Experiment study on stability of heavy metals Cr and Pb in solidified body of river and lake sediment

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Abstract. The residual soil containing heavy metals after solidification/stabilization treatment (test residual soil), was selected as the study object of heavy metal release kinetics. Firstly, the properties of test residual soil were analyzed, and then the test residual soil was placed in the treatment tank and tested under different composite conditions. The test conditions include temperature, simulated rainfall, simulated rainfall pH and simulated light intensity. Different compound conditions were selected for testing, and each composite condition test was conducted in two groups. The experiment lasted 110 days. The simulated rainfall test was conducted every 10 days. The soil samples and leachate samples were sampled at each time. At the same time, the overflow and leachate samples were measured. The heavy metal content in each sample was analyzed and the release rule of heavy metals in the remaining soil was deduced.

1. Introduction
Urban rivers and lakes are seriously silted up due to the long-term impact of the surrounding industrial and agricultural wastewater discharge, so dredging and cleaning of river and lake sludge should be carried out regularly. At present, sludge dewatering and landfill treatment in most areas of our country has great impact on the environment, low degree of resource utilization, and is limited by environmental and land conditions. The dredged sediment is mainly composed of clayey and fine silty sand particles. The pollutants mainly include heavy metals and refractory organic pollutants, among which heavy metals are the most toxic to water and organisms[1-2]. In order to prevent sludge from solidifying and pollute the environment preventable, it is usually necessary to treat heavy metals in sludge before solidification landfill[3]. Solidification/stabilization technology is considered to be a practical, economical and effective method for the treatment of sludge containing heavy metals. It has been successfully applied in many research cases at home and abroad[4-5].

However, when sludge is dewatered and solidified and enters the landfill site, its properties may be changed by environmental factors such as acid rain, landfill time, etc. Hazardous substances such as heavy metals in mud cake are released from the solidified body into the environment, which also has a serious impact on environmental organisms and human health, and brings great risks to environmental safety in China[6-7]. Therefore, it is necessary to carry out toxicity assessment of heavy metals under environmental conditions to ensure the safety of landfill after sludge solidification to the environment and human body.
At present, there is no systematic technical method for evaluating the stability and toxicity of heavy metals in sediment solidified, especially in actual environmental conditions such as acid rain, high temperature, long-term landfill leaching stability of heavy metals in sediment solidified and toxicity test method, as well as in actual environmental conditions of outdoor column leaching test method. Through the development of this project, in view of the stability evaluation needs of heavy metals in the residual soil after solidification of dredged sediment in our country, the toxicity evaluation method of heavy metals in the residual soil was established to provide support for the stability evaluation of heavy metals in the residual soil.

2. Materials and methods

2.1. Analysis of residual soil properties

The solidification/stabilization treated residual soil contains heavy metal as the research object of heavy metal release kinetics. Use the typical 30m3 residual soil samples by natural drying process. The residual soil sample was crushed by rolling, and after that screened out (through a 2mm sieve hole), and the upper part soil of the sieve was rolled till all the residual soil samples were sifting and mixed up with the screened residual soil. By sampling and analyzing the contents of heavy metals in the treated residual soil, the results were shown in table 1. The content of Cr and Pb in the test residual soil was higher than others, therefore, the main research object was Cr and Pb in the test residual soil (Table 1).

| Element | Cd  | Pb    | Cu    | Zn    | Ni   | Cr    | As  | Hg  |
|---------|-----|-------|-------|-------|------|-------|-----|-----|
| Content | 0.13| 65.7  | 46.86 | 29.53 | 19.86| 237   | 1.06| 0.56|

Notes: Numerical Compare with Soil Environmental Quality Risk Control Standard for Soil Contamination of Agricultural Land: Table 1 Risk Screening Values for Soil Contamination of Agricultural Land (essential items), GB15618—2018.

2.2. Test method

The test residual soil was placed in the treatment tank (H1.2m, 1m, with overflow holes at the top, percolation holes at the bottom and sampling holes at the side wall), and the experiments were carried out under different synthetic conditions. The experimental conditions include temperature, simulated rainfall, simulated rainfall pH and simulated light intensity, temperature was 25°C or 40°C, the simulated rainfall was the maximum rainfall with single raindrop, pH of simulated rainfall was 4 or 7. The simulated light intensity was 1 or 3 times of local average annual sunshine intensity. Different compound conditions were selected for testing, and each composite condition test was conducted in two groups (the “○ ○”as shown in table 2). The experiment lasted 110 days. The simulated rainfall test was conducted every 10 days. A simulated rainfall test was carried out and then the samples were taken. The soil samples and leachate samples were sampled at each time. At the same time, the overflow and leachate samples were measured. (Graphite Furnace Atomic Absorption Spectrophotometer GB/T17141-1997 and Flame Atomic Absorption Spectrophotometer HJ491-2009 were used for the determination of Pb in soil quality). The release rule of heavy metals in various samples were determined and analyzed stability of the residual soil to be studied. Field trials of rainfall simulation experiment temperatures were controlled by constant greenhouse, at the same time, the simulated rainfalls were controlled by flow meters, the simulated rainfalls pH were adjusted by acid-base reagent, and the simulated illumination intensity was realized by UV lights. Table 2 presents the specific design scheme.
Table 2. The test design schedule.

| Other parameters | Temperature | 25°C | 35°C |
|------------------|-------------|------|------|
| pH               | Light intensity | -    | -    |
| 4.0              | 1 times average sunshine intensity | ○○ | ○○ |
|                  | 3 times average sunshine intensity | ○○ | ○○ |
| 7.0              | 1 times average sunshine intensity | ○○ | ○○ |
|                  | 3 times average sunshine intensity | ○○ | ○○ |

Notes: The ‘○’ was experimental device.

3. Results and discussion

A total of 16 test devices were numbered 1<sup>th</sup> to 16<sup>th</sup>. Firstly, 1<sup>st</sup> and 2<sup>nd</sup> were parallel experiments, the test conditions as follows: 1 times average sunshine intensity, temperature =25°C, simulated rainfall pH=4; Secondly, 3<sup>rd</sup> and 4<sup>th</sup> were parallel experiments, the test conditions as follows: 1 times average sunshine intensity, temperature =40°C, simulated rainfall pH=4; Thirdly, 5<sup>th</sup> and 6<sup>th</sup> were parallel experiments, the test conditions as follows: 1 times average sunshine intensity, temperature =25°C, simulated rainfall pH=7; Fourthly, 7<sup>th</sup> and 8<sup>th</sup> were parallel experiments, the test conditions as follows: 1 times average sunshine intensity, temperature =40°C, simulated rainfall pH=4; Fifthly, 9<sup>th</sup> and 10<sup>th</sup> were parallel experiments, the test conditions as follows: 3 times average sunshine intensity, temperature =25°C, simulated rainfall pH=4; Sixthly, 11<sup>th</sup> and 12<sup>th</sup> were parallel experiments, the test conditions as follows: 3 times average sunshine intensity, temperature =40°C, simulated rainfall pH=4; Seventhly, 13<sup>th</sup> and 14<sup>th</sup> were parallel experiments, the test conditions as follows: 3 times average sunshine intensity, temperature =25°C, simulated rainfall pH=7; At last, 15<sup>th</sup> and 16<sup>th</sup> were parallel experiments, the test conditions as follows: 3 times average sunshine intensity, temperature =40°C, simulated rainfall pH=7.

3.1. The influence of different test conditions on the release rule of Cr in experiment residual soil (simulated rainfall test)

The experiment was conducted in parallel experiments (the average values of parallel trials in each group were taken as test results), and the stage leaching behavior of Cr was studied under different temperatures, pH values and light intensity. The test results as shown in Figure 1.

Figure 1 Cr leaching rate generation factors for: ① Under different temperature and light intensity, pH value was studied to test the effect of Cr leaching rate in the sediment. The results show that the change of pH has little effect on the leaching rate of Cr in the test sediment (Shown in graphs 1 and 3, graphs 2 and 4, graphs 5 and 7, graphs 6 and 8). ② Under different temperature and PH value, sunshine intensity was studied to effect of Cr leaching rate in the sediment. The results show that the change of sunshine intensity has little effect on the leaching rate of Cr in the test sediment (Shown in graphs 1 and 5, graphs 2 and 6, graphs 3 and 7, graphs 4 and 8). ③ Under different sunshine intensity and PH value, temperature were studied to effect of Cr leaching rate in the sediment. The results showed that the change of temperature had little effect on the leaching rate of Cr in the test sediment (Shown in graphs 1 and 2, graphs 5 and 6, graphs 3 and 4, graphs 7 and 8).

3.2. Analysis total leaching amount of Cr in experiment residual soil (simulated rainfall test)

Each set of parallel experiments under different temperature, pH values and illumination intensity was used to study the accumulative leaching of Cr. The experimental results as shown in Figure 2.
As shown in Figure 2, the accumulation of leaching rate for 1# ~ 16# test Cr has an inflection point after 30 days, and then the accumulation of leaching rate for Cr did not increase and the leaching rate of Cr at the inflection point was low. In another word, it can be seen that more than 98% of the Cr in the test soil was at a steady state, and there was no need for a further observation.

3.3. The influence of different test conditions on the leaching rule of Pb in experiment residual soil (simulated rainfall test)

The process adopted parallel experiments (the average values of parallel trials in each group were taken as test results), and the stage leaching behavior of Pb was studied under different temperatures, pH values and light intensity. The test results as shown in Figure 3.
Figure 3 Pb leaching rate generation factors for: ① The effect of pH on the leaching rate of Pb in the test sediment was studied under different temperatures and sunshine intensity. The results show that the change of pH has little effect on the leaching rate of Pb in the test sediment (Shown in graphs 1 and 3, graphs 2 and 4, graphs 5 and 7, graphs 6 and 8). ②The effect of sunshine intensity on the leaching rate of Pb in the test sediment was studied under different temperatures and pH. The results presented that the change of sunshine intensity has little effect on the leaching rate of Pb in the test sediment (Shown in graphs 1 and 5, graphs 2 and 6, graphs 3 and 7, graphs 4 and 8). ③The effect of temperature on the leaching rate of Pb in the test sediment was studied under different sunshine intensity and pH. The results presented that the change of temperature had little effect on the leaching rate of Pb in the test sediment (Shown in graphs 1 and 2, graphs 5 and 6, graphs 3 and 4, graphs 7 and 8).

![Figure 3. Leaching rate of Pb in residual soil at different periods.](image)

![Figure 4. Cumulative leaching rate of Cr in experiment residual soil.](image)
3.4. Analysis of total leaching amount of Cr in experiment residual soil (simulated rainfall test)

Each set of parallel experiments under different temperatures, pH values and illumination intensity was used to study the accumulative leaching of Cr. The experiment results as shown in Figure 4.

As shown in Figure 2, the accumulation of leaching rate for 1# ~ 16# test Cr has an inflection point after 90 days, and then the accumulation of leaching rate for Cr did not increase and the leaching rate of Cr at the inflection point was low. It could be seen that more than 99% Cr in the test soil at steady state, didn’t need for a further observation.

4. Conclusions

(1) Stage analysis of leaching rule of Cr and Pb

The experiment was carried out by parallel test in each group, respectively (the average value of parallel test in each group). The leaching regularity of Cr and Pb in different temperature, pH value and illumination intensity was studied. The results presented that the leaching of Cr and Pb in the residual soil was basically unaffected by the changes of temperature, pH value and illumination intensity.

(2) Analysis of cumulative leaching of Cr and Pb

Analysis the experiment, which was conducted in parallel groups, the cumulative leaching rule of Cr and Pb under different temperature, pH value and light intensity was studied, The cumulative leaching rates of Cr and Pb in 1~16# test changed at inflection point after 30 and 90 days respectively, and the cumulative leaching rates no longer increased and the leaching rates of Cr and Pb at inflection point were low. The result presented that more than 98% Cr and 99% Pb in the residual soil at stable state, didn’t need for a further detection and observation.

Reference

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