

Overview of Methods, Technologies, and Equipment for Measuring River Sediment Concentration

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Abstract

China has always attached great importance to the measurement of sediment concentration in rivers. When a large amount of sediment flows into rivers, it can cause a sharp increase in sediment concentration, leading to a series of natural disasters such as soil erosion. Soil erosion not only reduces soil fertility but also causes serious ecological damage and economic losses. Therefore, the methods and technical equipment for detecting river sediment concentration have important reference value and research significance. This article first starts with the impact of river sediment concentration on the water environment, and introduces traditional methods for measuring sediment concentration, such as filtration method, drying method, displacement method, etc; Then, the structure, principle, and application of current explored technologies such as isotopes and optics are elaborated, and the influence of sediment concentration on monitoring flow accuracy is derived using the ultrasonic time difference method as an example. Finally, by monitoring and predicting the sediment concentration of rivers in the Yellow River, Yangtze River, and Kashgar region of Xinjiang, possible directions for future measurement of sediment concentration in rivers are proposed.

Keywords

Soil Erosion; Sand Content; Measurement Method; Ultrasonic Time Difference Method.

1. Introduction

Hydraulic model test and modern measurement technology are a course combining theory and practice. In fact, there is some confusion in the listening theory. In this semester, I had the honor to participate in a project of river engineering model factory in Zhiyuan Building, and I had a full understanding of the theoretical knowledge of the textbook in practice. The selected topic is a review of river sediment content measurement method, technology and equipment, which is one of the topics of interest. This paper will briefly discuss the sediment content of rivers from its influence to how to measure and how to improve it.

2. The Severity of Soil Erosion was Judged from the River Sediment Content

2.1. Impact of Soil Erosion on Water Environment

The sharp reduction of water quantity is the main impact of soil erosion on the water environment, and even leads to water depletion in severe cases. Moreover, soil erosion will also make the river sediment content is too large will appear a large amount of siltation leading to the reduction of water.^[1] Soil erosion is one of the main causes of flood disaster. Soil erosion can lead to a decrease in surface water storage capacity. When faced with strong and heavy precipitation, due to the weak surface water storage capacity, the probability of water logging disaster increases, and the harm of the formation also increases. In addition, soil erosion will

not only cause floods and damage the water environment, but also increase the probability of natural disasters such as mudslides and landslides, posing a threat to the safety of local residents.

2.2. The Seriousness of Soil Erosion

Currently, soil erosion is severe in many parts of China and the sediment content of rivers in each region is increasing. For example, the Xijiang River is the largest river in the Pearl River basin, with a high sediment concentration, accounting for a large proportion of the sediment from the Pearl River into the sea. According to the data of the Gaoyao Hydrology Station, from 1962 to 2012, the annual average sediment transport capacity of the Xijiang River was 68.14 million tons^[2], Accounting for about 88% of the total sediment transport into the sea in the Pearl River basin. Such a high sediment concentration makes the Pearl River Estuary siltation serious, and also causes serious harm to the shipping, hydropower, aquatic products and other undertakings in the Xijiang River Basin. Therefore, it is urgent to improve the sediment content to prevent the occurrence of soil erosion. Then we should invest more research and improve the methods and technology.

3. The Direct Measurement Method and Principle Analysis of Sediment Content

3.1. Dryer Method

Drying method, also known as weighing method, that is, take a certain amount of samples, measure its original weight and the weight after drying, so as to determine the sediment content in muddy water. The sand content of the two forms can be measured by drying methods^[3]: Weight sand content ρ_m (kg / kg) and volume sand content ρ_v (m^3/m^3), The relation between the two is available in equation (1):

$$\rho_m = \rho_s \rho_v / (1 - \rho_v) \rho_w + \rho_s \rho_v \quad (1)$$

With the use of electronic scales, the weighing accuracy is greatly improved. However, because the drying method needs to treat the measured sample for drying, the drying temperature is generally 105°C, and the heating takes more than 10 hours. The requirements for the drying temperature and heating time also make the whole measurement process time-consuming and laborious. Therefore, the specific gravity method is usually used in the field measurements.

3.2. Specific Gravity Method

The specific gravity method determines the sediment concentration based on the influence of the sediment on the specific gravity. During the measurement process, a specific gravity meter, a balance and a measuring cylinder can also be used. If the total weight of the measured sample is G (kg), the volume is V (m^3), Then the sediment concentration (kg/ m^3) in the sample is:

$$\rho = \frac{\left(\frac{G}{V} - \rho_w \right) \cdot \rho_i}{\rho - \rho_w} \quad (2)$$

The device that uses this method to measure sediment content is simple, faster and more straightforward. However, when the sediment concentration is high, it is difficult to accurately read the data from the measuring cylinder, which partly affects the accuracy of the

measurements. In terms of the measurement accuracy, the drying method has a higher accuracy than the specific gravity method.

3.3. Replacement Method

The steps of the replacement method are: first take the water of the river as samples, measure the volume of the water sample, precipitate and concentrate the water sample; then pour the concentrated water sample into the specific gravity bottle, determine the mass of the concentrated water sample and the temperature of muddy water, and the sediment quality is calculated according to (3)^{W s}.

$$W_s = \frac{\rho_s}{\rho_s - \rho_w} (W_{ws} - W_w) = K(W_{ws} - W_w) \quad (3)$$

4. Indirect Measurement Method and Principle Analysis of Sediment Content

4.1. Capacitive Method

The capacitive method utilizes the electrophysiological characteristics of the change of the sediment content in the mud-water mixture. It measures changes in sediment concentration by measuring changes in capacitance. Due to the significant effect of temperature on capacitance, the output voltage at both ends of the capacitor showed a nonlinear increase with increasing temperature and soil salt content. Moreover, the influence of the runoff velocity limits the applicability of the capacitance method. During the process of slope erosion, under natural conditions^[3], It is difficult to determine the change in sand content by measuring the capacitance change.

4.2. Isotope Sand Detector

4.2.1. Isotopic Sand Measurement Principle

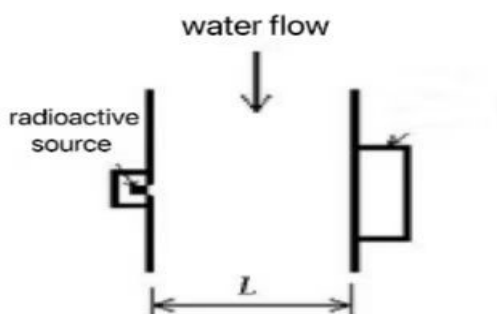


Figure 1. Isotope sediment measurement principle diagram

The isotope sand analyzer emits γ -rays from nuclear radioactive sources (Cs (cesium) or Am (Americium) elements) to penetrate the muddy water in order to measure sediment concentration.^[4] The isotope sand analyzer consists of a radioactive source γ radiation detector (see Figure 1). When the sand containing water flows between the radiation source and the detector, the radiation γ radiation from the radiation source passes through the sandy water and enters the detector. The energy radiated by the detector circuit γ is converted into a voltage signal, which is sent to the computer for processing. The higher the sand content in the water, the more radiation absorbed by γ sediment, the more radiation into the detector, the less γ rays, the smaller the converted voltage signal. The intensity of γ -ray transmission and the sand content have a certain relationship, which can be calculated by using this principle.

In Figure 1, the output signal decreases exponentially as the γ -rays pass through muddy water with thickness L [4] U_w , And is determined by Equation (4). If ρ is the density of muddy water and the output voltage of clear water, then the output voltage U of muddy water is:

$$U = U_w e^{-\mu m \rho L} \quad (4)$$

μ Where: m is the mass absorption coefficient of muddy water.

When the structure of the sediment detector is fixed, the calculation formula of sediment content S can be derived from the relationship between muddy water density and sediment content:

$$S = k \ln \frac{U_w}{U} \quad (5)$$

Where: k is the coefficient related to the mass absorption coefficient, density and muddy water thickness of pure water and dry sand. Using the relationship between sand content and output voltage in formula (5), measure the change curve of output voltage with the sediment content of muddy water by fitting the curve (calibrate with measured sand content in practical application). During the application, the sand content is calculated from the output voltage.

4.2.2. Main Characteristics of Isotopic Sand Measurement

Isotopic sand measurement system does not require manual intervention, data collection, transmission, [5] All processing is done automatically completed by the system.

Advantages: Isotopic sand measurement has the characteristics of high detection efficiency, good stability, wide range, and strong adaptability to the underwater environment. When the sand content is high, the sand measurement accuracy is relatively high. However, [6] due to the impact of radiation source radiation problems and the high requirements for green environmental protection, its promotion and application will be affected.

4.3. Water Sand Content Monitoring Technology of Transmission Spectrum

4.3.1. Research Background

Water sediment content monitoring has always been an important content of hydrological [7] observation and water conservancy construction. It is of great practical value to monitor sediment content in water in real time. [8] Traditional manual measurement methods are inefficient and monitored in real time. Although monitoring methods based on ultrasound and other instruments can achieve real-time measurement of sediment concentration in water bodies, they have their own shortcomings in safety, stability and measurement range. Material content monitoring technology based on spectroscopy has the advantages of fast, nondestructive, accurate and efficient, and has been widely used in various fields in recent years, providing new ideas and methods for the online monitoring of water and sand content. However, the direct transmission spectrum is susceptible to instability of the light source and external stray light, leading to spectral noise. Meanwhile, the measuring range of the strength saturation of the equipment is limited. on this basis, [9] We focus on direct transmission spectral noise treatment and multilevel calibration technology, and design a fast, large-scale online monitoring system based on transmission spectrum.

4.3.2. Experimental Principle

We analyze the concentration of water and the intensity of transmitted light. An experimental system for monitoring water and sand concentration using the cuvette support

laboratory,^[10]The standard solution was prepared to calibrate the actual correlation between the intensity and the sand content.

4.3.3. Experimental process

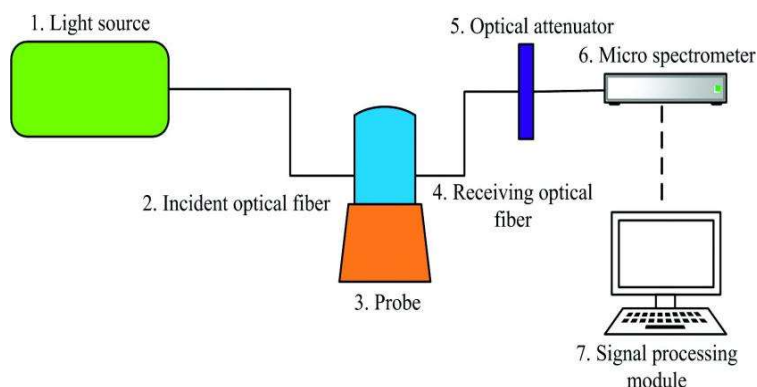


Figure 2. experimental flowchart

Advantages: Because the direct transmission spectrum measurement proves the relationship between the transmitted light intensity and the water sediment content, it shows that the method can achieve a large number of range and high precision sediment content stable measurement, which has the value of engineering application.

5. The Influence of Sediment Content on Monitoring Flow Takes the Ultrasonic Method as an Example

5.1. Research Background

If there is sediment in the water flow, it has a certain impact on the measurement accuracy of the flow flow, which has always been one of the important problems of hydraulics. Taking the ultrasonic time difference method as an example, studying the accuracy of the flow rate can analyze the influence of its accuracy^[11].

5.2. Test System

5.2.1. Basic Equipment for Test Tank and Flow Measurement

This test was conducted in an open channel sink in the room^[12], It mainly includes four parts of stilling pool, open channel section, tail pool and backwater pipe. As shown in Figure 3.

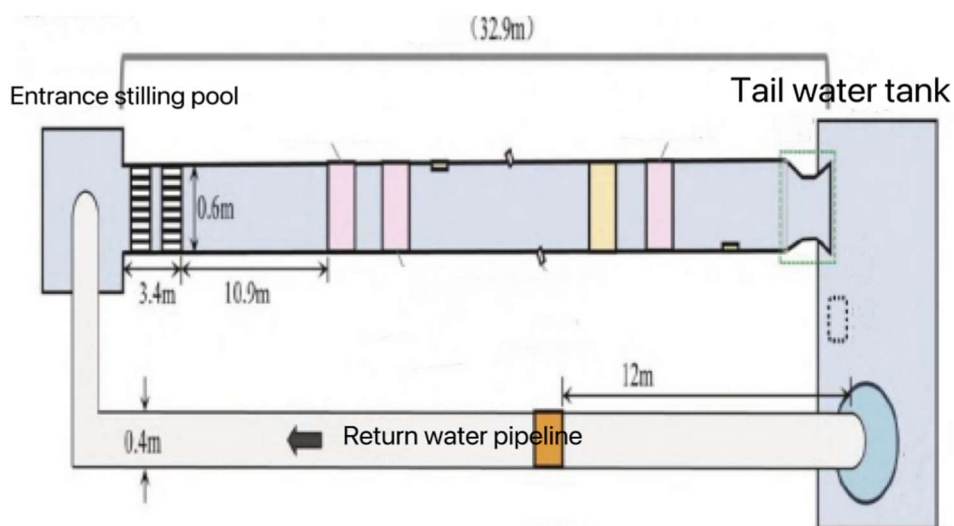


Figure 3. Open channel water tank diagram

5.2.2. Flow Measurement by Ultrasonic Time Difference Method

The ultrasonic time difference method calculates the flow rate v by measuring the time difference between the ultrasonic down current crossing time t_1 and the counter current crossing time t_2 (see Figure 4 for principle diagram). The transit time t_1 and t_2 are, respectively:

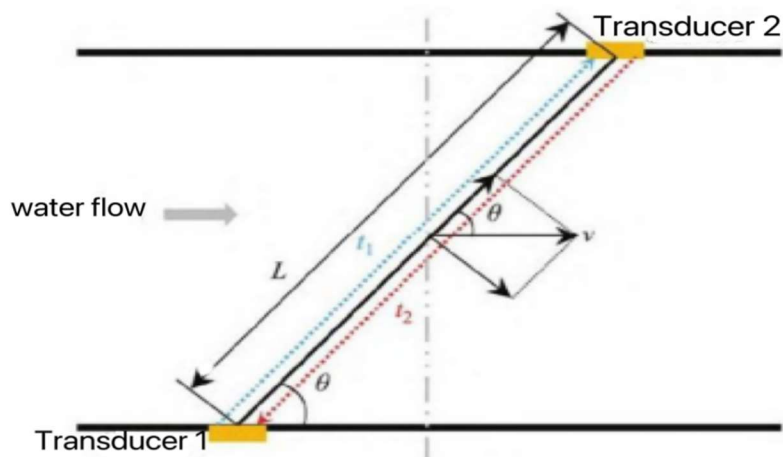


Figure 4. Flow chart of ultrasound time difference method

$t_1 = L(c + v \cos \theta) + \tau$ $t_2 = L(c - v \cos \theta) + \tau$, c and v are the sound and flow rates respectively, and τ is the circuit electronic time delay. The flow rate v can be obtained by different algorithms from t_1 and t_2 .

Due to the flow velocity v measured by the time difference method, the flow velocity can be further determined by the velocity area method. The vertical distribution of the open channel flow rate is not uniform. To improve the measurement accuracy, multiple layers of transducers can be arranged in different water depths, with alternating one or two pairs of transducers on each layer. According to the layered flow rate of the flow layer where each transducer is located, the flow rate of each layer is calculated layer by layer to obtain the total flow rate^[13].

Advantages: The quantitative research results can provide guidance for the optimal design of ultrasonic flow measuring equipment, so as to improve its adaptability and accuracy in open channel sand flow measurement and promote its application.

6. Research on the Sand Content Prediction of the Model

6.1. The Prediction of River Sediment Content in ARIMA Model

River sediment content prediction is very important to analyze river erosion and sediment change, and is an important basis for analyzing river erosion and sediment change.^[14]At present, many achievements have been made in the prediction of river sand content, among which the method of constructing autoregressive model combined with measured sand content data has high accuracy and strong applicability in predicting river sand content. Recently, ARIMA models with strong mathematical statistical function have been applied to multivariate prediction. Combining ARIMA model to predict the river sediment content in Kashgar, Xinjiang, and analyze the calculation accuracy of the model according to the measured sediment content data, which has important method reference value.

consult literature^[15], We can get the ARIMA model prediction map as shown in Figure 5 to get the following conclusion:

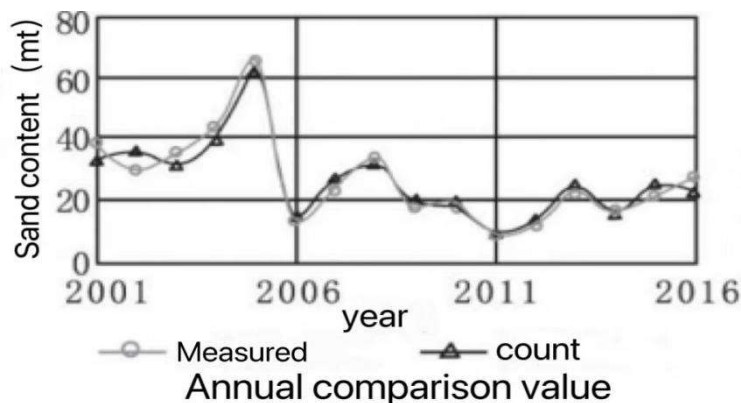


Figure 5. ARIMA model prediction chart

Combining the ARIMA model to predict river sediment content in Kashgar, Xinjiang shows that the model has good accuracy^[15]. The error of sand content prediction can be controlled within 20%, and its correlation coefficient can reach more than 0.70. It can be used to predict the annual sediment content of rivers in Kashgar, but the accuracy of predicting monthly sediment content still needs further analysis.

6.2. Analysis of Wavelet Neural Network Model

6.2.1. Research Background

In the process of river management, the sediment deposition will be evaluated, and the sand content of the river should be accurately grasped. The neural network model is relatively simple to operate but can not meet the accuracy requirements, so the wavelet neural network model is introduced^[16].

6.2.2. Model Principle

The wavelet analysis function is mainly formed by a basic single wavelet function, with α after horizontal displacement τ and scaling displacement.^[17]Then internally integrate with the wavelet analysis signal function $f(x) \in L_2(\mathbb{R})$. This integral process is called the wavelet function change process, and the specific expression of the wavelet change function is as follows:

$$W_{f(\alpha,\tau)} = \frac{1}{\sqrt{\alpha}} \int_{-\infty}^{\infty} f(x) \psi\left(\frac{t-\tau}{\alpha}\right) dt, (\alpha > 0) \tag{6}$$

Where τ is the horizontal displacement in the wavelet analysis function; α is the lateral expansion in the wavelet analysis function; t is the calculated moment.

6.2.3. Model Application

The model is applied in Tanghe. After the comparative analysis of annual scale sand content prediction and the comparative analysis of hourly scale sand content prediction, the improved wavelet neural network model is easier to converge and significantly improved than the traditional network model. Moreover, the improved predicted value of the wavelet neural network model has a good agreement with the measured value, which can be further popularized.

7. Research Progress

From the literature and online data, it can be concluded that the traditional sediment measurement method is still in use, and undergraduates will go to the laboratory to complete the traditional sediment measurement test during the study; isotope measurement, ultrasound

online technology, transmission spectrum online monitoring technology are the current research and promotion direction, because the accuracy is indeed smaller than the traditional measurement method.

8. Conclusion

The current research progress of sediment content measurement and monitoring technology has been mentioned above, so I think the conclusion is that the traditional measurement method is the foundation just like the foundation, and the isotope monitoring and later research model are the directions that will continue to investigate in the future. This paper is a topic of great interest to me, The whole idea is as follows: Why did the sediment content first start to prevent natural disasters? And the introduction of traditional direct measurement methods to several monitoring methods and techniques that are more recently available, What are their respective advantages that can be applied to what aspect, Since I studied the model course, I also searched some monitoring studies on sediment content in the model to other factors that it may affect, such as flow, That is a framework and all the ideas for my whole paper.

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