Stabilization of Contaminated Soil by Dicalcium Phosphate

Amin Falamaki
Payame Noor University, Iran

Hossein Tavallali
Payame Noor University, Iran

Sharbanoo Rezanejad Farahmand
Payame Noor University, Iran

Commemorate the Legacy of Ralph B. Peck
Seventh International Conference on
Case Histories in Geotechnical Engineering
April 29 - May 4, 2013 CHICAGO
and Symposium in Honor of Clyde Baker

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Amin Falamaki
Department of Eng, Payame Noor University
PO Box 19395-3697, Tehran, Iran,

Hossein Tavallali and Sharbanoo Rezanejad Farahmand
Department of Chemistry, Payame Noor University
PO Box 19395-3697, Tehran, Iran,

ABSTRACT

Stabilization of heavy metals contaminated soils using phosphate amendments is relatively a simple, quick and cheap method to reduce the transport of contaminants in the environment. The objective of this study is to stabilize the polluted soil using dicalcum phosphate (DCP). In this study a series of leachate column tests were conducted to find out the effect of DCP on Pb and Cu polluted soil. In addition, to understand the concentration of DCP on the efficiency of the method, different samples with different polluted soils were tested. DCP with 0.1, 0.2 and 0.5 mg/kg dry soil were added to the polluted soil and the samples were kept for 1 month. Break through curves were prepared to analyze the results. The results show that DCP may stabilize heavy metals in the soil. Increasing the concentration of DCP, decreases the concentration of metals in the effluent, means more stabilized metals in the soils. The results also show that 0.2 mg/kg dry soil of DCP is enough to stabilize the metals from the first stages of the tests.

INTRODUCTION

One of the most inexpensive methods for removing contaminants from the soil is solidification/stabilization. This technique is very efficient technique for the sites contaminated with toxic metals, and involves mixing of binders, into the soil, in order to transform soils into a solid material with low leachability of contaminants. According to Voglar and Lestan (2011), the main objective of S/S is to develop a procedure that produces a stable and sustainable end product, which will pose the minimum threat to the environment.

Lee et al. (2011) demonstrated that stabilization techniques may improve soil physico-chemical and biological properties, are less expensive and therefore are more suitable for remediation of extensive areas of low-value land.

Among different stabilizers, a lot of investigations have shown heavy metal immobilization using phosphate-based binders is a very popular. Falamaki et. al, (2009) reported that Spance and Shi (2005) had summarized more than 50 studies concerning the phosphate stabilization and immobilization of contaminants. Different Phosphate compounds were used for stabilization of heavy metals and radionuclides such as phosphoric acid, diammonium phosphate, mono-basic calcium phosphates, tricalcium phosphate, apatite, hexametaphosphate etc.(Park et al., 2011; Miretzky et al., 2008; Tavallali et al., 2010; Melamed et al., 2003; Thawornchaisit et al., 2009; Theodoratos et al. 2002).

The purpose of this research is stabilization of heavy metals contaminated soils using dicalcum phosphate (DCP). In addition, the optimum amount of DCP is investigated.

MATERIALS AND METHODS

Dicalcium Phosphate Characterization

In this study dicalcium phosphate used as the contaminant stabilizer. It is, also known as calcium monohydrogen phosphate, a dibasic calcium phosphate. It is usually found as the dihydrate, with the chemical formula of ($CaHPO4$, $2H_2O$), but it can be thermally converted to the anhydrous form. It is practically insoluble in water, with a solubility of 0.02 g per 100 mL at 25 °C. It contains about 23 percent calcium in its any hydrous form. Dicalcium phosphate is mainly used as a dietary supplement in prepared breakfast cereals, dog treats, enriched flour, and noodle products. It is also used as a tableting agent in some pharmaceutical preparations, including some products meant to eliminate body odor. It is used in poultry feed. It is also used in food industry.

Soil Characterization

The soil used for this research is fine silty sand collected from Shiraz sand mine site (Fars province, Iran). The soil sample was transferred to plastic bags and transported to the laboratory. The soil samples were dried at 110°C temperature with oven, homogenized, and sieved to less than 2mm. Soil pH was measured near to 7. The aggregation analysis using sieve showed that 57.4% of the soil was sand.

Experimental Program

In order to achieve the aims of this study an experimental program was scheduled as given in Table 1.

Table 1. Experimental program

Row	Experiment	DCP/Dry soil (% by weight)
1	T0 - No additive- No pollutant	-
2	T1- No additive- Pb polluted	0
3	T5- DCP - Pb polluted	0.1
4	T6- DCP - Pb polluted	0.2
5	T7- DCP - Pb polluted	0.5
6	T8- No additive- Cu polluted	0
7	T12- DCP - Cu polluted	0.1
8	T13- DCP - Cu polluted Cu	0.2
9	T14- DCP - Cu polluted	0.5

Chemical immobilization treatments were evaluated using leachate column test, similar to the method described by Tavallali et al., (2011). This is a standard method described in ASTM D 4874-95. The Leachate column test was carried out by passing the influent solution through a bed of dry soil or soil-contaminant mixture or soil-contaminant-stabilizer mixture contained in a column.

Figure 1 illustrates a schematic diagram of the apparatus which is designed for this study. The apparatus consists of two tank of Plexiglas with six cells that made of Pyrex glass. The distance of tank No. 2 to leachate output level of soil column in all cells was identical (h =1 m). Column diameter and length are 56.4 and 7.5 mm, respectively. Filters were placed between the soil matrix and end caps on each end of the column to prevent loss of fines from the soil column. Soil samples were saturated with influent solution (water) at room temperature. Passing the leachate is conducted in an up-flow mode.

Contaminated soil samples were prepared by mixing the soil with Pb(NO3)2 or Cu(NO3)2 solutions at a concentration of 500 mg / kg dry soil and were kept in sealed plastic bags for one month to prevent loss of moisture. After 1 month, DCP solution was added to the contaminated samples the ratio of DCP selected 0.1, 0.2, and 0.5 % in this study. The samples were kept for 2 week and then the leachate column tests were conducted. The amount of soil poured and compacted in each cell was 280 gr. The columns were leached for 80 pore volumes and the leachate samples were collected and analyzed for Pb and Cu concentration by flame atomic absorption spectrometer.

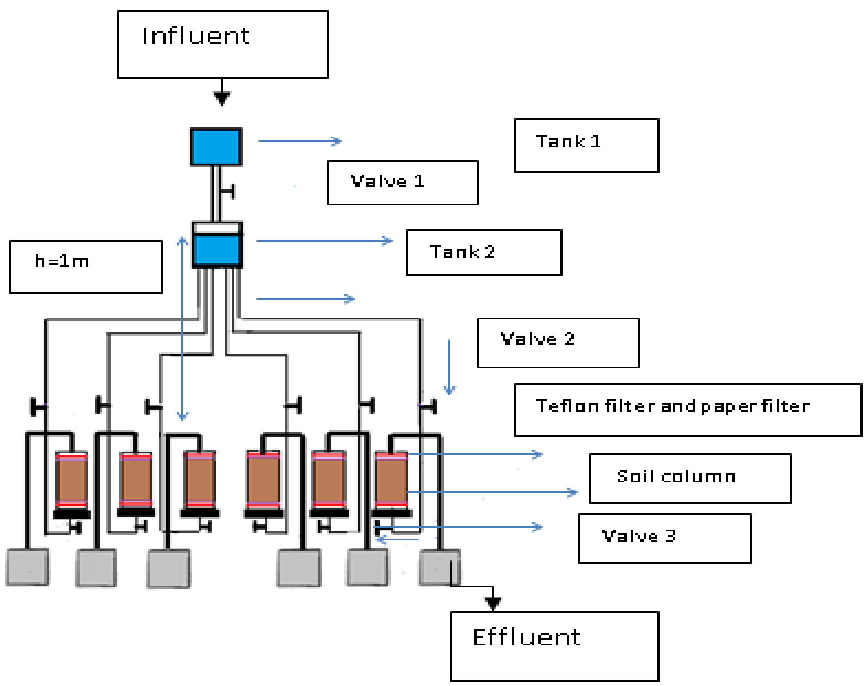

Fig. 1. Schematic diagram of the apparatus

RESULTS AND DISCUSSION

Repeatable results of experiments (Test T0) conducted in this study shows that soil samples are clean and without any contaminant. Fig. 2 shows that the amount of extracted Cu and Pb is negligible in the soil.

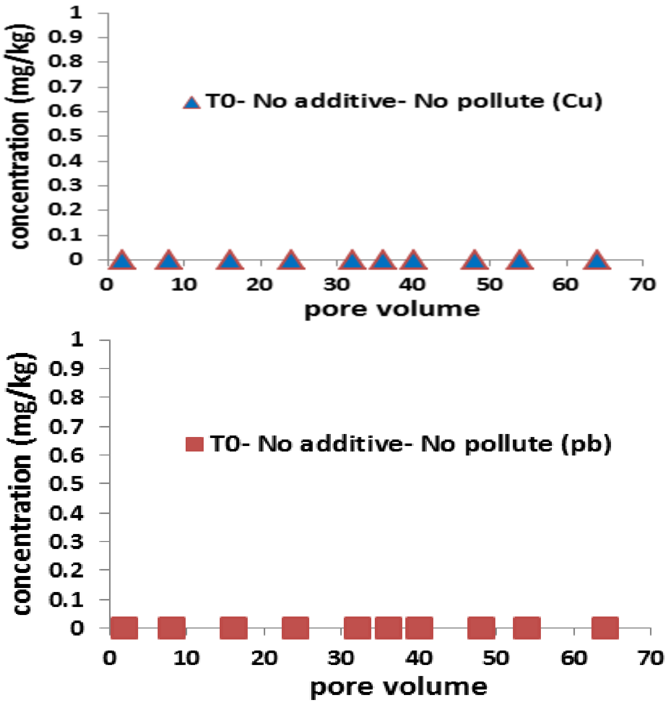

Fig 2. Extracted Cu and Pb is negligible in non-polluted soil

Fig 2. shows the break through curve for the artificially polluted soil samples by lead and copper (Tests T1 and T8). It is clear that Pb and Cu were extracted by effluent continuously; however, the amount of free and soluble Pb cations seems to be more than Cu cations. The concentrations of Pb and Cu in effluents of the tests are uniformly about 5 and 3 mg/L, respectively. Factors such as solubility, cation exchange capacity, etc. may cause this difference.

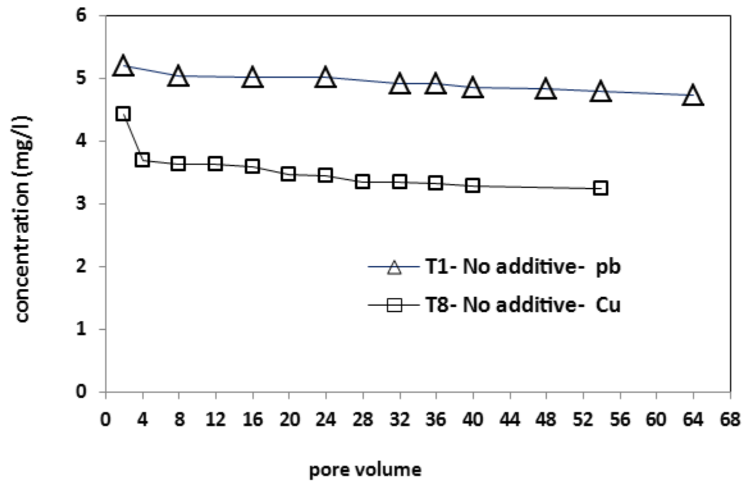

Fig 2. Break through curve for the artificially polluted soil samples by lead and copper

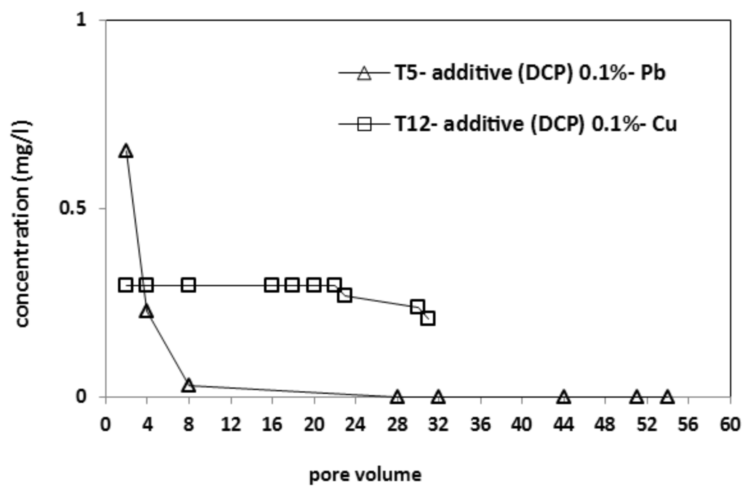

Fig.3. Effect of 0.1% DCP on the Pb and Cu immobilization

Adding 0.1% DCP (by weight / kg dry soil) to the polluted soil samples in Tests T5 and T12 caused a dramatic behavior in break through curve as depicted in Fig. 3. The concentrations of Pb and Cu in effluents reach to about 0 and 0.3 mg/L, respectively. This means that most of the Pb was stabilized through the soil; however, a uniform transport of Cu is accomplished by the effluent in Test T12.

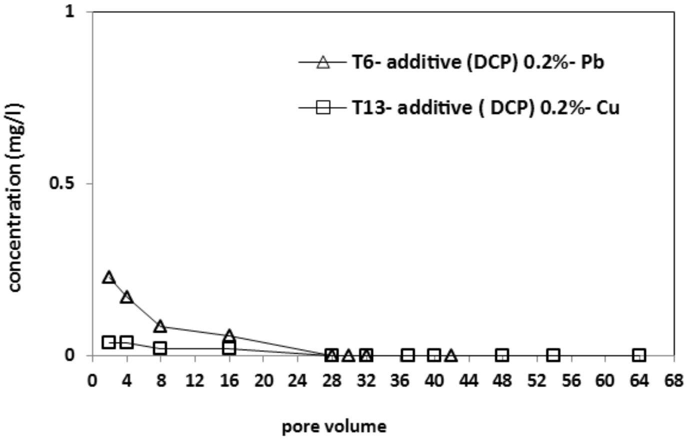

Fig.4. Effect of 0.2% DCP on the Pb and Cu immobilization

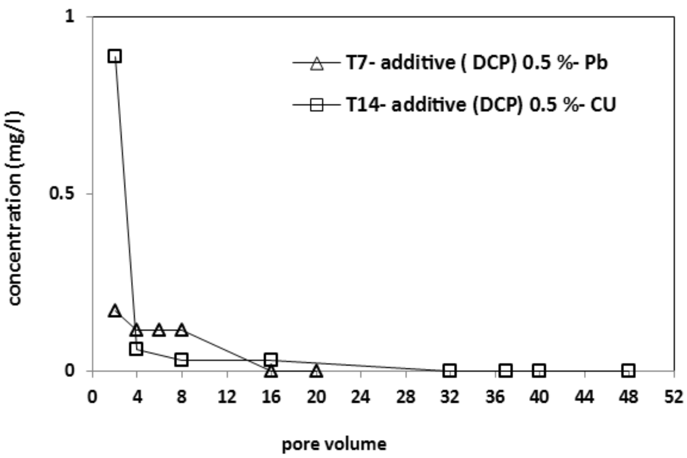

Fig.5. Effect of 0.5% DCP on the Pb and Cu immobilization

To find out the effect of the DCP concentration on the efficiency of lead and copper stabilization through the soil (and probably optimum content of DCP), Tests T6, T7, T13 and T14 were performed. In the two former tests the DCP amount increased to 0.2% and in the two latter increased to 0.5% by weight and the break through curves were plotted in Fig. 4 and 5, respectively.

Contrary to 0.1 %, increasing DCP to 0.2 % causes that most of the Cu were stabilized, According to Fig. 4. The same results were also obtained by Fig. 5.

In addition, Pb has stabilized through the soil in Fig. 4 and 5 which confirms the results of Fig.3. It should be pointed out the in all tests performed in Fig. 3 to 5 some free metals were extracted in the first stages of the tests. Therefore, the optimum concentration of DCP for stabilization of Cu for the studied sand seems to be 0.2% by weight per kg dry soil while this seems to be 0.1% for stabilization of Pb through the soil.

To compare the results for a certain metal, i.e. Pb or Cu, Fig. 6 and 7 was provided. As previously explained, a large amount of these metals were stabilized and fixed if DCP is added to the contaminated soil.

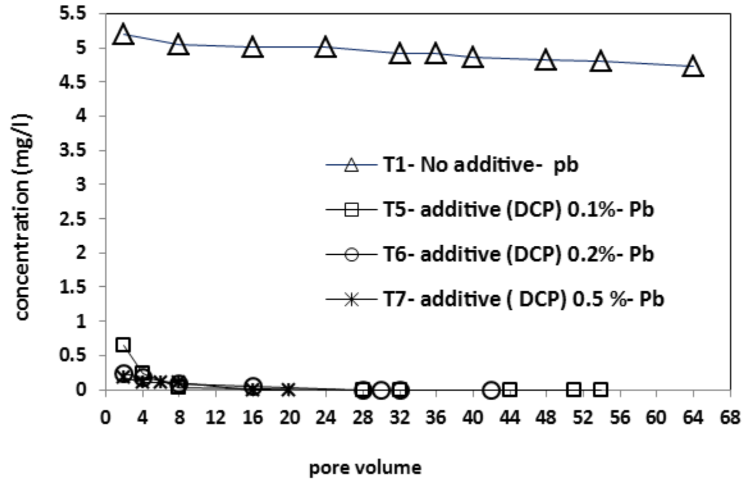

Fig.6. DCP stabilization of lead polluted soil

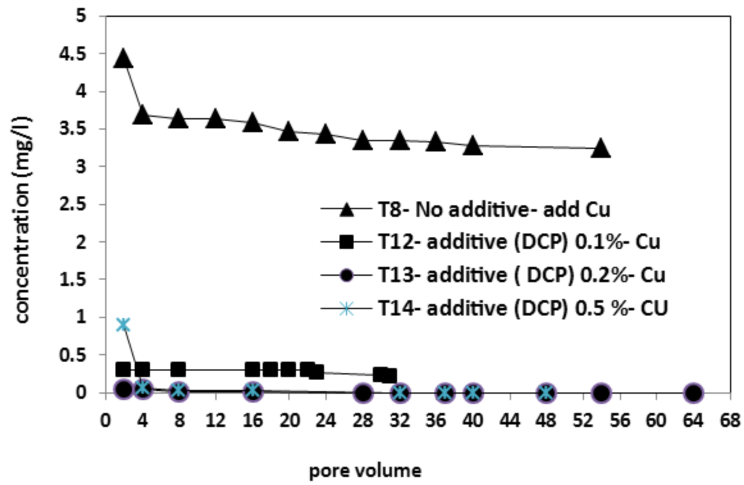

Fig.6. DCP stabilization of copper polluted soil

CONCLUSION

In this paper stabilization of heavy metals contaminated soils using dicalcum phosphate (DCP) was investigated. A series of leachate column tests were conducted to find out the effect of DCP on Pb and Cu polluted soil. DCP with 0.1, 0.2 and 0.5 mg/kg dry soil were added to the polluted soil and the samples were kept for 1 month. Break through curves were prepared to analyze the results.

For polluted soil without any stabilizer, the concentrations of Pb and Cu in effluents of the tests are uniformly about 5 and 3 mg/L, respectively. This means that the contaminant transports freely through the soil.

Adding 0.1% DCP (by weight / kg dry soil) to the polluted soil samples caused the concentrations of Pb and Cu in effluents reach to about 0 and 0.3 mg/L, respectively. Increasing DCP increases the efficiency of Cu stabilization. The optimum concentration of DCP for stabilization of Cu for the studied sand seems to be 0.2% by weight per kg dry soil while this seems to be 0.1% for stabilization of Pb through the soil.

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