Role of Additives on Remediation and Improvement of Geotechnical Properties of Heavy Metal Contaminated Soils by Solidification/Stabilization Technique

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EXECUTIVE SUMMARY

The indiscriminate and unscientific disposal practices of solid wastes in and around the dumping sites in developing as well as developed countries are causing severe lithospheric (soil and water) pollution in these areas. The continuous increase of soil and water pollution due to discharge of industrial and domestic waste in the landfill sites are of real concern to the people residing nearby the sites (Maheshwari et al. 2015). The toxic leachate from these sites migrates through the sub-surface soil media causing serious depletion of surrounding soil and groundwater qualities which limits redevelopment of the area for future infrastructural activities (Xia et al. 2018). Conventionally, the top soils in these sites are removed/ replaced by a good quality soils which is expensive, time-consuming and sometimes impracticable due to non-availability of large quantities of soils.

The various in-situ/off-situ land decontamination techniques such as soil washing, phytoremediation, vitrification, excavation and disposal, etc. are readily available, however, these are either time consuming or expansive or both (Gong et al. 2018). Solidification/Stabilization (S/S) with additives is a good alternate solution to simultaneous immobilize the contaminants and improvement of strength properties of soils. Most of the earlier studies also used similar or different stabilizers for improvement of engineering properties of soil. S/S technology is gaining popularity for in-situ remediation of heavy metals contaminated soils because of its higher efficiency, low cost and lesser time consuming in comparison to the other available technologies (Du et al. 2014; Zhang et al. 2015).

The present study aimed to examine the efficacy of a balanced mixture of three locally available sustainable and inexpensive materials viz. fly ash (FA), blast furnace slag (BFS) and quick lime (QL) to solidify/stabilize As, Cr, Cd, Pb, Zn, Hg, Cu, Ni polluted site at Eastern Kolkata, West Bengal India through mechanical blending. Moreover, attempts were also made

to lessen the metals leachability from the contaminated site through stabilization and to improve the strength parameters of the stabilized soil through solidification so that the reclaimed land can be used for habitation as well as infrastructural developments.

The physico-chemical characterization as well as the pozzolanic activity tests (Strength Activity Index and Frattini test) were performed to examine the potential of these additives to be used in remediation and improvement of the geotechnical properties for heavy metal contaminated soil. The engineering properties of the virgin soil samples were evaluated following the procedures illustrated in Bureau of Indian Standard (BIS 2720). The optimum amounts of FA, QL and BFS to be used as additives in the soil were estimated using Box Behnken Design (BBD) model in Response Surface Methodology (RSM) tools described by researchers elsewhere in the literature (Bingöl et al., 2012; Turan et al., 2013). The additives blended soil was tested in the laboratory to determine it's specific gravity, soaked California Bearing Ratio (CBR) value, as well as Maximum dry density (MDD) & Optimum moisture content (OMC) according to the guidelines described in the BIS 2720. The background heavy metal concentrations of the soil sample collected from the landfill site were determined. The soil was found highly contaminated with As, Cr, Cd, Pb, Zn, Hg, Cu, Ni, and well above the threshold values. Moreover, the surface, as well as sub-surface water in and around the study area, are also contaminated due to prolong lateral and vertical advective dispersion of the pollutants as reported by Maiti et al. (2016). The quality of virgin soil was found to be poor as reflected by MDD (13.20 kN/m^3), UCS (50 kN/m^2), and soaked CBR values (4.82%). After S/S treatment, the average MDD and soaked CBR values were obtained as 14.23 kN/m^3 and 28.60 %, respectively. It was observed that Specific Gravity (G) and Unconfined Compressive Strength (UCS) were increased to 2.48 and 65 kN/m^2 respectively after curing for 7 days. The concentrations of heavy metals in the leachate of the multi-metal contaminated soil were decreased significantly after blending with FA, QL & BFS additives at an optimized amount of 5, 20, and 20 % by weight of soil mass after the curing for a period of 3 and 7 days.

Moreover, numerical modelling was also performed considering a geotechnical engineering practical problem to ascertain the degree of strength improvement achieved of the solidified/stabilized multi-metal contaminated soil. The vertical displacement of the embankment founded on contaminated soil was estimated as 194.3 mm under drained condition. Whereas, the vertical displacement of the same embankment founded on stabilized soil was estimated as 136.3 mm under drained condition. The factor of safety value was also found to be increased from 2.5 to 3.2 under the drained condition of the model embankment slope founded on additives stabilized soil. The scanning electron microscope (SEM) micrographs of the heavy metal contaminated and additive stabilized soil were also studied. The micrograph of the contaminated soil was compared with the stabilized soil. The aggregation seen in the stabilized soil is absent in the contaminated soil. The SEM micrographs of the stabilized soil indicated the crystalline format with visible edges. Overall, a much denser matrix is observed, showing the formation of fibers and the continuous mass of the stabilized soil, which increased the strength of the contaminated soil.

So, immobilization of the heavy metals in the contaminated land as well as improvement of the geotechnical properties indicate mechanical stabilization as a good solution in contaminated soil remediation. Thus, the metal-contaminated sites can be rejuvenated for various infrastructural activities as well as waste minimization can also be achieved. Finally, the present study results provide a novel idea for in-situ improvement of contaminated sites through mechanical mixing with low-cost binders, and thus reclamation of the polluted sites can be achieved. Future infrastructural activities can also be initiated without replacing the contaminated soil. However, Pilot scale study was not conducted in the present scope of research and which is necessary for verification of the laboratory scale research outcomes in field condition.