufu township in Youyang County. The river in the vicinity of the monitoring point is straight, and there is no pollution source in upstream and downstream, which means the monitoring point can represent the basic characteristics and conditions of the water quality pollution of the Youshui River.

According to the characteristics of the Youshui River, the water quality monitoring frequency is set to one time per month, from January 2016 to December 2016. And each time monitor 18 indicators, and the sampling and preservation all adopts the national standard method[3-4]. All the indicators are performed twice in parallel detection and analysis.

2.2. Monitoring indicators and detection method
Referring to the ‘Environmental quality standards for surface water’, ‘Standards for drinking water quality’ and related information, 18 water quality monitoring indicators of three types are selected, according to the characteristics of Youshui River. The first type is general chemical indicators, including dissolved oxygen (DO), permanganate indicators, chemical oxygen demand (COD), five-day chemical oxygen demand (BOD5), ammonia nitrogen (NH3-N), petroleum, fluoride, total phosphorus (TP), anionic surfactant (LAS), copper (Cu) and zinc (Zn), a total of 11 indicators. The second type is toxicological indicators, including 6 indicators of cyanide, arsenic, mercury, hexavalent chromium, lead, cadmium. The third type is biological indicator, including 1 indicator fecal coliform bacteria. The testing standard, method and instrument of water quality indicators are list in Table 1.

| Serial number | Indicators type | Monitoring indicators | Testing standard | Testing method | Testing instrument |
|---------------|----------------|-----------------------|------------------|----------------|-------------------|
| 1             | General chemical indicators | DO | HJ 506-2009 | Electrochemical probe method | Portable DO instrument |
| 2             | Permanganate index | GB11892-89 | Potassium Permanganate method | / |
| 3             | COD | GB11914-89 | Potassium dichromate method | Visible spectrophotometry |
| 4             | BOD5 | HJ 505—2009 | Dilution and inoculation | Biochemical incubator |
| 5             | NH3-N | HJ535-2009 | Spectrophotometry | Visible spectrophotometry |
| 6             | Petroleum | HJ637-2012 | Infrared spectrophotometry | Infrared oil measuring instrument |
| 7             | Fluoride | HJ/T84-2001 | ion chromatography | ICS-90 |
| 8             | TP | GB11893-89 | Ammonium molybdate spectrophotometry | Visible spectrophotometry |
| 9             | LAS | GB7494-87 | Methylene blue spectrophotometry | Visible spectrophotometry |
| 10            | Cu | GB7475-87 | Atomic absorption spectrophotometry | Atomic absorption spectrophotometer TAS991-AFG |
| 11            | Zn | GB7475-87 | Atomic absorption spectrophotometry | TAS991-AFG |
| 12            | Cyanide | HJ484-2009 | Isonicotinic acid and pyrazolone Spectrophotometry | Spectrophotometer TAS991-AFG |
| 13            | Arsenic | HJ 694-2014 | Atomic Fluorescence Spectrometry | Visible spectrophotometry |
| 14            | Mercury | GB7467-87 | Two-stupid carbonyl dihydrazine Spectrometry | Visible spectrophotometry |
| 15            | Hexavalent chromium | Lead | GB7475-87 | Atomic absorption spectrophotometry | Atomic absorption spectrophotometer TAS991-AFG |
| 16            | Cadmium | HJ/T347-2007 | Membrane filter method | / |

3. Water quality assessment
There are two types of Water quality assessment, single factor evaluation [5-6] and comprehensive evaluation. The typical single factor evaluation cannot simultaneously evaluate water quality classification or quantitatively compare water quality indicator of the same classification water [7]. The commonly used comprehensive evaluation cannot indicate whether the river water quality has reached the standard functional areas, nor to make clear that how many water quality indicators cannot meet the requirements. And its formula is complex and not convenient to use [8-10].

The Youshui River is not only an important surface water in Youyang, but also a centralized source of drinking water. Simply evaluating whether the water quality indicator meets the ‘environmental quality standards for surface water’ does not reflect the overall situation of the water. Therefore, a simple and suitable river water quality evaluation method, which combine single index with comprehensive water quality index, was developed in this study to evaluate Youshui River water quality. And this could provide a reference for China’s surface water environmental quality assessment.

3.1. Indicator grading
Based on relevant regulations and the actual situation of Youyang County, the Chongqing section of Youshui River should meet the III class water quality requirements according to ‘environmental quality standards for surface water’ (Referred to as GB3838). However, the Youyang section of the Youshui River is an important surface water in Youyang County. And it is also the drinking water centralized source for Daxi town, Houxi town, Youchou town and other towns. Therefore it should be managed and protected as class II water, and should meet the II class water quality requirements according to ‘environmental quality standards for surface water’.

In this study, the water quality indicators are graded from level 1 to level 6, in which, from level 1 to level 5 is the same with that from I to V class standard, and level 6 means the water quality is inferior to that of class V, according to the ‘environmental quality standards for surface water’ [11]. In order to facilitate the evaluation, the value of the level 6 indicators which is inferior to V class standard is determined to be 0 point. And the water quality value gradually increase 2 points with each level and thus the value of the whole water quality grade system from level 1 to level 6 is respectively 10, 8, 6, 4, 2, 0.

3.2. Water quality index calculation
The monthly average value of each indicator is graded according to the formulated scoring standard (Cik). For indicators that have the same standard limit value but are of different grades, their score value is determined as their average value.

The index of single indicator (Ai) and the index of single moment index (Ak) are calculated as in equation (1) and equation (2).

\[ A_i = \frac{\sum_{k=1}^{m} C_{ik}}{m} \]  
\[ A_k = \frac{\sum_{i=1}^{n} C_{ik}}{n} \]  

In which, \( A_i \) is the index of i indicator in the evaluation period, and \( A_k \) is the index of k moment. \( A_{ik} \) is the index of i indicator at k moment, while \( C_{ik} \) is the grading value of i indicator at k moment, and \( C_{i1} \) is the grading value of i indicator that meets the requirement of level 1. m is the total number of moments in the evaluation period, and n is the total number of monitoring indicators.

The comprehensive water quality index (A) is calculated as in equation (3).

\[ A = \frac{\sum_{i=1}^{n} A_i}{n} = \frac{\sum_{i=1}^{n} \sum_{k=1}^{m} A_{ik}}{mn} \]
Table 2. Water quality assessment results of Youyang section of the Youshui River.

| Indicators type | Monitoring indicator | A_{i1} | A_{i2} | A_{i3} | A_{i4} | A_{i5} | A_{i6} | A_{i7} | A_{i8} | A_{i9} | A_{i10} | A_{i11} | A_{i12} | A_{i13} |
|-----------------|----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| General chemical indicators | DO | 1 | 0.8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.98 |
| | Permanganate index | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| | COD | 0.9 | 0.9 | 1 | 1 | 1 | 1 | 1 | 1 | 0.9 | 0.9 | 0.9 | 0.9 | 0.94 |
| | BOD_{5} | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | NH_{3}-N | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| | Petroleum | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Fluoride | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1 | 1 | 1 | 1 | 1 |
| | TP | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.8 | 0.4 | 0.4 | 0.4 | 0.8 | 0.8 | 0.8 |
| | LAS | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Cu | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Zn | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Cyanide | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Arsenic | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Mercury | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Hexavalent Chromium | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Lead | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Cadmium | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Biological indicator | Fecal coliform bacteria | 0.8 | 0.8 | 0.4 | 0.4 | 0.4 | 0.4 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| | A_{i} | 0.93 | 0.92 | 0.91 | 0.91 | 0.91 | 0.92 | 0.93 | 0.93 | 0.93 | 0.95 | 0.95 | 0.95 | / |
| | A = 0.93 |

3.3. Comprehensive Evaluation of water quality
In this study, a water quality classification assessment standard is developed, which could evaluate both the indicators grade and the comprehensive level of surface water quality, and is shown in Table 3.

Table 3. The water quality classification assessment standard

| Evaluation grade | Score | Water quality state |
|------------------|-------|---------------------|
| I                | 1.0   | The water quality is very good, and all the indicators meet the class I standard of GB3838 |
| II               | 0.8~1.0 | The water quality is good, and most of the indicators can meet the class II standard of GB3838 |
| III              | 0.6~0.8 | The water quality is good, and most of the indicators can meet the class III standard of GB3838 |
| IV               | 0.4~0.6 | The water quality is poor, and most of the indicators can meet the class IV standard of GB3838 |
| V                | 0.2~0.4 | The water quality is poor, and most of the indicators exceed class IV standards of GB3838 |
| VI               | 0~0.2 | Water pollution is serious, most of the indicators exceed the class V standard of GB3838 |

4. Results and Discussions

4.1. The calculation results of single indicator index Ai and single moment index A_{i}
From Table 2 and Table 3, it can be seen that from January to December, 2016, all the 18 monitoring indicators’ single index(A_{i}) of the Youshui River of Youyang section were above 0.6. In which, 2 indicators’ (total phosphorus, fecal coliform) single index A_{i} were between 0.6 and 0.8, which belong
to grade III, 5 indicators’ (DO, COD, permanganate index, NH$_3$-N, fluoride) single index $A_i$ were between 0.8 and 1, which belong to grade II, and 10 indicators’ (petroleum, LAS, copper, zinc, cyanide, arsenic, mercury, six valence chromium, lead and cadmium) single index $A_i$ all is 1, which belong to grade I. The calculation results of $A_i$ are shown in Figure 1.

![Figure 1. The results of water quality assessment of Youshui River—single indicator index ($A_i$).](image)

The calculation results of $A_k$ were all above 0.91, which belong to grade I. In which, the $A_k$ index from March to May were the lowest, of 0.91, while the $A_k$ index from October to December, were the highest, of 0.95. And it changes little with time.

However, in terms of single indicator, the $A_{ik}$ indexes of total phosphorus and fecal coliform bacteria changed dramatically with time. The $A_{ik}$ index of fecal coliform bacteria from March to June are 0.4, belonging to IV level. The total phosphorus’ $A_{ik}$ index from January to May are 0.6, belonging to grade III, and its’ $A_{ik}$ index from July to September are 0.4, belonging to grade IV. The calculation results of $A_k$ are shown in figure 2.

![Figure 2. The results of water quality assessment of Youshui River—single moment index($A_k$).](image)

4.2. The calculation results of the comprehensive water quality index $A$

From Table 2 and Table 3, it can be seen that the comprehensive water quality index ($A$) of the Youshui River is 0.93, which belongs to grade II.

In general, the water quality comprehensive evaluation grade of Youshui River in Youyang section belongs to II level which means that its water quality is in good condition. Though most of the
indicators of Youshui River can meet the class II standard of ‘environmental quality standards for surface water’, the single index of total phosphorus and fecal coliform belong to grade III, in some months even grade IV, indicating that the water quality of Youshui River needs to be further improved.

Therefore, this study proposed to use 3 types indexes, the single indicator index $A_i$, single moment index $A_k$ and the comprehensive water quality index $A$, to quantitative evaluate the single indicator quality, the water quality and the change of the water quality with time.

During the monitoring period, the temperature of Youshui River are from 3.2 °C to 24.8°C. the flow rate of the river is $42.0\text{m}^3/\text{s}~628.5\text{m}^3/\text{s}$. There is no obvious relationship between $A_k$ and water temperature or flow rate, and their relationship may need further studies.

5. Conclusion and Recommendations
On the basis of investigation and analysis of historical data, water quality evaluation results are consistent with the actual situation of the Youshui River. The water quality of the Youshui River becomes better, and this is due to the implementation of series of water environmental regulation measures in recent years. However, the indexes of total phosphorus and fecal coliform of Youshui River exceed the standard seriously, which is mainly due to the excessing emissions of living sewage and livestock sewage along Youshui River, and the non-point source pollution from agriculture etc. To solve the problem, this study proposes the following recommendations.

Further strengthen the comprehensive management of the Youshui River water environment, and focus on remediation for coastal farmers’ living sewage, livestock wastewater emissions. For example, improve the drainage network, establish biogas digesters, and develop sanitary toilets, promote the usage of agricultural waste water and so on [12]. Ensure that the rural households living sewage and livestock wastewater could discharge standards or achieve zero emissions.

Strengthen the control of agricultural non-point source pollution, encourage the development of ecological agriculture, promote the use of organic pesticides and rationally use chemical fertilizers, and reduce the intensity of agricultural non-point source pollution. Protect the vegetation, strengthen the management of construction projects, improve the rate of greening and vegetation coverage, comprehensively control the soil erosion, so as to reduce the pollution and the effect of surface runoff on the Youshui River.

The Environmental Protection Bureau, Health Bureau and other relevant administrative departments should strengthen their supervision, prevent environmental emergencies caused by pollution of the Youshui River, and strengthen the health protection and management of water by removing cattle circle, toilets and other pollution sources that around the drinking water intake points [13].

References
[1] Yang Z B 2010 Drinking water and health, Problems that should be paid attention to in medicine J. Med. Res. 39 pp 5-7
[2] Chen J Q 1996 Global change and sustainable developpment of water resources Adv. Water Sci. 3 pp4-9
[3] State Environmental Protection Administration of China 2002 Monitoring and analytic methods of water and wastewater 4th (Beijing: Environmental Science Press of China)
[4] The state bureau of quality and technical and National Environmental Protection Agency 2009 Water Quality-Guidance on Sampling Techniques (Beijing: Standards Press of China)
[5] Jiang H H, Zhu J P, Liang D H and Wu Z L 1999 The relationship between comprehensive pollution index assessment and water quality type distinguishing Environ. Monit. China 15 PP46 -48
[6] Guo J S, Wang H and Long T R 1999 Analysis and development of water quality evaluation method Chongqing Environ. Sci. 21 pp1-3
[7] Xu Z X 2005 Single factor water quality identification index for environmental quality
assessment of surface water *J. Tongji Univ. (Natural Science)* 33 pp321-325

[8] LIU S, Zhu J P and Jiang H H 2003 Comparison of several methods of environmental quality using complex indices *Environ. Monit. China* 15 pp33-37.

[9] Guo J S, Long T R, Huo G Y and Wang H 2000 A comparison of four methods of quality assessment *J. Chongqing Jianzhu Univ.* 22 pp6-12

[10] Lan W H and An H Y 2002 Discussion of methods of water quality assessment *Arid Environ. Monit.* 16 pp167-169

[11] Cheng X R, Fang Z and Xue Y W 2001 Monitoring and evaluation of water quality of southwest zone of East Lake *J. Wuhan Univ.* 34 p98

[12] Lucy O'Shea 2002 An economic approach to reducing water Pollution Point and diffuse sources *Sci. Total Environ.* 282 pp49-63

[13] Xiang Q, Liu C M and LI L J 2007 Discussion and Countermeasures on safety drinking water in the Rural Areas in China *Acta Geogr. Sin.* 62 pp907-916