Research Paper Engineering

A Study on Geotechnical Properties of Heavy Metal Contaminated Soil

Arpita V Patel | Assistant Professor, Civil Engineering Department, Parul institute of Engineering and Technology, Limda, Waghodia, Vadodara

ABSTRACT

Problem statement: Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are barium (Ba), chromium (Cr), zinc (Zn), copper (Cu), nickel (Ni), cobalt (Co), Vanadium (V) and (Sr). A.K.KRISHNA and P.K.GOVIL concluded that environmental properties of black cotton soil are highly affected by heavy metals. Heavy metal contamination has not just affected the environmental properties of the soil but will also alter the geotechnical properties of heavy metal-contaminated soil. Approach: This study presented the geotechnical properties of Heavy metal-contaminated soils as well as uncontaminated soils for comparison. Testing programs performed on the studied soils included basic properties, Atterberg limit, and compaction test. The Black cotton soils used procured from GUJARAT AGRICULTURAL BIOTECHNOLOGY INSTITUTE, SURAT. Soil samples were artificially contaminated with Barium (Ba) – 471.7 mg/kg, chromium (Cr) – 305.2 mg/kg, zinc (Zn) - 139 mg/kg, copper (Cu) – 137.5 mg/kg, nickel (Ni) - 79 mg/kg, cobbalt (Co) – 51.3 mg/kg, Vanadium (V) – 380.6 mg/kg, (Sr) – 317.9 mg/kg. Results: The results showed that the Heavy metal contamination decreased the specific gravity and Optimum Moisture Content. The liquid limit, plastic limit and Maximum Dry Density were seen to decrease with heavy metal as contaminant. Conclusion: The results showed that the addition of Heavy metal has minor effects to the geotechnical properties of the studied clayey soil. Contaminated clayey soils might be used for geotechnical purposes and these results will benefit to engineers or decision makers in recycling or re-using of contaminated soils.

KEYWORDS Contaminated soil; Heavy metal; Specific Gravity, Atterberge limit, Compaction characteristics

INTRODUCTION

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are barium (Ba), chromium (Cr), zinc (Zn), copper (Cu), nickel (Ni), cobalt (Co), Vanadium (V) and (Sr).Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation, and their total concentration in soils persists for a long time after their introduction. Changes in their chemical forms (speciation) and bioavailability are, however, possible.

The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal, human), drinking of contaminated ground water, Reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems. The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation.

Contemporary legislation respecting environmental protection and public health, at both national and international levels, are based on data that characterize chemical properties of environmental phenomena, especially those that reside in our food chain. While soil characterization would provide an insight into heavy metal speciation and bioavailability, attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental and associated health effects (risks) of these heavy metals. Risk assessment is an effective scientific tool which enables decision makers to manage sites so contaminated in a cost-effective manner while preserving public and ecosystem health.

In soil contamination, possible sources of contamination, basic chemistry, and the associated environmental and health risks of priority heavy metals (Ba, Cr, Co, Zn, Sr, Cu, V, and Ni) which can provide insight into heavy metal speciation, bioavailability, and hence selection of appropriate remedial options.

Heavy metals in the soil from anthropogenic sources tend to be more mobile, hence bioavailable than pedogenic, or lithogenic. Metal-bearing solids at contaminated sites can originate froma wide variety of anthropogenic sources in the form of metal mine tailings, disposal of high metal wastes in improperly protected landfills, leaded gasoline and leadbased paints, land application of fertilizer, animal manures, biosolids (sewage sludge), compost, pesticides, coal combustion residues, petrochemicals, and atmospheric deposition.

Land contamination is not only harmful for the subsurface water aquifers but structures existing on it. Any changes in engineering properties and behaviour of soil strata may lead to loss of bearing capacity, an increase in total or differential settlement of foundation system of structures consequently leading to failure of structures thereby causing loss of property and life.

LITERATURE REVIEW

Soil Contamination Due to Heavy Metals from an Industrial Area of Surat, Gujarat, Western India by A.K.KRISHNA

and P.K.GOVIL.
Heavy metals such as Ba, Cu, Cr, Co, Ni, Sr, V and Zn are found in an industrial area of a surat. They check environmental effect of the heavy metals on soil. The soil sample was collected from a top 10 cm layer of soil. In this study, spatial variation in an elemental composition of soil is investigated by collecting and analyzing 25 surface soil samples from surat. Distribution map of heavy metals and correlation diagrams were prepared to investigate source of contamination.

They collect sample and put in plastic bag to avoid use of metals than soil Sample dried for two days and disaggregated with mortar pestle. The sample was finely powdered 250 mesh size (US Standard) using swing grinding mill. Now soil sample were analyzed for heavy metals by using Philips PW 2440 X-ray fluorescence spectrometer. The heavy metal loads of the soils in the study area are 471.7 mg/kg for Ba, 137.5 mg/kg for Cu, 305.2 mg/kg for Cr, 51.3 mg/kg for Co, 79.0 mg/kg for Ni, 317.9 mg/kg for Sr, 380.6 mg/kg for V and 139.0 mg/kg for Zn.

They concluded that environmental properties of black cotton soil are highly affected by heavy metals.

HEAVY METALS WHICH ARE ADDED IN SOIL
Barium (Ba) – 471.7 mg/kg
chromium (Cr) – 305.2 mg/kg
zinc (Zn) - 139 mg/kg
copper (Cu) – 137.5 mg/kg
nickel (Ni) - 79 mg/kg
cobbalt (Co) – 51.3 mg/kg
Vanadium (V) – 380.6 mg/kg
(Sr) – 317.9 mg/kg

SCHEDULE OF WORK
The black cotton soil used for this study was procured from "GUJARAT AGRICULTURAL BIOTECHNOLOGY INSTITUTE, SURAT.

Heavy Metals used for this study were collected from Durga Enterprise, Vadodara.

The soil was dried to sun light for 5 days and finely powdered to 300 micron size. The addition of heavy metal was done in the powered form.

Following tests were performed on virgin black cotton soil and heavy metal contaminated soil:
Liquid Limit Test
Plastic Limit Test
Specific Gravity
Standard Procter Test

Results and Discussion:
Basic geotechnical properties of the virgin black cotton soil and heavy metal contaminated soil instead of basic and engineering properties of uncontaminated silty and virgin black cotton soil was found 44% and 27.5% respectively. The Plasticity index (PI) for uncontaminated soil was found 16.5%. The average value of Liquid Limit and Plastic limit for Heavy metal contaminated soil was found 49% and 29.72% respectively. The Plasticity index (PI) for uncontaminated soil was found 19.28%.The type of soil was CI in both cases.

Table:1 Basic geotechnical properties of the virgin black cotton soil and heavy metal contaminated soil.

Sr no.	Property	Virgin black cotton soil	Heavy metal Contaminated soil
1	Specific gravity	2.15	2.04
2	Liquid limit (%)	44	49
3	Plastic limit (%)	27.5	29.72
4	Optimum moisture content (%)	21.42	20.83
5	Maximum dry density (gm/cc)	1.541	1.5497

Table:2 Change in geotechnical properties of Black cotton soil due to heavy metal contamination

Sr no.	Property	Change in property in percentage
1	Specific gravity	-5.12
2	Liquid limit (%)	11.36
3	Plastic limit (%)	8.07
4	Optimum moisture content (%)	-2.75
5	Maximum dry density (gm/cc)	0.56

(-) sign indicates decreases and (+) sign indicates increases in property

The change in geotechnical properties of Black cotton soil was observed as below (From Table 2)

The specific Gravity of Black cotton soil decreased by 5.12% due to Heavy metal contamination. The liquid limit and plastic limit increased by 11.36% and 8.07% due to contamination. The optimum moisture content was observed to be decreased by 2.75% and Maximum dry density increased by 0.56% due to contamination.

Conclusions :
The results shows that the addition of heavy metals in prescribed content had decreased the Specific gravity and Optimum Moisture Content of black cotton soil. However the affect of contamination on Specific gravity and Optimum Moisture Content was found very small as shown in Table2. The liuid limit, Plastic limit and Maximum Dry Density was observed to be increased due to contamination. The amount of increase in liquid limit and plastic limit was found moderate while change in maximum dry density was found very less as shown in table2.

So finally the conclusion arrives from this study is that the effect of heavy metal contamination on geotehnical properties of blackcotton soil is negligible.

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