Study on Water quality Monitoring Method of Jialing River based on Sentinel-2 MSI Sensor Data

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Abstract. Remote sensing monitoring has become an important means to evaluate urban water status, which plays the key role in maintaining the balance of urban ecological environment. In this study, based on the Sentinel-2 MSI sensor data, an inversion model of water quality parameters was established to monitor the concentration of chlorophyll a and suspended matter, and turbidity in some sections of the Jialing River. The results show that the inverted water quality parameters in this study are all within the normal range, and remote sensing technology can be effectively applied to regional water quality monitoring.

1. Introduction

With the rapid development of urbanization in China, industrial production, agricultural irrigation and people's daily water consumption are increasing steadily. The industrial wastewater and domestic sewage produced from human production are discharged into the river, resulting in the deterioration of river water quality, serious damage to the river ecosystem, and a great impact on the urban landscape and urban development. Meanwhile, this has caused serious harm to the regional ecological environment, living environment and people's health. Therefore, monitoring and controlling water pollution has become an urgent urban environmental problem [1-2].

Traditional water quality monitoring methods mainly use ground station monitoring, leading to limited monitoring scope, as well as difficulty in long-term continuous large-scale monitoring [3]. In contrast, remote sensing technology can quickly and continuously identify the changes of water quality distribution in the entire water area from the whole space field and multiple time series.

The concentration of chlorophyll a, suspended matter and turbidity in water are important index parameters for water quality monitoring [4]. Wang et al. used Landsat-8/OLI, FY-3A/MERSI and HJ-1B/CCD remote sensing images as data sources, combined with the measured chlorophyll a concentration and water spectral characteristics, to obtain the spatial distribution of chlorophyll a concentration in Jiaozhou Bay [5]. Song et al. chose Taihu Lake as the experimental area, compared and analyzed the TASSAN model, the ratio model and the near infrared estimation model to calculate the concentration of suspended solids, and finally concluded that estimation of suspended solids in Taihu Lake by using the peak height of near infrared (812 nm) yields the best result [6]. Keiner et. al used
Landsat-TM data to retrieve three water quality parameters: chlorophyll, suspended matter and soluble organic matter [7]. Dall et al. used MODIS images to construct three characteristic band inversion models to retrieve the concentration of chlorophyll a in water body [8].

The use of remote sensing technology for water quality monitoring has become comparatively mature, but most of the studies are mainly aimed at the inversion of a single factor of water. In this paper, based on the Sentinel-2 satellite images, the chlorophyll a concentration, suspended matter concentration and turbidity of the middle and lower reaches of the Jialing River are inversed, and the water quality in the study area is comprehensively discriminated and evaluated, which can assist the relevant departments to quantificationally analyze the pollution sources.

2. Area overview and data sources

2.1. Area overview
The Jialing River is composed of four major river systems: Xihan River, Bailong River, Qujiang River and Peijiang River. It flows through Shanxi, Gansu, Sichuan and Chongqing province, and finally merges into the Yangtze River at Chaotianmen in Chongqing. In recent years, with the development of industry, the growth of cities and the development of cascade power stations, the water pollution in the Jialing River basin is becoming more and more serious, and the water quality of some sections of the river can only maintain the III quality of surface water. Therefore, in this study, the middle and lower reaches with serious pollution are selected as the study area, and the location distribution is shown in figure 1.

In this paper, the river is simplified according to the spatial distribution, the study area can be roughly divided into five sections, in which R2 represents Qujiang River, R3 represents Peijiang River, and R1, R4 and R5 represent different sections of the Jialing River, respectively.

2.2. Data sources
The Sentinel-2 includes two satellites (A and B), each with a multispectral imager. The clipping swath width of the image obtained is 290km. The sensor contains 13 bands. The spectra cover the visible light to the shortwave infrared part. The spatial resolution includes 10m, 20m and 60m. The two satellites complement each other, and the revisit interval is 5 days.

3. Inversion of water quality parameters
The spectral information corresponding to the remote sensing image band varies, as the composition and concentration of the water quality parameters change. Thus, the model can be established according to the relationship between the spectral information of the remote sensing image and the water quality parameters.
In this paper, the model analysis method is used to invert the water quality parameters such as chlorophyll a concentration, suspended matter concentration and turbidity in the study area, so as to obtain the spatial distribution of water quality.

### 3.1. Inversion of chlorophyll a concentration

The concentration of chlorophyll a is an important index to evaluate the eutrophication and pollution of water body. The spectral information of remote sensing images varies with the concentration of chlorophyll a in water body. In general, the spectral characteristic of water containing chlorophyll a is the highest in the near infrared band and the lowest in the red band [9]. Therefore, in this paper, the red band and near red band of the image are used to invert the concentration of chlorophyll a. The inversion model is expressed as:

$$C_{chl} = \left(113.36 \times \left(\frac{1}{R_{rs}(665)} - \frac{1}{R_{rs}(704)}\right) \times R_{rs}(740)\right) + 16.45^{1.124}$$  \hspace{1cm} (1)

where, $C_{chl}$ is the concentration of chlorophyll a, whose unit is mg·m$^{-3}$; $R_{rs}(665)$, $R_{rs}(704)$ and $R_{rs}(740)$ are the remote sensing reflectance data of Sentinel-2 MSI images at 665nm, 704nm and 740nm, respectively.

### 3.2. Inversion of suspended matter concentration

The spectral information of the water body with higher suspended matter concentration is different from that of the normal water body. The reflectivity of the normal water body is stronger in the blue-green band of visible light, while the reflectivity of infrared and near infrared band is lower. The reflection of the water body with higher suspended matter concentration has the phenomenon of ‘red shift’ [10]. Therefore, the differences of green and red bands in remote sensing images are selected to retrieve the concentration of suspended matter in water, whose expression is as below:

$$C_{spm} = 255.78 \left(\frac{R_{rs}(655)}{R_{rs}(561)}\right) - 166.89$$  \hspace{1cm} (2)

where, $C_{spm}$ is the concentration of suspended matter in g·m$^{-3}$; $R_{rs}(655)$ and $R_{rs}(561)$ are the remote sensing reflectance data of red band and green band light of remote sensing images, respectively.

### 3.3. Inversion of turbidity

Turbidity reflects the hindered degree of light transmission in water body. The scattering and absorption of incident light by suspended matter or soluble matter in water body will cause the attenuation of incident light, then affect the heat absorption and appearance of water body. Its inversion model is as follows:

$$Y_{tur} = 393.56 \frac{R_{rs}(665)}{R_{rs}(492)} - 232.54$$  \hspace{1cm} (3)

where, $Y_{tur}$ is the turbidity, NTU; $R_{rs}(665)$ and $R_{rs}(492)$ are remote sensing reflectance of red light and blue light corresponding to sensor data, respectively.

### 4. Inversion results and analysis

#### 4.1. Inversion results and analysis of chlorophyll a concentration

With the chlorophyll a concentration inversion model, the inversion experiment of chlorophyll a concentration in the study area was carried out, and the spatial distribution of chlorophyll a concentration was obtained, as is shown in figure 2. The chlorophyll a concentration in different area of the study area is counted, as is shown in Table 1.
Table 1  | Statistical results of chlorophyll a concentration in the study area

| Global statistics (mg·m⁻³) | Section mean value (mg·m⁻³) |
|-----------------------------|------------------------------|
| Max                         | Min                          | Mean                       |
|                            | R1                           | R2                         | R3                         | R4                         | R5                         |
| 7.38                       | 3.42                         | 5.83                       |

Table 1 illustrates that the chlorophyll a concentration in the study area is mainly distributed between 3.42 and 14.38 mg·m⁻³, and the average chlorophyll a concentration in the study area is 6.19 mg·m⁻³. Among all the sections, the average chlorophyll a concentration of R4 was the highest (6.53 mg·m⁻³), followed by that of R2 (6.22 mg·m⁻³). The lowest one appeared in R3 (4.56 mg·m⁻³). The chlorophyll a concentrations of R1 and R5 were almost the same, which were 5.92 mg·m⁻³ and 5.93 mg·m⁻³, respectively.

4.2. Inversion results and analysis of suspended matter concentration

Based on the suspended matter concentration inversion model, the suspended matter concentration inversion experiment was carried out. The spatial distribution of suspended matter concentration in the study area was obtained, as is shown in figure 3. The suspended matter concentrations in different area is statistically analyzed, with results shown in Table 2.

Table 2  | Statistical results of suspended matter concentration in the study area

| Global statistics (g·m⁻³) | Section mean value (g·m⁻³) |
|---------------------------|----------------------------|
| Max                       | Min                        | Mean                       |
|                            | R1                         | R2                         | R3                         | R4                         | R5                         |
| 9.37                      | 2.53                       | 6.04                       |

Table 2 indicates that the suspended matter concentration in the study area is distributed within 2.53 and 9.37 mg·m⁻³, and the average is 6.04 g·m⁻³. Among all the sections, the average suspended matter concentration of R5 was the highest (7.32 g·m⁻³), followed by that of R2 (6.41 g·m⁻³). The lowest one appeared in R3 (4.31 g·m⁻³). The suspended matter concentrations of R1 and R4 were 5.95 g·m⁻³ and 6.23 g·m⁻³, respectively.

4.3. Inversion results and analysis of turbidity inversion

By solving the turbidity concentration inversion model, the spatial distribution of turbidity concentration was obtained, as is shown in figure 4. The turbidity concentration in different area is statistically analyzed, with results shown in Table 3.

Table 3  | Statistical results of turbidity concentration in the study area

| Global statistics (NTU) | Section mean value (NTU) |
|-------------------------|--------------------------|
| Max                     | Min                      | Mean                       |
| 10.22                   | 3.07                     | 6.75                       |

| R1 | R2 | R3 | R4 | R5  |
|---|----|----|----|-----|
| 6.37 | 6.86 | 4.62 | 6.67 | 9.25 |
Table 3 implies that the turbidity concentration in the study area varies between 3.07 and 10.22 NTU, and the global average in the study area is 6.75 NTU. Among all the sections, the average turbidity concentration of R5 was the highest (9.25 NTU), followed by R2 (6.86 mg·m⁻³). The lowest value appeared in R3 (4.62 NTU). The turbidity concentrations of R1 and R4 were 6.37 NTU and 6.67 NTU, respectively.

5. Conclusion and discussion

The water quality parameters of water body are sensitive to the infrared and near infrared bands of remote sensing images, in which the spectral characteristics of polluted water bodies are obviously different from those of clean water body. This property can be used to identify the water quality of water body. In this paper, the water quality parameters of the study area are inverted based on the existing water quality parameter inversion models. By comparing the historical statistical data of the same period, it is found that the distribution range of the two is basically the same, and the inversion results can reflect the spatial distribution of water quality.

It should be noted that all the water quality inversion models carried out in this paper are general models, and the regional adaptability is not high. In the future, the inversion model of water quality elements in the study area should be combined with the field measured data to improve its regional applicability and inversion accuracy.

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