Remediation of a heavy metals contaminated site in urban area: a case study from southern China

H. Huang, Y.F. Wang, S.J. Wang, Y.C. Liu, B. Zhang & Y. Yang

*Research and Development Department, China State Science Dingshi Environmental Engineering Co., Ltd,
Beijing, P.R. China*

ABSTRACT: The reuse of former industrial sites is recognized as one solution to increase land use in major cities in China. As many former industrial sites are located near the heart of a city, the restoration of these sites would increase revenues and reacquire what was once prime real estate. A 76 years old paper mill has been closed in 2012 and left a site contaminated with As, Pb Cu and Zn. The successful remediation of the site has been achieved by the CSSDS using stabilization/solidification with the independently developed in situ deep injection-mixing equipment.

1 INTRODUCTION

A former paper mill which was established in 1938 and was one of the largest news-printing paper providers in China, the mill was closed in 2012. The abandoned site was planned to reuse as local government reserve land for future development. Considering the site investigation results (Table 1), top soils were excavated and disposed. Heavy metals in deep soil layers were stabilized/solidified by selected amendments. The appropriate amendments were injected into soils with an in situ deep injection-mixing equipment. The S/S project lasted for over four months and treated soils on the contaminated site have been assessed by the certified organization.

2 METHODS

2.1 Site description

The site locates in a former paper mill in a southern city in China. The contaminated site was used as the pulp workshop, thermal power station and wastewater

treatment plants. The field investigation showed that the contaminated area was 11,735 m² and the main contaminants were As, Pb Cu and Zn. Total concentrations of each heavy metal are: As 56–1652 mg kg⁻¹, Cu 310–673 mg kg⁻¹, Pb 181–10600 mg kg⁻¹, Zn 324–26500 mg kg⁻¹.

2.2 Remediation technologies

Top soils (0.2–0.3 m) were excavated and disposed (Table 1).

For deeper soils, stabilization/solidification was used to immobilize As, Pb Cu and Zn. Amendments used in this project were mixtures of lime, iron-based material and clay (lime: iron-based material: clay = 2:1:1). The application rate of amendments to soil was between 1% and 4%.

Depending on the site condition, cement was also applied with rate of 5%–10%.

2.3 In situ deep injection-mixing equipment

The independently developed in situ deep injection-mixing equipment was used to inject amendments and mix amendments with soils. An injection-mixing system consists of two identical agitating shafts and one injection pipe. The JBS-II biaxial mixing drill (Fig. 1) was used in this project. Parameters of the equipment are shown in Table 2. Total drilling points on the site was 19,558, with depth of 5.7 m for each borehole.

The engineering process is shown in Figure 2.

2.4 Assessment of remediation

After the completion of remediation, 187 soil samples were collected on site. All soil samples were analyzed according to the standard extraction toxicity methods.

Table 1. Site characterization and remediation targets.

Depths (m)	Project quantity (m ³)	Remediation technologies	HM con. in soil leachate (mg L ⁻¹)	Remediation targets* (mg L ⁻¹)
1 0.2~0.0	2347	excavation and	–	–
2 0.0~0.3	3521	disposal		
3 -0.3~-6.0	66888	In situ stabilization/solidification	As:0.1-0.3 Cu:0.2-0.6 Pb:0.2-1.0 Zn:0.1-1.5	0.05 1.5 0.1 5

*: Treated soils are leached and the HM concentration in the leachate qualifies the IV criteria of 'Chinese Quality Standard for Groundwater' (GB/T14848-1993).

Figure 1. JBS-II biaxial mixing drilling system.

Table 2. Parameters of the in situ deep injection-mixing equipment.

Components	Parameters
Borehole (mm)	1200 × 700
Drilling depth (m)	18~20
Max. torque (kN · m)	29.2
Power head drilling speed (r min ⁻¹)	24.2
Step length (m)	1.1

Figure 2. Engineering flow diagram of stabilization/solidification.

3 RESULTS AND DISCUSSION

3.1 Stabilization/solidification of HMs

Solidification/stabilization reduced the mobility of contaminants in the environment through both physical and chemical mechanism (Kumpiene *et al.*, 2008). The concentrations of As, Cu, Pb and Cu in the leachate of treated soil were below the IV criteria of ‘Chinese Quality Standard for Groundwater’ (GB/T14848-1993). Over 50% to 80% of contaminants on site were not presented in soil leachate, which indicated a relatively high stabilization performance. The selected amendments consist of iron-based material which has been demonstrated to effectively reduce As mobility and phytoavailability (Warren *et al.*, 2003). Lime is a commonly used alkaline amendment for mobilizing HMs by raising pH and co-precipitation. It is effective for Cu and Pb but increase of Cr and As (Seoane and Leiros, 2001). Research also indicates that Cu, Zn and Pb could be retained in soil with iron or clay materials (Wang *et al.*, 2001).

3.2 Deep injection-mixing equipment

The equipment has the advantage of combining injection and mixing together during the drilling, this could ensure the complete reaction of amendments with HMs presented in soils.

Treatment process is not affected by the soil texture, especially for the soils with low permeability and for medium/hard formations. Soils in south

Figure 3. Schematics of borehole distributions.

China are loam and with high water content. When amendments injected into soils by common injection system, amendments diffusion is constrained by the soil physiochemical characteristics. Therefore, mixing soils with amendments during the injection process is necessary for this site remediation. Soils are under an efficient mixing could maintain a turbulence status, therefore amendments and soils are completely mixed, providing an optimal condition for stabilization reaction.

The equipment has a larger injection range, which is 1200 mm × 700 mm (Table 2). Proper drilling point distribution design guarantees no gaps between adjacent drilling points (Fig. 3).

3.3 Project cost

Total cost of the project is 18.69 million CNY, and the cost for treating a cubic meter of soil by using this technology is approximate 300 CNY.

4 CONCLUSIONS

A former paper mill site was contaminated by HMs and remediated by stabilization/solidification. Selected amendments were applied by using the independently developed in situ deep injection-mixing equipment. The contaminants in soils were successfully immobilized.

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