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Impact of tide on vertical Cu transport in a River-connected lake

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Abstract - A typical river-connected lake, Jinshan Lake, was selected as the study area. By the combination of field experiment, laboratory experiment and mathematical model, we plotted the relationship between the concentration of DCu-SCu and FDI, and constructed the mathematical model of the migration and transformation of HMCu in Jinshan Lake. We choose a typical diurnal tide to simulate and revealed the vertical migration characteristics of HMCu in Jinshan Lake during a diurnal tide. The results show that: (1) The release rate of DCu was proportional to FDI and background content, respectively. (2) Due to the nearby industrial enterprises and terrain characteristics, SA loads the most HMCu, the average concentration is 70.07mg/kg. According to the characteristics and geographical location of LC, the concentration of copper in the two states fluctuates greatly (DCu: 43.20~74.77 mg/kg, SCu: 53.63~74.67mg/kg). The fluctuation trend of SCu in ZA is significantly different from that in other areas, which mainly due to the complex hydraulic distribution and the sorption-desorption process of HMs in sediment particles. The hydraulic disturbance of JG is the least and relatively stable, which is the farthest from the inlet of the lake and is the least affected by the Yangtze river. (3) The FDI in a diurnal tide reaches the suspension condition of fine sediment particles in each region. FDI and sediment concentration on the vertical exchange of two - state Cu is significant.

keywords: river-connected lake; Cu, Jinshan Lake, tidal action

1. Introduction

Heavy metal (HM) pollution in lakes has become a global environmental and public health concern due to its high toxicity, persistence and difficulty to be degraded (Abdullah and Royle, 1972; Jerome and Henry, 1983; Zahra et al., 2014). Rapidly growing anthropogenic activities, such as industrial and agricultural development, city construction and exploitation of mineral resources, have made the hazard of HMs in lakes a common and far reaching problem (Guo et al., 2015; Ramamoorthy and Kushner, 1975). Due to the toxicity, abundance, persistence, and subsequent bio-accumulation of these metals, lakes are facing with serious threatens to their roles in freshwater supply, fishery, biodiversity preservation and ecological balance maintenance (Robert et al., 1972; Gunvor et al., 2005; Lee et al., 2000; Miller et al., 2014; John and Barbara, 2003). Examples can be observed in Lake Burullus (one of the most important lakes in north Delta of Egypt) (Yasser et al., 2017), Lake Victoria (the largest of the African Rift lakes) (Andama et al., 2016), Lake Erie (North America) (Opfer et al., 2011), Lakes Biwa and Kasimagaura (Japan's largest lakes) (Mito et al., 2004), Lake Taihu (the 3rd largest freshwater lake in China) (Li et al., 2017), Lake Balaton (the largest lake in Central Europe) (Nguyen et al., 2005), and Lake Moreno Oeste (the mountain lake in Patagonia) (Guevara et al., 2010).

HMs always exist as sedimentary and suspended phase in lake. Their influence towards environment will vary with different form of HMs(eg: Suspended metal in Lake Tshangalele, Katanga province, Democratic Republic of

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Congo) (Squadrone et al., 2016) will accumulate in fishes and be consumed by local inhabitants. Due to sediments not only acts as a reservoir, but also the potential source of pollutants in the aquatic system (Varol, 2011; Nemati et al., 2011), it plays a significant role of reserving HMs, and resuspending by flow disturbance.

HMs entering lakes from diverse sources are finally deposited in the sediments, apart from biological consumption (Linda et al., 2007). However, these particulate phase metals may not permanently sequestered in sediments. They may be resuspended by wave and current-induced disturbance intensity, biotic and abiotic speciation, and entrance to the trophic web by benthic organism, causing secondary contamination and hazards to overlying water, and critically degrade the aquatic system (Suresh et al., 2012d; Akcay et al., 2003; Frederick and Robert, 1981d). Hence, sediment as an integral and dynamic part of the lake is both a carrier and a potential source of HM contaminants. Given that most HMs accumulated in the surface sediments within 5~10 cm (Zahra et al., 2014; Zhang et al., 2015d) and suspended in the overlying water, which dominate the HMs' dynamic transportation between these two phases, it's essential to figure out the particular exchange mechanism.

The recent study of HM vertical distribution in lakes mainly focus on the characteristics of distribution and its causes. For example, Mohammed and Babatunde studied key HMs transformation processes are adsorption and plant uptake (Mohammed and Babatunde, 2017), Li and Gao found that the distribution of Cr, Cu, Pb and Zn were controlled by both absorption of fine-grained sediment and colloid flocculation (Li and Gao, 2012), Yang et al. collected sediment cores from Taihu Lake, and determined that the total content of Cd, Pb, Cu, and Cr decreased with increasing depth (Yang et al.,). These researchers provided useful information to local managers and decision makers. However, most of them were traditionally confined by taking ship-borne sediment samples and analyzing these them in a laboratory. Moreover, many studies dealing with particulate metals in the lake suffer from not explicitly considering the different particle-size classes, which have significant consequences for entrainment, transport and deposition of HMs.

In this work, against at the lake influenced by tidal action with complex flow disturbance intensity, we selected Cu as the HM impact factor(HM_{Cu}), Jinshan Lake as the study area. Jinshan Lake, with an area of 6.8 km^2 and a volume of 16 million m^3 on average, is located at middle and lower reaches of the Yangtze River in Jiangsu Province, China (Fig. 1). It is one of the most typical river-connected lakes in China. The lake receives water from Leading Channel and drains into the Yangtze through Jiaonan Gate. Due to the dual effects of upstream runoff and downstream tidal current, the spatial and temporal distribution of water between Jinshan Lake and the Yangtze River is unevenly, and the hydrodynamic conditions are changeable, which lead to the complicated characteristics of the lake water environment. We used laboratory experiment and numerical simulation to (1) investigate the Cu vertical transport mechanism associated with varied grain size between the overlying water and the surface sediment, (2) develop and validate an improved metal model that places particular emphasis on Cu transport with size fractionated sediments, (3) use numerical simulation to quantitatively reveal the transportation of HM between sedimentary and suspended phases within one diurnal tide in meso-timescale. This study may provide insights for policy makers who are attempting to prevent HM pollution and improve the water quality of inland freshwater lakes.

2. Methods and Materials

2.1 study area

Influenced by tides in the Yangtze River, non-regular semidiurnal tides occur in the Jinshan Lake with high and low tides twice during a day. The rising tides last for 3.42 hours and the ebb tides last for 9 hours on average. The low tides usually occur at 18:00 and 6:00 the next day, and high tides occur at 21:00 and 9:00 the next day. Based on years of statistical data, the water level in Jinshan Lake is 3.87m in flood season and 1.97 m in dry season on average. The tidal range is smaller in flood season, about 1.16m, while larger in dry season, about 1.55 m. The surface area of Jinshan Lake is 6.8 km^2 on average, and the regulation storage is 1.6×10^7 m^3 on average, which frequently change with tide level.

Hydrology and the concentration of Cu for simulation experiment were obtained by field investigation in 2014. Particles size data were collected from the *Hydrological Yearbook of the Yangtze River Basin, China*.

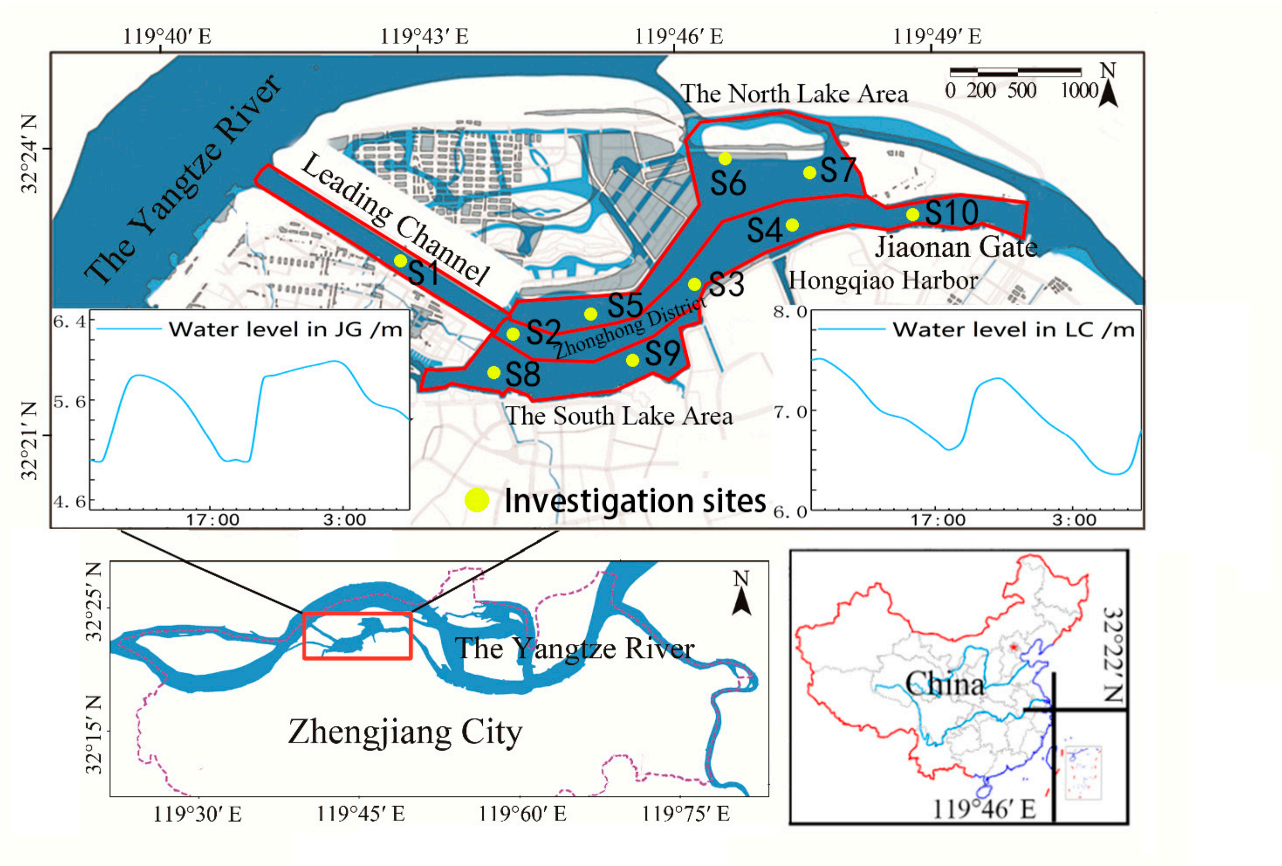

Fig.1 Research area and monitoring points

2.2 Field Investigation

To study the content distribution of Cu in the sediment of the Jinshan, field investigation was conducted on June 18, 2014. For the representation of investigation sites, the Jinshan Lake was divided into five districts according to the distinction of water depth of the lake, which is Leading Channel (LC), Zhonghong Area (ZA), North Lake Area (NA), South Lake Area (SA), Jiaonan Gate (JG), respectively. Ten investigation sites（32°13′14.83″ N~32°13′28.08″ N, 119°25′31.09″ E~119°28′42.84″ E）were set in the lake according to the environmental geographic characteristics (Fig. 1). 10 cm of the surface sediment at each site was collected with the Petersen sampler. Following the requirements for preservation and testing of Cu, the samples were kept at low temperature. After being dried in a natural condition, the samples were ground to tiny size with impurities like plants removed and passed through the sieve of 0.149 mm aperture. For testing, the samples were then digested with a HCl-HNO_3-HF-$HClO_4$ solution.

2.3 Laboratory Experiment

To study Cu vertical transportation mechanism in Jinshan Lake under different disturbance intensity, we carried out experiment in the Molecular Biology Laboratory of Nanjing Geography and Limnology Institute, Chinese Academy of Sciences in September 2014. The annular flume (Fig. 3) was applied to the simulation of flow process. The device is composed of flume and top lid, which could rotate independently with the control of computer system. The flume and top lid are made of acrylic material with the outer diameter of 240 cm and the inner diameter of 160 cm. The annular water channel is 40 cm in width and 41 cm in depth. There are several sample outlets set in different height on the external wall of the flume. The top lid could go up and down controlled by the computer system. The flume and top lid rotate in opposite directions driven by the continuously variable motors, generating water flow under the effect of shear stress. Due to the curvature, rotation of the flume will bring centrifugal force outward along the radius on water flow, generating outward secondary flow. When top lid rotates in the opposite direction, it will produce centrifugal force inward along the radius on water flow, creating inward secondary flow. Since centrifugal force is related to rotation rate, through adjusting the rotation rates of top lid and flume, the centrifugal force can cancel each other out, so as to eliminate secondary flow (Li et al., 2004). Before the experiment, a small amount of sawdust was used as a tracer indicator for calibrating the rotation rates of the top lid and flume to generate expected currents.

Because the sediments of Jinshan Lake are marked by a prevalence of the particles in the range of 8-63μm, three sediment size classes, fine-silt (8-16μm), medium-silt (16-32μm), and coarse-silt (32-63μm), were determined for the experiment. The separation of sediment into different sizes was finished with a modified elutriator apparatus (Follmer and Beavers, 1973). Because Cu release amount varied under different initial content conditions, we set three groups of releasing experiment. Sediment for each experiment group was the original natural sediment deposited bed surface of Jinshan Lake, and the covering water was tap water with HM content below the detection limit. When the sediments were whisked until smooth, they were spread at the bottom of the flume with the thickness of 6 cm. After one day's natural sedimentation till dense for the sediments, water was slowly injected into the flume to the water level of 24 cm. To fit the measured flow velocity range of Jinshan Lake, flow disturbance intensity in the flume was set as 0 $m^2 \cdot s^{-2}$, 0.005 $m^2 \cdot s^{-2}$, 0.02 $m^2 \cdot s^{-2}$, 0.045 $m^2 \cdot s^{-2}$, 0.125 $m^2 \cdot s^{-2}$, 0.245 $m^2 \cdot s^{-2}$ for each group of experiment by adjusting the rotation rate of the flume and top lid. Rotation for each velocity condition lasted for 30 minutes for a stable flow. Since we focused on effects of dynamic disturbance on transportation of HMs, pH, temperature and other factors which also make contributions were adjusted to a consistent level for the experiment with the temperature at 20°C and pH at 7.0. Water samples were taken from the outlets on the flume wall to test dissolved and suspended Cu content, and the two together was the total Cu amount. Vacuum filtration was applied to water samples with 0.22 μm glass fiber microporous filtration membrane to separate water and suspended sediment. The separated water samples were stored in the refrigerator at 4°C with HNO_3 added to the samples which make $pH<2.0$. Dissolved Cu content was tested by inductively coupled plasma mass spectrometry (ICP-MS). For the separated suspended sediment samples, after being dried with impurities removed, they were finely ground to pass through 100 mesh sieve and were stored in sealed polyethlene bags. Suspended Cu content was tested by ICP-MS after digestion.

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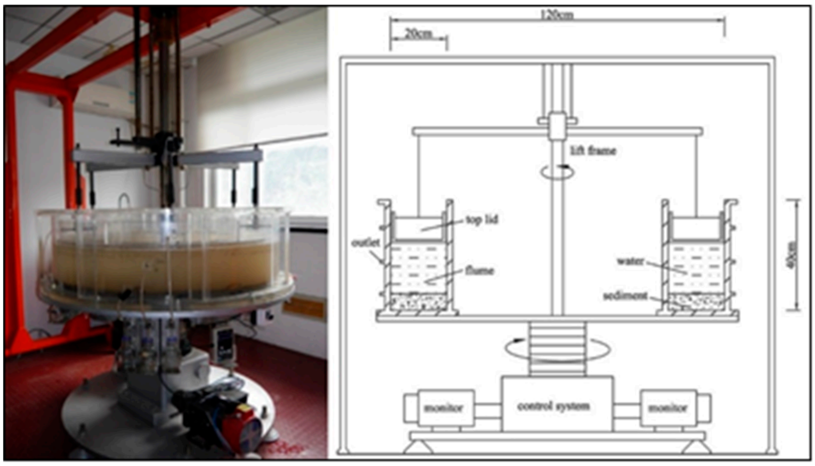

Fig.2 Schematic diagram of annular tank test device

2.4 Numerical Model

2.4.1 Controlling Equation

Here, two-dimensional mathematical model coupling water flow, suspended particles and HMs are applied to the simulation of Cu migration process in Jinshan Lake. The basic control equation is shown as in equation (1).

$$\begin{cases} \frac{\partial h}{\partial} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \\ \frac{\partial (hu)}{\partial t} + \frac{\partial (hu^2+gh^2/2)}{\partial x} + \frac{\partial (huv)}{\partial y} = gh(s_{0x} - s_{fx}) + hfv + hF_x \\ \frac{\partial (hv)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2+gh^2/2)}{\partial y} = gh(s_{0y} - s_{fy}) + hfu + hF_y \\ \frac{\partial (hS)}{\partial t} + \frac{\partial (huS)}{\partial x} + \frac{\partial (hvS)}{\partial y} = \frac{\partial}{\partial x}\left(D_x h \frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial x}\left(D_y h \frac{\partial S}{\partial y}\right) + F_s \\ \frac{\partial (hC_u)}{\partial t} + \frac{\partial (huC_u)}{\partial x} + \frac{\partial (hvC_u)}{\partial y} = \frac{\partial}{\partial x}\left(E_x h \frac{\partial C_u}{\partial x}\right) + \frac{\partial}{\partial x}\left(E_y h \frac{\partial C_u}{\partial y}\right) + S_{Cu} \end{cases} \quad (1)$$

where h is water depth; t is time; u and v are the depth-averaged velocity components in the x and y directions respectively; g is acceleration of gravity; s_{0x} and s_{fx} are the bed slope and friction slope in the x direction; s_{0y} and s_{fy} are the bed slope and friction slope in the y direction; F_x and F_y are the friction force components in the x and y directions, they can reflect the wind stress; f is Coriolis parameter.

S is suspended particle concentration; D_x and D_y are the dispersion coefficient of suspended particles in the x and y directions under dynamic condition; E_x and E_y are the dispersion coefficient of cadmium in the x and y directions under dynamic condition; S_{Cu} is the source-sink vector of Cu; F_s is the source-sink vector of suspended particles, representing the net flux of rising and settling particles, which could be expressed as in equation (2) according to the concept of shear stress.

$$F_s = -A\omega S\left(1 - \frac{\tau}{\tau_d}\right) + BM\left(\frac{\tau}{\tau_e} - 1\right),\ A = \begin{cases} 1, & \tau \le \tau_e \\ 0, & \tau > \tau_e \end{cases},\quad B = \begin{cases} 1, & \tau \ge \tau_e \\ 0, & \tau < \tau_e \end{cases} \quad (2)$$

Where M is the coefficient of scouring; ω is the flocculation settling velocity of particles; τ is the shear stress on lake bed surface; τ_d is the critical deposition shear stress; τ_e is the critical suspension shear stress; when $\tau \geq \tau_e$, particles suspended from sediment surface, and scour occurs; when $\tau \leq \tau_d$, particles settle into sediment, and deposition occurs. For numerical simulation, critical deposition shear stress is usually a little smaller than critical suspension shear stress(Cao, Wang et al., 1993). To simplify the calculation, critical deposition shear stress and critical suspension shear stress are considered the same in this paper, and directly determined by the experiment result. Then velocity at neither deposition nor suspension state will not be in a range (from critical deposition velocity to critical suspension velocity), but a "point" (critical suspension velocity).

S_{Cu}, the source-sink vector of Cu, which is determined by the experiment results, is a function related to water flow and initial Cu content in sediment, shown as in equation (3).

$$S_{Cu} = \begin{cases} -20.7\tau^2 + 24.99\tau - 0.483, \ C_{u_0} \geq 0.64\ mg/kg \quad (R^2 = 0.9644) \\ -0.64\tau^2 + 10.71\tau, -0.43 < \ C_{u_0} < 0.64\ mg/kg \quad (R^2 = 0.9711) \\ -7.53\tau^2 + 12.49\tau - 0.19, \ C_{u_0} \leq 0.43\ mg/kg \quad (R^2 = 0.9901) \end{cases} \tag{3}$$

where Cu_0 is the initial Cu content in sediment in each calculation cell, mg/kg; τ is the shear stress on lake bed surface, which is determined by velocity and water depth.

2.4.2 numerical solution

The basic controlling equations are combined to be calculated. The formula (2) can be written as the following unified form (Ding, Pang et al., 2004).

$$\frac{\partial_q}{\partial_t} + \frac{\partial f(q)}{\partial_x} + \frac{\partial g(q)}{\partial_y} = b(q) \tag{4}$$

Where q is the vector of the conserved physical quantities; $f(q)$ and $g(q)$ are respectively the flux vectors in the x and y directions; $b(q)$ is the source-sink vector; the detailed expressions are as follows:

$$\begin{cases} q = (h, hu, hv, hS, hC_u)^T \\ f(q) = \left(hu, hu^2 + \frac{gh^2}{2}, huv, huS, huC_u\right)^T \\ g(q) = \left(hv, huv, hv^2 + \frac{gh^2}{2}, hvS, hvC_u\right)^T \\ b(q) = (0, gh(S_{0x} - S_{fx}) + hfv + hF_x, gh(S_{0y} - S_{fy}) - hfu + hF_y, \nabla \cdot (D_i \nabla(hS)) + Fs, \nabla \cdot (E_i \nabla(hC_u)) + S_{C_u})^T \end{cases} \tag{5}$$

Where superscript T is the transposing operator; ∇ is the gradient operator. Developed in the framework of finite volume method (FVM) on an unstructured grid the flux vector splitting (FVS) scheme was employed to calculate the normal numerical flux of variables across the interface between grids. Detailed calculation steps were documented in references(Zhao, Chen et al., 2000; Hu, Tan ET AL., 1995).

2.4.3 Numerical experiment

The model was calibrated and validated with the measured Cu content in Jinshan Lake in July 2014. Based on the terrain data, Jinshan Lake was divided into 2642 meshes with 2880 nodes by

Gambit software, and the mesh size was 50×50m. The calculation boundaries were the flow discharge of the LC, DCu content of the Yangtze River, and the water level in JG. The time step Δt was set as 1s for the calculation stability and accuracy.

3 Results and Discussion

3.1 Distribution of copper in sediment

Based on the measured data, we plotted the spatial distribution of HMCu by R language. The results(Fig.3) showed that the spatial distribution of HMCu in sediment is uneven. SA has a higher concentration of HMCu in Sediments (the average value is 65.6mg/kg), while the NA has the lower level (the average value is 52.9mg/kg). The high concentration in SA was mainly caused by the anthropological activities because that SA is near to the centre urban in Zhenjiang City, in which case some industrial source and urban non-point source entered into the lake through two rivers: Yunliang River, Hongqiao Port, respectively.

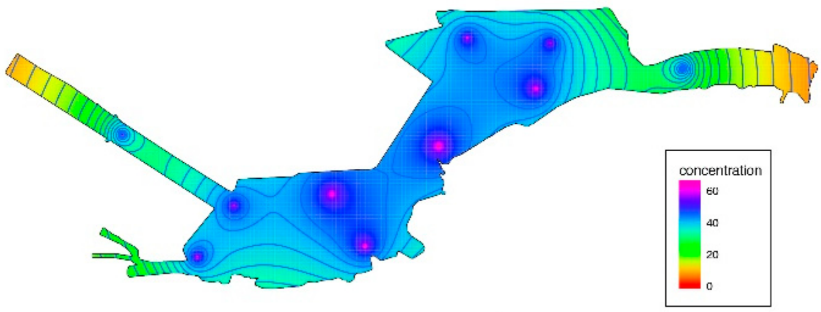

Fig3 The distribution of sedimentary Cu in Jinshan Lake in 2014

3.2 Results of annular tank experiment

The primary existence of HM in water is deposited and suspended phase. Therefore, we focused the study on the above two condition. Resuspension of sediments is influenced by the disturbance intensity near the bed. Because of the water level difference between the experiment and reality, we used the flow disturbance intensity (FDI) to indicate the water condition. The calculation process has been included in the reference (Deng Chen et al., 2001; Liu Xu et al., 2006). The results have been exhibited in Fig.4, which shows that:

(1) Under the same low turbulence intensity, the concentration of deposited copper (DCu) decreases with the increase of water depth, which is related to the size of sediment particles. At this time, the main suspended sediment particles are fine-silt (8-16μm), and the critical turbulence intensity is near 0.02 m^2/s^{-2}. When the turbulence intensity reaches 0.125 m^2/s^{-2}, reaching the critical resuspension condition of the coarse-silt (32-63μm) and SCu resuspended obviously.

(2) The concentration of suspended copper (SCu) is affected by the FDI and water level of the flow. The overall situation is that the concentration of SCu decreases with the increase of water level in the same FDI, which is related to the content of HM copper in the sediment adsorption. Under the same water depth, FDI is higher, the ability of sediment particles to adsorb HMs is reduced, and the desorption process of HMs is dominant. When the water level is high, and FDI of the water flow is large, the fluctuation does not meet the above relationship because there are many movements such as collision and secondary settlement between the particles.

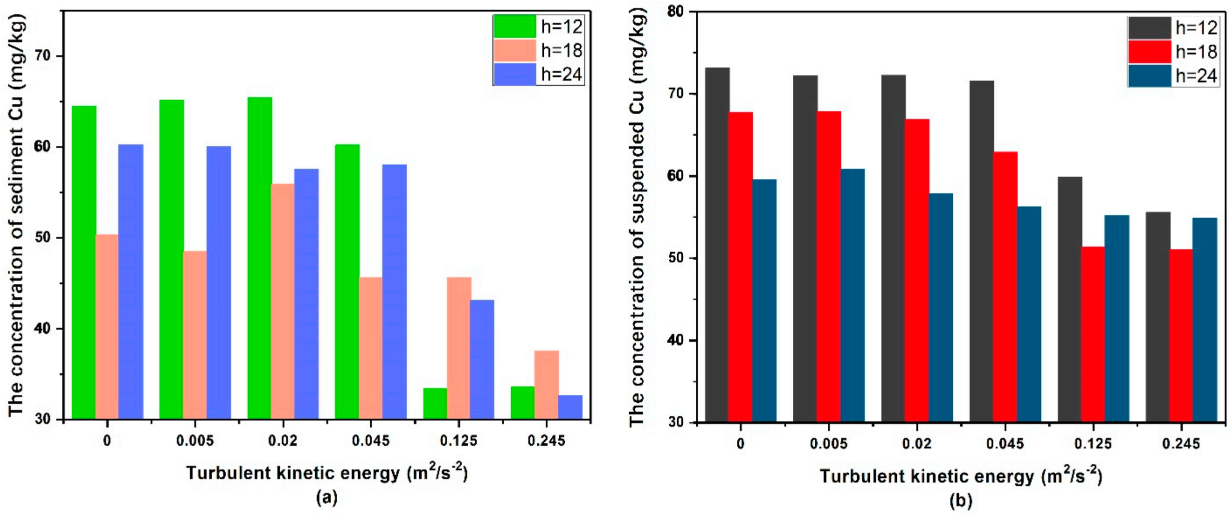

Fig.4 Distribution of turbulent kinetic energy and sedimentary (a)-suspended (b) particle concentration under different water depth conditions

3.3 **Model calibration**

The result showed that: the calculation products fit well with the measured values, with the relative error less than 15%. The model could accurately reflect the hydrodynamic condition and Cu migration process in Jinshan Lake.

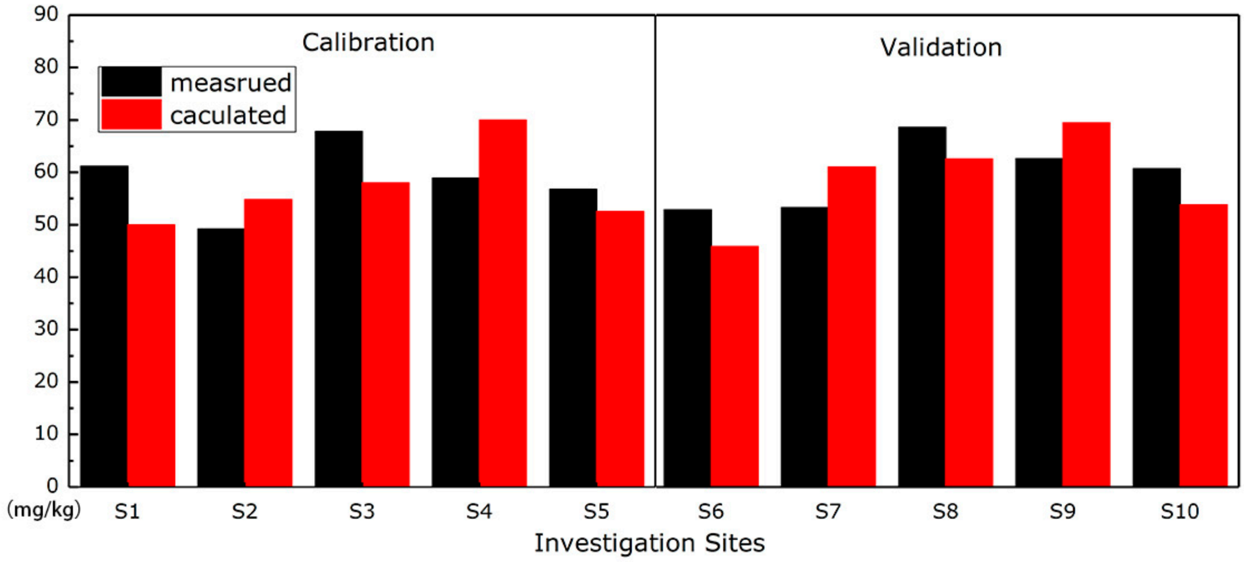

Fig.5 The results of calibration and validation

3.4 Vertical transportation of Cu in Jinshan Lake

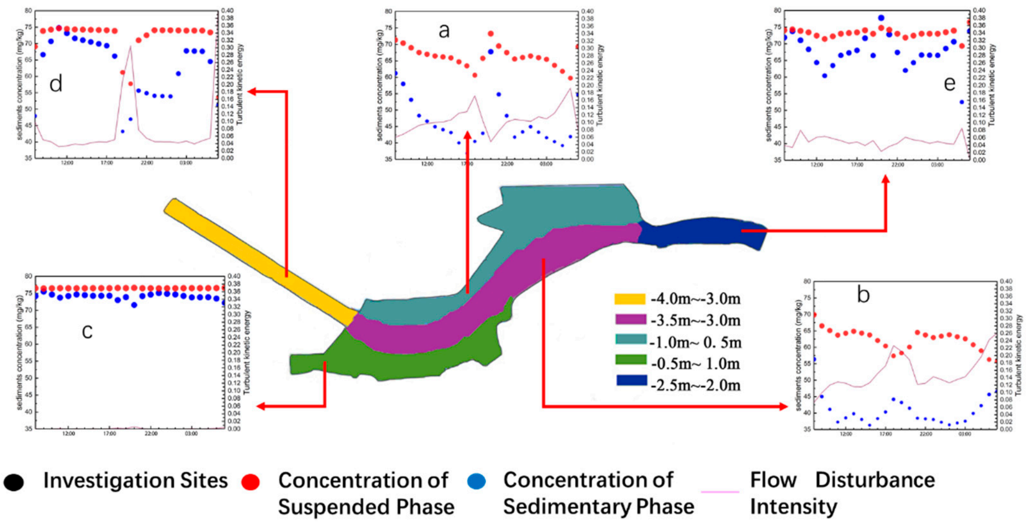

Fig.6 The fluctuation of SCu and DCu in different lake area in one diurnal tide

Tidal characteristics in Jinshan Lake is obvious with twice high and low tide daily. To quantitatively analyze the migration characteristics of HMCu in Jinshan Lake during one diurnal tide, we selected diurnal tide in flood season from April 21 to 22, 2004.

(1) HMCu distribution in Jinshan Lake exhibits two peaks In two troughs. As different areas relative to the river into the lake are at different locations, where the time to reach the high and low tide are different. Besides SA, the value of FDI in each lake area reached the minimum sedimentation value (0.02m^2/s^{-2}) in the experiment. Since the concentration of SCu is affected by the sorption-desorption process of suspended sediment particles, the overall performance is inversely proportional to FDI, but both show higher concentration than DCu.

(2) The maximum range of fluctuation of SCu and DCu was found in LC (53.63-74.67mg/kg, 43.20-74.77mg/kg) and the lowest in SA (76.44-76.63 mg/kg, 71.56-75.53 mg/kg).

In SA, FDI is the lowest and stable (0-0.004 m^2/s^{-2}), which is mainly due to the terrain of the lake bed causing sediment deposition. The influx of tidal water from the LD flowed primarily along the original direction under inertia, which caused larger FDI in ZD and made SA be the lake corner. In addition, developed industrial enterprises around SA, causing higher HMs emission, made the concentration of DCu and SCu (70.07mg/kg, 76.53mg/kg, respectively) in SA is the highest in the whole lake, with the highest fluctuation (range from 71.56-75.54 mg/kg, 76.44-76.63 mg/kg, respectively) The change of SCu concentration is affected by the sorption-desorption process of suspended sediment particles. When FDI is very low, this process is weakened and the migration between the two phases is not obvious.

In LD, affected greatest by the Yangtze River, where is relatively narrow. Water went into it, and FDI fluctuations became the largest. At 8:00 on the 21st, FDI (0.1 m^2/s^{-2}) reached the resuspension condition of medium silt (16-32μm), and the sorption effect of suspended sediment particles on HMs was enhanced.

Sediments per mass unit absorbing the mass of Cu increased and stabilized at about 9:00 (FDI = 0.05 m^2/s^{-2}). When the FDI is steady (FDI=0.03m^2/s^{-2}) at 11:00, part of medium silt began to settle. This process lasted to 18:00 when the FDI reached the second peak (0.21/ m^2/s^{-2}), the concentration of SCu decreased rapidly, which mainly because the overlarge FDI making the desorption process dominant. Until 7:00 on the 22nd, the process of Cu vertical transportation is similar.

(3) The variation of DCu concentration in ZD is synchronized with the change of FDI.This change is characterized in contrast with the experimental results and the rest of the districts. That may be related to the hydraulic distribution, water depth, sediment concentration and sediment layer, Yangtze River flow backward and other factors in Jinshan Lake: ZD has a high sediment concentration, rapid flocculation settlement, deep water depth and flocculation sedimentation efficiency is greater than the benefits of resuspension. When the sediment particles in theZD are mainly coarse silt, the sorption capacity of coarse silt on HMs is lower than that of medium and fine silt. The resuspension of the coarse silt resulted in an increase in the concentration of DCu resulting in the situation shown in Fig.5. Due to the complex hydrodynamic conditions of river-connected lake it is necessary to analyze the distribution of sediment particles in the whole lake.

(4) The FDI of the flow in the JD is low and stable, which has little effect on the process of sorption and desorption of HMs. The fluctuation ranges from 69.35 to 74.79mg/kg； The overall trend of concentration of DCu is consistent with that of the NA, LC and SA. The concentration of SCu and DCu is inversely proportional to the intensity of water flow disturbance.

4 Results

We selected typical river-connected lake, Jinshan Lake in Zhenjiang City, in the middle reaches of Yangtze River in China as the study area. Firstly, through the field experiment, laboratory experiment and mathematical model, we plotted the relationship between the concentration of DCu-SCu and FDI, and constructed the mathematical model of the migration and transformation of HMCu in Jinshan Lake. Then we choose a typical diurnal tide to simulate and revealed the vertical migration characteristics of HMCu in Jinshan Lake during a diurnal tide. The results show that:

(1) The release rate of DCu was proportional to FDI and background content, respectively.

(2) Due to the nearby industrial enterprises and terrain characteristics, SA loads the most HMCu, the average concentration is 70.07mg/kg. According to the characteristics and geographical location of LC, the concentration of copper in the two states fluctuates greatly (DCu: 43.20~74.77 mg/kg, SCu: 53.63~74.67mg/kg). The fluctuation trend of SCu in ZA is significantly different from that in other areas, which mainly due to the complex hydraulic distribution and the sorption-desorption process of HMs in sediment particles. The hydraulic disturbance of JG is the least and relatively stable, which is the farthest from the inlet of the lake and is the least affected by the Yangtze river.

(3) The FDI in a diurnal tide reaches the suspension condition of fine sediment particles in each region. FDI and sediment concentration on the vertical exchange of two - state Cu is significant.

Thesis research results play an important role in master the fluctuation characteristics of HMs in river-connected lake along the middle and lower reaches of the Yangtze river under special environment, And also has important reference value on repairing pollution of HMs and water environmental protection work.

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