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Impact of Enhancement by NaOH on Solidification/Stabilization of Contaminated Bentonite

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Abstract

Cement-based solidification/stabilization is one of the common methods for increasing the stability of heavy metals in contaminated soils. However, the presence of heavy metals such as lead ions causes a delay and prevention in cement hydration which makes this method inapplicable. Enhancement of contaminated clayey soils by NaOH can remove the problems associated with cement hydration delay in the presence of heavy metal ions. The main objective of this paper is to determine the impact of enhancement on solidification/stabilization of contaminated soils in extreme acidic and alkaline environment. To achieve the above mentioned objective, samples of contaminated bentonite by 50 and 100 cmol/kg-soil of lead nitrate at two different conditions of enhancement by NaOH and without enhancement were solidified/stabilized by 10 and 50 percentages of cement. The extreme acidic and alkaline conditions simulated by performing of equilibrium soil washing, and endorsed TCLP test in solidified/stabilized cured samples. In addition, a series of XRD experiments were performed to address the rate and quantity of CSH formation. The achieved results indicate that at extreme alkaline conditions the enhancement of contaminated bentonite has decreased the leach-ability of lead ions around 96%. With a decrease in pH of samples to the quantities less than 5, the use of enhancement in samples has reduced the quantity of leachate in comparison to unenhanced samples around 90%. This is attributed to the contaminant retention by clay fraction of bentonite and contaminant solidification by CSH gels.

Key words: *Cement, Solidification/Stabilization, Enhancement, Bentonite, Heavy Metal Contaminant.*

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Extended Abstract:

1. Introduction

Cement based stabilization/solidification is one of the common methods to prevent the transportation of heavy metal ions to the ground water (Wu et al., 2018). In this process, the application of cement plays two important roles which include the stabilization of heavy metal ions due to the high pH of cement and solidification of heavy metal ions by the formation of pozzolanic components (Ouhadi et al., 2021). Heavy metals ion can prevent the normal hydration of Portland cement (Niu et al., 2018) which reduces the extent of formation of pozzolanic components such as CSH and CAH (Li et al., 2019). The stabilization/solidification process should reduce the concentration of heavy metals in leachate through toxicity characteristic leaching procedure test (TCLP). According to the USEPA (USEPA, 1992) the maximum allowable leachate in TCLP test for Pb ions should be less than 5 mg/l (Intrakamhaeng et al., 2020). The solubility characteristics of lead ions indicate that its solubility behaviour is dependent to variation of pH (Lee et al., 2005). However, there has not been enough research to investigate the impact of pH variations upon stabilization/solidification of heavy metal contaminated clayey soils (Kang et al., 2020). Therefore, the main objective of this research is to address the impact of enhancement by sodium hydroxide upon stabilization/solidification of contaminated bentonite by cement.

2. Materials and methods

In the current study, bentonite is used which its dominant clay fraction is smectite. Table (1) shows some of the geo-environmental characteristics of bentonite sample.

Table 1. Some of the geo-environmental characteristics of bentonite sample.

Parameter	Bentonite	Method
pH (1:10, soil/water ratio)	9.9	ASTM D4972, 2016
Carbonate content (%)	10	Ouhadi et al., 2011
CEC (cmol/kg)	62.2	Ouhadi and Deiranlou, 2017
Specific surface area (m^2/g)	418	Eltantawy and Arnold, 1973
Soil classification	CH	ASTM D3282, 2016
Liquid limit (%)	319	ASTM D4318, 2016
Plasticity index (%)	275	ASTM D4318, 2016
Mineral composition based on XRD analysis (%)	Montmorilonite, Quartz, Calcite	Moore and Reynolds, 1989

The bentonite sample is laboratory contaminated with 50 and 100 cmol/kg-soil of lead nitrate. Then, samples are stabilized/solidified with cement at two conditions of un-enhanced and enhanced by NaOH. A series of TCLP, ELT, and PTCLP experiments were performed upon stabilized/solidified samples to investigate the impact of NaOH enhancement upon leachate characteristics of contaminated bentonite. In addition, XRD experiments were used to determine the extent of CSH and lead-carbonate components in stabilized/solidified samples.

3. Results

The obtained results indicate that in extreme acidic and alkaline conditions, the enhancement with NaOH causes a noticeable reduction in leachate of Pb ions from stabilized/solidified samples. The

achieved results of this paper prove that the application of enhancement by NaOH increases the intensity of CSH peak. For instance, in NaOH enhanced sample containing 50 cmol/kg-soil of lead nitrate which is stabilized/solidified by 30% cement the intensity of CSH peak is twice of unenhanced sample.

4. Conclusion

The results of this research indicate that the use of enhancement by NaOH in cement based stabilization/solidification process of contaminated bentonite reduces the negative influence of Pb ions upon cement hydration. Therefore, the quantity of CSH in stabilized/solidified samples increases which causes a reduction on the concentration of Pb ions in leachate of samples. Furthermore, the NaOH enhancement of contaminated bentonite before addition of cement causes an increase in capability of bentonite to retain heavy metal ions. This consequently reduces the leachate concentration from stabilized/solidified sample.

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