

Experimental study on release of heavy metals in sediment under hydrodynamic conditions

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Abstract. In order to reveal the basic characteristics of the release of heavy metals in the sediment of the Nanchang section of the Middle Jiangxi River in the Poyang Lake River Basin, the experimental study was carried out. The release process of heavy metals Cu and Cd in the sediment under different hydrodynamic conditions was simulated by using the PES re suspension device. The results show that: 1) compared with the hydrostatic condition, the heavy metals in the sediment are more likely to migrate under the dynamic water conditions. The greater the disturbance shear stress is, the greater the heavy metal release is; 2) the initial release rate is slower in the middle period than the latter; 3) the influence degree of the migration of heavy metals in the hydrodynamic condition is $Cu > Cd$.

1. Introduction

In recent years, with the production and life of human beings, a large number of heavy metals have entered into rivers, lakes and other water bodies, thus causing serious threat to the ecological environment of water and human health. At present, the research of heavy metals is mainly focused on the study of the static release of heavy metals in the sediments, or through the study of dynamic experiments through simulated experimental tanks. The study of the dynamics of the basic structure of the sediments is less [1, 2]. For urban rivers such as Ganjiang River, which belong to Poyang Lake basin, hydrodynamics plays a very important role in the evolution of its ecological environment. The source of power in the river is mainly divided into natural and man-made factors. The natural factors mainly include wind wave, water flow, storm, tide and so on. Human factors mainly include ship transportation, sand mining, fishing and other human activities. The release of heavy metals in the sediment under the hydrodynamic conditions mainly includes the release of heavy metals in the physical suspension process and the release of water-soluble heavy metals in the chemical oxidation process. A large number of studies have found that the release of heavy metals in the sediment is mainly affected by the shear stress in the process of re suspension, and the factors such as temperature, PH, salinity, dissolved oxygen and other factors affect [3-5].

The Ganjiang River is a typical open system, which is disturbed by a lot of hydrodynamic conditions, including the activities of ship navigation, sand mining and fishery development along the line, so that the heavy metals in the sediment are suspended and redistributed in different media. At present, there are few studies on the release of heavy metals in Ganjiang River. Gong Xiaofeng and others have done some research on the adsorption of Cu on the sediments of Ganjiang River, [6]. Based on the current situation of heavy metal pollution in the Ganjiang River, this paper will choose the representative heavy



metal Cu and Cd as the research object. Through the PES (particle entrainment simulator) device simulation of the hydrodynamic conditions, the release of heavy metals in the sediment of the Ganjiang River is studied, which provides a certain science for the disposal of the sediment and the control of the water environment of the Ganjiang River. According to [7, 8].

2. Materials and methods

2.1. Selection of samples

The field survey was carried out in October 2016. The site collection project includes collecting sediment core samples and surface sediments. The sampling points are located in the area near the Ganjiang Nanchang section of the Bayi Bridge, and the specific sampling site is shown in Figure 1.



Figure 1. Experimental site sampling diagram

Sediment core samples were collected at the sampling points with columnar sampler. The sediment in the columnar sampler is slowly introduced with a piston and transferred to a clean glass cylinder with a diameter of 12.7cm. The thickness of the cylinder is 7.5cm. The cylinder opens a small hole of 8mm from the bottom 8cm at the bottom, and the rubber tube is put on the outlet of the small hole to prepare the sample and sampling for the experiment. After 3 cm water sample was added to the sample surface, the container was sealed to avoid disturbing the sediment. After returning to the laboratory, the sample was stored in the dark at 4 C. At the same time, some surface sediments were collected at the sampling sites, stored in sealed pockets and brought back to the laboratory for physical and chemical properties analysis [9,10].

2.2. Experimental device

The experimental device we selected is sediment resuspension oscillator PES (particle entrainment simulator). The device is a relatively simple experimental instrument for simulating the effect of mud shear force on sediment entrainment. First of all, it was invented by Rouse to study the structure of sediment with different characteristics. The device was then applied to simulate the sediment resuspension process in the five Great Lakes of the United States by Tsai et al. [11 and 12]. In recent years, the device has been widely used to simulate the characteristics of sediment resuspension in coastal, estuarine and lake sediments, as well as the migration of pollutants in the sediment water interface. The PES device is composed of a diameter of 12.7cm plexiglass cylinder and an oscillating barrier driven by a variable speed motor. The [13] is composed of an oscillating barrier. The crankshaft is driven by the motor by rotation, which makes the barrier vibrate up and down above the sediment at an amplitude of 2.54 cm, thus simulating the disturbance conditions of external forces.

By adjusting the speed of the motor, the oscillating frequency of the barrier can be changed, and the different intensity of the disturbance is generated on the surface of the sediment, and the shear stress

produced by the external forces of various strength on the bottom of the natural water body is simulated. In this study, there are three main hydrodynamic forces, namely, the release of heavy metals in low speed, the release of heavy metals under the medium speed power and the release of heavy metals under the condition of high speed power. Under three different dynamic conditions, the contents of heavy metals Cu and Cd were measured by atomic absorption spectrophotometer respectively.

2.3. Experimental method

Three groups of hydrodynamic conditions were set up in this experiment, namely, low speed condition (group A), medium speed condition (group B) and high speed condition (group C). The experimental samples taken are brought back to the laboratory to carry out the hydrodynamic simulation experiment. The vibration frequency of the barrier can be changed by adjusting the speed of the motor, and the different intensity of the disturbance is produced on the surface of the sediment, and the shear stress [14, 15] produced by the external force of various strength to the bottom of the natural water body is simulated.

Under three different dynamic conditions, the overlying water and sediment in the A, B and C three groups were respectively sampled at 0, 1, 3, 5, 7 and 11 d respectively. The contents of Cu and Cd were measured by atomic absorption spectrophotometer respectively.

3. Results and discussion

3.1. Changes of heavy metals in sediment during the process of resuspension

The contents of heavy metals Cu and Cd in sediments are shown in figures 2 and 3. The two kinds of heavy metals change obviously in the sediment with time, and the decrease is more obvious at the time of first days. It shows that the release of the two heavy metals has been released under the hydrodynamic conditions, and the release of the two kinds of heavy metals is different, which is mainly related to the characteristics of the heavy metals. Under the different hydrodynamic conditions, the variation of the release amount was basically changed to group C (high speed) > B group (medium speed) > A group (low speed), of which Cd was more obvious than Cu, which showed that the release of heavy metals had similar release characteristics, and the greater the water power was, the greater the release of heavy metals.

As shown in Figure 2 and Figure 3, the change of Cu content in the sediment decreased greatly at first days, and changed less after fifth days, and was basically in a stable state after 11 days. The maximal release amount of A group, B group and C group were 1.560, 1.592 and 1.609mg/kg respectively, and the overall performance was C group > B group > A group. The change of Cd content in the sediment decreased obviously in the first day, and there was a recovery in the third day. It may be due to a larger adsorption of the sediment on the Cd, that is, the adsorption amount > release amount, and basically tend to be stable in eleventh days. The maximum release of A, B and C groups is 0.102, 0.130, and 0.140mg/kg, respectively. The C group is now group > B > A group.

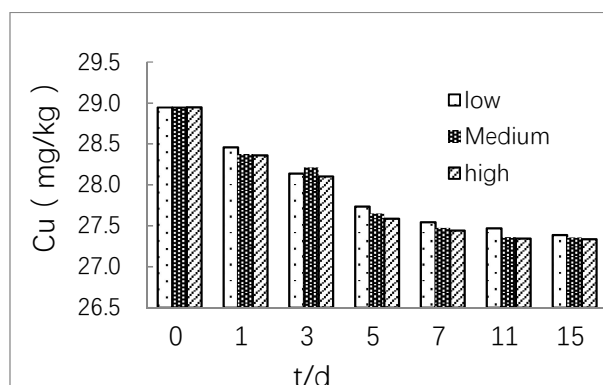


Figure 2. Changes of Cu content in sediments under different hydrodynamic conditions.

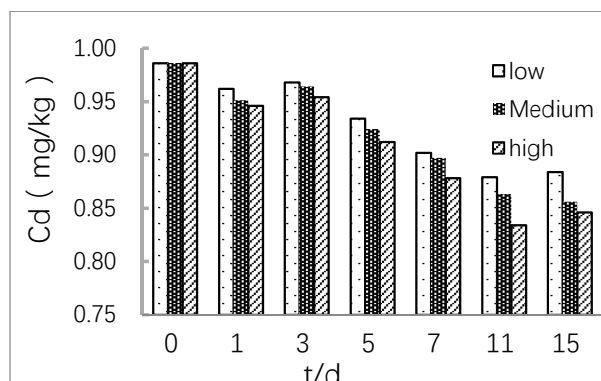


Figure 3. Changes of Cd content in sediments under different hydrodynamic conditions.

3.2. Changes of heavy metals in overlying water during the process of resuspension

The changes of heavy metal Cu and Cd contents in overlying water of three sets of A, B and C devices are shown in time. The change trend of Cu and Cd is similar, and the order of concentration in overlying water is C group (high speed) > B group (medium speed) > A group (low speed), which is in accordance with the order of flow velocity. The stronger the hydrodynamic force, the higher the concentration of heavy metals in overlying water. The variation of heavy metals Cu and Cd in overlying water with time under different hydrodynamic conditions was analyzed.

As shown in Figure 4, the amount of Cu in the overlying water is the largest in the first day, and then the release process slows with the passage of time. After 11d, the balance is basically reached, in which the greater the hydrodynamic force is, the faster the release. As shown in Figure 5, the concentration of Cd in the overlying water is similar to that of the A device and the B device. The concentration reaches the maximum at 1d, and then begins to decline after 1d, and then gradually tends to balance, but the concentration in the C device increases gradually and reaches the maximum in 11d. This indicates that the Cd of the sediments is released at high speed.

In the test, when the overlying water oscillates with the oscillator, when the shear stress reaches the extent that the sediment particles can be moved, the particles are re suspended, and the heavy metals in the particles are released, and the heavy metal content in the overlying water is increased. In general, the greater the shear stress produced by the flow, the more the resuspension material into the overlying water, especially in the waters of high water temperature and large flow in summer, and the heavy metals enriched in the sediment are easy to release into the water body during the sediment suspension process.

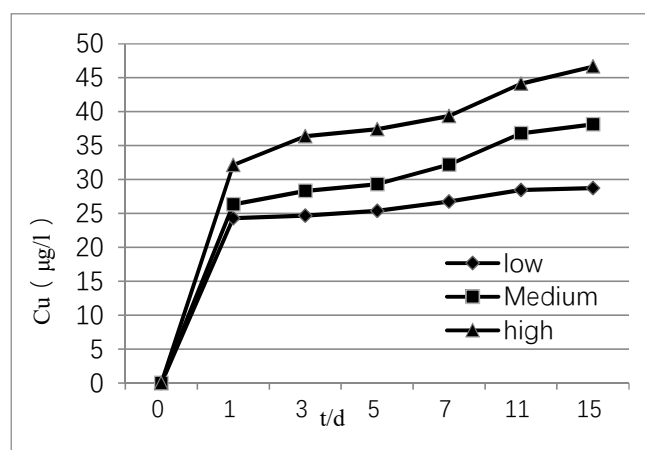


Figure 4. Release of heavy metal Cu from overlying water

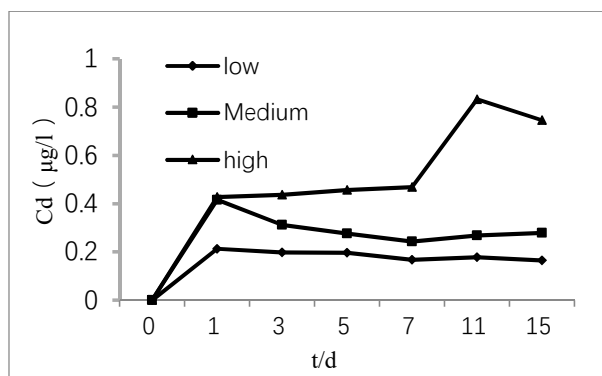


Figure 5. Release of heavy metal Cd from overlying water

3.3. Release regularity of heavy metals

The analysis of the content of heavy metals in water and sediment shows that the release rate of heavy metals in the sediment is slow at the beginning stage, and the release rate of heavy metals is very fast and the release rate is great with time. The reason is that some heavy metals adsorbed by the sediment are released to the water body quickly. The release of heavy metals began to increase slowly after reaching a certain concentration. This is because the heavy metals in the form of weak adsorption state have been released completely, and the whole process may be caused by the complexation of soluble organic matter in the water environment. When the heavy metal active ions in the sediment are exchanged between ions, the complex can be formed with the soluble organics. The release of heavy metals from sediment to the water environment resulted in a slow increase in the release of heavy metals.

Heavy metals in sediment will be released into overlying water or interstitial water when environmental conditions change. Heavy metals in overlying water may be adsorbed by suspended matter, and there is a concentration gradient between the gap water and overlying water, so the migration of heavy metals in the sediments is directional. In the experiment, the overlying water is clean tap water, the content of heavy metals is low, and the shear action of hydrodynamic forces leads to the sediment resuspension, which will greatly affect the migration process of heavy metals in the sediments. The heavy metals in the sediments are more likely to migrate under the dynamic water conditions than the hydrostatic conditions. In fact, the hydrodynamic conditions are different, and the migration process of heavy metals will be different.

4. Conclusion

(1) the effects of different hydrodynamic conditions on the 2 metals in different media are different. The order of the content and size of Cu and Cd in overlying water is high speed > medium speed > low speed, and the greater the intensity is, the maximum release rate of Cu and Cd in the sediment is high speed > middle speed > low speed, that is, the greater the turbulence intensity, the greater the release amount; the overall performance is that the release amount of heavy metals in the sediment is high speed > medium speed > low speed.

(2) the migration rules of the 2 heavy metals are different under the condition of moving water. The migration of Cu and Cd to the overlying water body is mainly influenced by the sediment resuspension, which is released by the migration of suspended particles, and the degree of migration is different because of the difference of the hydrodynamic strength.

(3) compared with hydrostatic conditions, heavy metals in sediments are more likely to migrate under dynamic water conditions. Moreover, the 3 different hydrodynamic conditions have different effects on the change of heavy metal content in different medium, and the degree of influence on the migration of different heavy metals is Cu > Cd. Acknowledgments

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