Application Research on Stabilizing Treatment of Dredged Sediment

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Abstract. In order to improve water quality, to ensure the capacity of normal flood discharge and river transport, it carried out a lot of dredging work across the country recently. For harmful sediment's second pollution and recycling use, this study selected five kinds of sediment. And point A was determined as the research object by using the geo-accumulation index to evaluate the heavy metal. Then the sediment was mixed with lime, fly ash, kaolin clay, sodium silicate, sodium carbonate and polyvinyl alcohol as mud stabilizing materials. Experimental research shows that, copper loss of stabilized soil's toxicity leaching agent reaches more than 95%, and the permeability coefficient was 10-5 cm/s orders of magnitude. In this paper, it ensures GW7 as the best choice of plants experiments, which are 5% fly ash, 1% lime, 3% kaolin clay, 3% sodium silicate, 3% sodium carbonate and 1% polyvinyl alcohol, through the ways of permeability, water retention, SEM and XRD. The scheme effectively stabilizes copper, and keeps the plants as better form than others. But it has different effect on different plants. Thus it should consider planting varieties optimization in actual applications.

1 Introduction

With the deepening of Zhejiang Province "five water treatment", it appeared a lot of dredged sediment in a short time. Because dredged sediment had high moisture content and large volume, it needed a large amount of land for stacking. In addition, a big part of dredged sediment is polluted by different degree, especially the urban river sediment, it contains a lot of organic matter, nitrogen and phosphorus nutrition, and some harmful heavy metals, pathogenic bacteria, virus microorganism, and toxic organic compounds, and so on. It make the mud easy to blacken and rot [1]. If untreated direct stacking, it would cause secondary pollution, especially in cultivated land. Therefore, the dredging sediment's stabilization and harmlessness disposal has become one of the problems to be solved urgently.

Stabilization refers to the transformation of harmful substances into substances with low solubility, low toxicity and low mobility, that reduces the pollution potential of waste materials [2]. Stable technology is generally implemented by curing, that the curing materials change the soil mechanics properties, and reduce pollutants dissolved out[3]. The techniques mainly include cement, thermoplastic materials, hot and hard materials, lime, large encapsulation, self-cementing, and glass solidification, etc. [4-5].

According to the literature, lime, cement, fly ash can improve the soil pH, and reduce the microorganism and organic matter content in the sediment, while steady heavy metals form of cadmium and chromium. Because microbial decomposition and metabolism constantly changes sediment chemical conditions, it will affect the form of heavy metals [6]. Kaolin is basically neutral and has fine pores on the surface, which offers good adsorption and desorption properties to nitrogen, phosphorus, potassium and organic carbon [7]. And Iron powder, sodium carbonate and sodium silicate can stabilize copper [8].

In 2016, Zhejiang Province had dredged more than 100 million cubic meters sediment. At present, its utilization mode was simplex, that mainly was backfilled. In this, the use of agricultural fields is accounted for 22%, and backfill is at 33%, contained low-lying areas, mines and reclamation areas backfill. And landscaping is at 7%. But agricultural fields and landscaping are affected by mud properties. Additionally, the search for land is increasingly difficult as the backfill area decreases. Although the concept of "dredging sediment is an available resource" has been gradually recognized, it is necessary to carry out systematic research to translate this understanding into practice[9].

Based on the problems of dredged sediment's high water content, diversified pollution, and it has difficulty in storage yard, this paper put forward to use mud as planting soil through solidifying single pollution factor silt, which will provide more resource utilization possibility for polluted sediment.

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2 Screening of Sediment

2.1 Evaluation Standard of Geo-accumulation Index Method

The geo-accumulation index (Igeo) is a quantitative index of heavy metal pollution in water environment. Because it not only considers the man-made pollution factors, environmental geochemical background values, etc., but also in consideration of the dynamics of background value by the natural rock forming effect. Therefore, the application is widely distributed[10]. Evaluation standard of geo-accumulation index is shown in table 1.

Table 1. Evaluation Criterion of Geo-accumulation Index and Pollution Series

Level	I_{geo}	Degree of Contamination
0	(-∞，0)	No
1	(0,1]	Mild
2	(1,2]	Less Moderate
3	(2,3]	Moderate
4	(3,4]	Less Heavy
5	(4,5]	Heavy
6	(5,+∞)	Serious

2.2 The Calculation Formula of Geo-accumulation Index

Computational formula of geo-accumulation index is shown in formula (1). The background value of heavy metals in soil of Zhejiang Province [13] is shown in table 2.

$$I_{geo} = \log_2[C_n/(K * B_n)] \quad (1)$$

Where Cn is the content of heavy metal n in sediment, Bn is the background value of heavy metals in soil of Zhejiang Province, K is correction factor, and usually K is 1.5.

Table 2. Soil element background values of heavy metals in Zhejiang Province

heavy metal	background values
Cu	22.63
Zn	83.06
Pb	23
Cd	0.17
Ni	23.93
Hg	0.17
As	6.88

2.3 The Evaluation Results of Geo-accumulation Index

This study screened five different sediments as research object. The results of Igeo were shown in table 3. The results showed that the Igeo of Cu in sample A was less heavy pollution, and the factor was relatively simple. Therefore, the test chose sample A, and its physical properties were shown in table 4.

Table 3. Geo-accumulation index(Igeo) calculation of heavy metal in sediment

The sample of Sediment	I_{geo} Cu	I_{geo} Zn	I_{geo} Pb	I_{geo} Cd	I_{geo} Ni	I_{geo} Hg	I_{geo} As
A	3.15	0.74	1.59	0.08	0.33	0.61	0.83
	Less Heavy	Mild	Less Moderate	Mild	Mild	Mild	Mild
B	1.7	0.97	1.15	1.85	0.51	0.25	0.5
	Less Moderate	Mild	Less Moderate	Less Moderate	Mild	Mild	Mild
C	-0.63	-0.22	-0.06	-1.67	-1.58	-0.41	0.29
	No	No	No	No	No	No	Mild
D	-0.56	-0.02	-0.06	-0.28	0.03	-1.21	-0.27
	No	No	No	No	Mild	No	No
E	0.34	0.25	-0.56	-0.21	-0.92	-2.21	0.05
	Mild	Mild	No	No	No	No	Mild

Table 4. The statistical table of point A sediment's physical property

The sample of Sediment	A
moisture content（%）	51.8
wet density（g/cm³）	1.67
dry density（g/cm³）	1.1
void ratio（%）	1.486
liquid limit（%）	54.6
plastic limit（%）	31.2
the specific gravity of solids	2.74
coefficient of vertical permeability（cm/s）	4.4×10^{-7}

3 the Stabilization Experimental Scheme on Sediment

Firstly, it took 5% fly ash + 1% lime +3% kaolin as the main curing agent, because the Igeo of Cu in sample A was less heavy pollution. The mixing amount of curing agent was in percentage of dried mud quality. And the specific solutions were determined by the adjustment of pH. They were shown in table 5. In this experiment, it studied the reduction rate of copper concentration, water retention and permeability.

Table 5. Curing ratio test scheme

Sample number	the mixing amount of curing agent /%					pH
	Na_2SiO_3	Na_2CO_3	$MgSO_4$	$Fe_2(SO_4)_3$	PVA	
GW 0	/	/	/	/	/	6.9

Sample number	the mixing amount of curing agent /%					pH
	Na_2SiO_3	Na_2CO_3	$MgSO_4$	$Fe_2(SO_4)_3$	PVA	
GW 6	3	/	/	3	1	7.3
GW 7	/	3	/	3	1	8.6
GW 8	1	1	1	3	1	6.2
GW 9	/	/	3	3	1	5.4
GW 10	/	/	6	/	1	7.9

4 Results Analysis

4.1 Heavy Metal Leaching Test

Heavy metals are mostly stabilized in the form of metal hydrates and metal hydroxides in solidified bodies [3]. Heavy metal morphology are change by pH of soil. Thus, it affects the bio-availability of heavy metals[11]. On the condition of acidic, H^+ can destroy the hydration products and obstruct the settlement of metal compounds, or reduce calcium hydroxide concentration reacted with OH^-, which promoting the dissolution of hydration products and accelerating the leaching of heavy metals [12].

The test took acetic acid solution (pH = 4.93 + 0.05) as leach liquor. It simulated acid condition, then study all kinds of solidified sediment's stability. Refer to "soil environmental quality standard" (GB15618-1995), it tested eight heavy metals' content and leaching concentration of copper, zinc, nickel, lead, cadmium, chromium, mercury and arsenic. As shown in table 6, according to "surface water environment quality standard" (GB 3838-2002), leaching liquid of original sample GW0's copper, lead and cadmium were beyond standard of the class V water quality. Solidified sediments of GW6-GW10's toxic leaching results were much better, and they meet standard of the class I ~ III water quality.

Table 6. The heavy metals table of solidified sediment leachate

Testing items	GW0	GW6	GW7	GW8	GW9	GW10
Cu（mg/L）	4.29	0.02	ND	0.12	0.18	0
Zn（mg/L）	0.55	0.42	0.39	0.38	0.21	0.45
Ni（mg/L）	0.23	0.17	0.06	0.27	0.28	0.14
Pb（mg/L）	0.15	ND	ND	ND	7.7×10^{-3}	ND
Cd（mg/L）	2.0×10^{-2}	5.5×10^{-4}	ND	1.5×10^{-3}	3.0×10^{-3}	4.5×10^{-4}
Cr（mg/L）	0.03	ND	ND	0.04	0.05	0.04
Hg（mg/L）	8.0×10^{-4}	ND	ND	ND	6.0×10^{-5}	5.0×10^{-5}
As（mg/L）	1.0×10^{-3}	ND	ND	4×10^{-4}	1.0×10^{-4}	ND
surface water environment quality standard	Beyond class V	I~III	I~III	I~III	I~III	I~III

Copper leaching reduced rate before planting (α_n) and copper leaching changed rate before and after planting (Δx_n) were calculated by formula (2) and (3).

$$\alpha_n = \frac{\rho_0 - \rho_n}{\rho_0} \quad (2)$$

$$\Delta x_n = \frac{\rho_n - \rho_n'}{\rho_n'} \quad (3)$$

Where ρ_0 is original sample's copper leaching concentration before planting (mg/L), ρ_n is solidified sediment of n's copper leaching concentration before planting (mg/L), ρ_n' is solidified sediment of n's copper leaching concentration after planting (mg/L).

From figure 1, copper leaching reduced rate before planting reached more than 95%. It proves that the group of Na_2SiO_3, Na_2CO_3, $MgSO_4$ and $Fe_2(SO_4)_3$ can stable copper ions effectively.

As shown in the figure 2, solidified sediment GW7's copper leaching concentration was minimum after planting kale, and it was basically the same as before curing. This shows that GW7 is the most effective for curing copper, and there is no soluble free copper ion in solidified sediment.

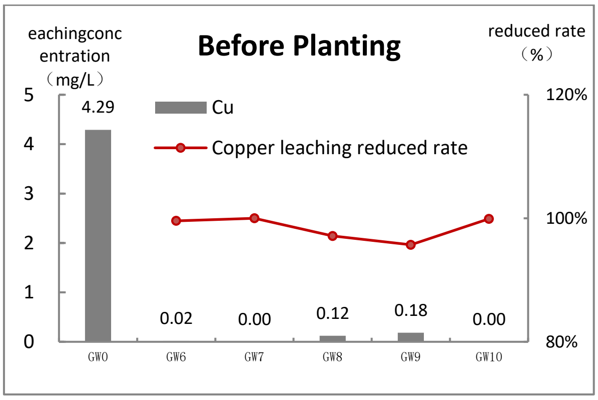

Fig. 1. The reduction rate of preplant stabilized soil's copper leaching

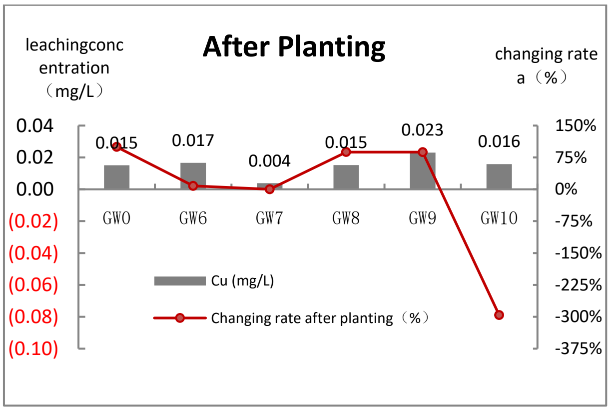

Fig. 2. The change rate of planting stabilized soil's copper leaching

4.2 Percolation Test

According to "Rules of Geotechnical Testing" [14], infiltration is the phenomenon of water moving in porous media. It tested the seepage rate of solidified sediments under 20kPa vacuum pressure in order to understand the influence of different dosage of curing stabilizer.

As shown in the figure 3, it used quantifiable multiunit vacuum suction-filter device by Independent R&D[15]. It recorded the relationship between the suction filter water and time at 20℃, and drawed the relation curve of water filter and time, and measure the mud sample thickness, then got the permeability coefficient of each solidified soil. It was calculated by constant head penetration test formula.

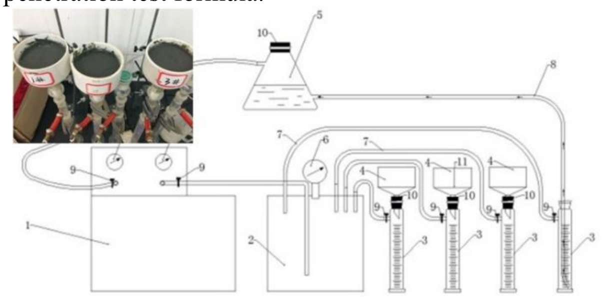

Fig. 3. The change rate of planting stabilized soil's copper leaching

From figure 4 and table 7, under the constant vacuum of 20kPa, the osmotic coefficient of GW10 is 10^{-4}cm/s, and the rest is about 10^{-5}cm/s. The ranking of infiltration is GW10＞GW8＞GW9＞GW0＞GW6＞GW7. At the same time, it shows that the seepage rate increases with time, because there is a lot of fiber in stabilized soil. It provides water seepage channels to improve late permeability.

Table 7. The table of solidified sediment permeability coefficient

vacuum degree	Sample number	water penetration rate mL/s	permeability coefficient cm/s
20kPa	GW0	0.88	6.07×10^{-5}
	GW6	0.73	5.01×10^{-5}
	GW7	0.45	3.11×10^{-5}
	GW8	1.24	8.59×10^{-5}
	GW9	1.14	7.88×10^{-5}
	GW10	8.57	5.92×10^{-4}

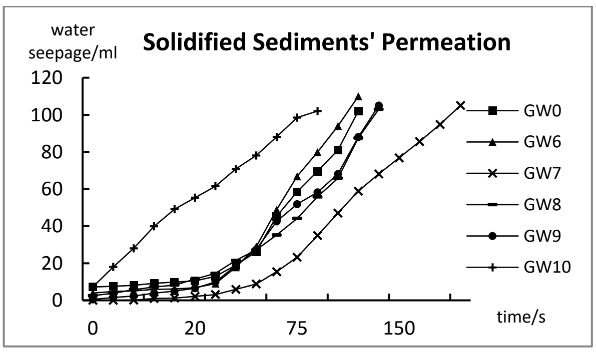

Fig. 4. The emission rate of GW0 and GW6-GW10 stabilized soil

4.3 Water Retention Test

It was helpful to research plant planting experiments through study soil water retention. Put the mud into beaker after stir well, add water to the saturation, and took out and put it in a funnel for 24 hours, then weigh the soil and calculate the initial water content. After that, weigh the soil every 24 hours, observed about 30 days, and calculated soil moisture content.

As shown in the figure 5, the ranking of water retention is GW10＜GW8＜GW6＜GW9＜GW0＜GW7. It is mainly consistent with the law of permeability.

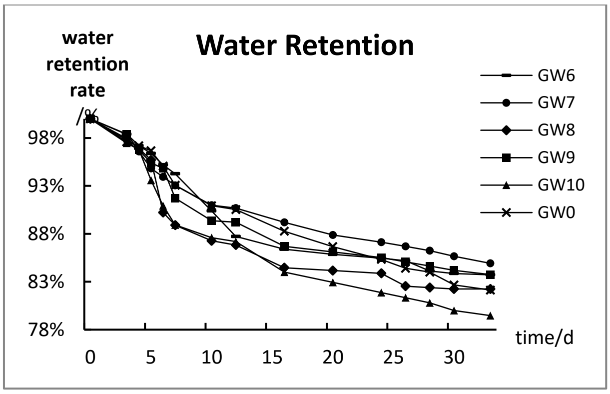

Fig. 5. The water-retention rate of GW0 and GW6-GW10 stabilized soil

4.4 Microscopic Test

From figure 6 and table 8, it had stronger peak and larger area near 26.72°. It proves that solidified sediments consists of quartz primarily. From figure 7, there is a lot of fiber in GW7. It is ensured that plants can breathe normally by the pore and seepage diameter. Therefore, the cultivation of kale grows best in the solidified soil of GW7.

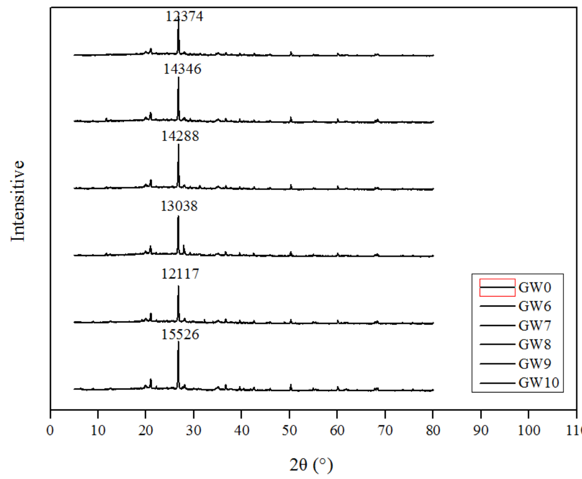

Fig. 6. XRD analysis of GW0 and GW6-GW10 stabilized soil

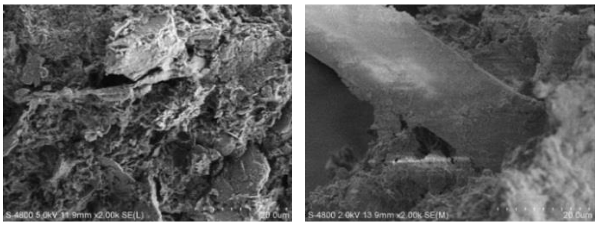

Fig. 7. GW0 and GW7 stabilized soil's SEM photos

Table 8. The eigenvalue of GW7 stabilized soil's XRD

Sample number	2θ（°）	d（Å）	Intensitive
GW7	20.92	4.24	3999
	26.72	3.33	13038
	27.86	3.20	4158
	50.22	1.81	2254

5 Conclusion

This paper presents and research stabilizing treatment of dredged sediment. The result shows that copper loss of stabilized soil's toxicity leaching agent reaches more than 95%, and the permeability coefficient was 10-5 cm/s orders of magnitude. And it ensures GW7 as the best choice of plants experiments, which are 5% fly ash, 1% lime, 3% kaolin clay, 3% sodium silicate, 3% sodium carbonate and 1% polyvinyl alcohol, through the ways of permeability, water retention, SEM and XRD. The scheme effectively stabilizes copper, and keeps the plants as better form than others. However, it has different effect on different plants. Thus it should consider planting varieties optimization in actual applications.

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