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ABSTRACT

Growth in industrialization results in urban areas to suffer from serious problems of environmental pollution as; the solid waste generation in these areas is very high, and its proper disposal is a major problem. Mainly contaminants from industries are metallic in nature among them the most common found is Lead. This metallic contaminant is inorganic in nature its concentration does not change with time. An estimation of contaminant transport through compacted fine-grained soils is of great importance for the remediation of contaminated sites and in the design of liners for waste containment facilities, which requires proper understanding of various processes that occur while the contaminants are transported through them. The concentration of the influent liquid is maintained at 100ppm. Selected soil exhibit distinct mineralogical and morphological characteristics from other soils available in the region. The shear strength tests will be carried out to address the geotechnical properties of the selected soil with heavy metal. This study enhances better understanding of the fate of selected heavy metals contaminant movement in selected soil and stabilizer (lime) effect on expansive soil. The results obtained from this study can be efficiently used to design landfill liners relying on this soil.

Keywords: *Lead, Semi-Arid Soil, Shear Strength, Lime, Landfill Liner.*

INTRODUCTION

The large production of wastes in modern society often poses a threat to not only to soil pollution but also has resulted in many incidents of groundwater contamination. In past few years, a great concern and importance has been expressed over problems of soil contamination with heavy metals due to rapid industrialization (Table 1) and urbanization. These elements can bio accumulate in plants and animals eventually making their way to humans through the food chain [1-3]. Soils are usually the interface between human activities the parts of the environment that should be preserved and protected [4]. Soil samples represent an excellent media to monitor heavy metal pollution because heavy metals are deposited in topsoil layers [5-11].
Furthermore, soils not only serve as sources for certain metals but can also function as sinks for metal contaminates. Studies of heavy metals indicated that many areas near urban complexes, mines or significant road systems contain enormous high concentrations of these elements. In particular, soils in such regions have been polluted from a wide range of sources with Pb and other heavy metals [12-14].
Therefore, analysis of heavy metals in soil offers an ideal means to monitor not only the pollution of the soil itself but also to quantity the overall environment, as reflected in soil [4,15-16].
Due to their contaminant effect, heavy metals are the primary focus of recent works [17-20]. The aim of the present study is to investigate the extent of contaminant attenuation of chemical

species by specific soils and whether the present retardation equation can successfully predict contaminant transport. These aspects form an essential basis for the design of clay liners for waste impoundment such as landfills. The understanding of these fundamental transport processes and mechanisms helps to the assessment of a wide range of industrial and mining activities on the groundwater system, and several potential uses of hazardous waste site remediation technologies. To predict the transport and the fate of various pollutant species, the transport parameters involved in the governing set of equations that describe the transport processes need to be accurately defined. The laboratory column experiments, which can be used to estimate the transport parameters of chemical species migrating through waste containment barriers, are discussed. The soils used and their properties, the preparation of leachate solution, the design of laboratory column apparatus, and testing procedure for conducting column testing and analysis of chemical are studied in detail. In geotechnical engineering this study has vital importance as the transport of contamination will not alter only physical and chemical properties but it adversely affects the geotechnical properties of soil.
Extensive literature is available on air and water pollution, but little effort has been made to determine how the ground soil responds to these hazardous or toxic substances. This study will help in various geotechnical aspects relating to soil-contaminant interaction.

1.2 Contaminant Generation:

Heavy metal contamination of soil results from anthropogenic processes such as mining [21], smelting [22] and agriculture [23] as well as natural activity. Chemical and metallurgical industries are among the most critical sources of heavy metals in the environment [24].
Contaminant categories include toxic and hazardous chemicals, radioactive materials, and by-products of manufacturing processes, which are identified on surfaces employed in specific industries, such as metals processing, chemical production, nuclear industry, pharmaceutical manufacture, and food processing, handling, and delivery.

1.3 Lead:

The most abundant heavy metal in nature, first explored for human use, was lead. It is highly toxic to living systems and has never been a nutritionally essential element; hence, it is regular monitoring in the environment is of utmost importance from a human health point of view. The toxicity of lead increases when it is accumulated in the human body to worsen the Central Nervous system. The primary source of lead pollution comes from batteries, cable sheathing, lead sheets, and pipes [25]. Although in some cases it can be recovered and recycled, in most cases it is in compound form, as in paints and petrol additives, are lost to the environment, landing in the aquatic environment. The permissible limit of lead in drinking water is 0.01ppm. Citric acid modified rubber leaf powder and monosodium glutamate modified rubber leaf powder were used to find sorption capacities, breakthrough times and column adsorption capacities were calculated [26]. Volatile fuel compounds mobility through the soil profile and risk of groundwater contamination were studied using column test [27].

The sources of above-mentioned metal ions and their health effects are discussed in Table 1.

Table 1: Sources of pollutants

METAL IONS	MAJOR SOURCES	HEALTH EFFECTS	REFERENCE
Lead	Paint, pesticide, automobile emission, mining, burning of coal, Pharmaceutical manufacturing, lead-acid batteries, pigments, glassware, ceramics, plastic, in alloys, sheets, cable sheathings,	Mental retardation in children, developmental delay, fatal infant encephalopathy, congenital paralysis, sensor neural deafness and, acute or chronic damage to the	[28-29]

	solder, ordinance, pipes or tubing	nervous system, epileptics, liver, kidney, gastrointestinal damage.	

MATERIAL AND METHODS

The present research work includes an attempt to find the effect of inorganic contaminant with influential parameter like shear strength of expansive soil. The purpose of this research is to evaluate the geotechnical characteristic of Al-Ghat soil.

Constituent Soil (Al-Ghat Expansive Clay)

The soil samples used in this study were sourced from Al-Ghat town of Saudi Arabia. Sampling from the terrain site was carried out at a depth of 3 m. Mineralogy reveals this soil as kaolinite type. The soil is expansive in nature with a different degree of expansion compared with other soils available in the region [30]. The Physical and chemical properties of soil were tested as per the relevant ASTM standard testing procedures and are presented in Tables 1 and two respectively. Al-Ghat is a town located 270 km to the Northwest of Riyadh at at latitude 260 32' 42'' N and longitude 430 45' 42'' E. The city is situated within a large wadi with surrounding high hills. The soil of Al- Ghat, in general, is brown to greyish brown near the surface and contains some gravel and clay turning into olive green silty shale below 1.5 to 5m. The expansive soil caused serious damage to buildings and light structures [31]. Figure 1 shows the distribution of the expansive soil in KSA and location of Al-Ghat town.

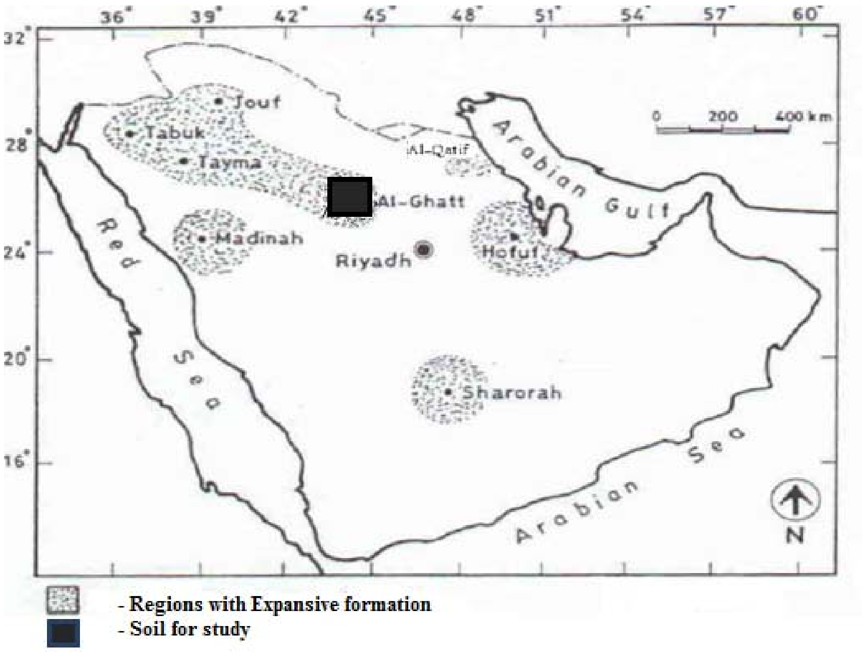

Fig. 1: Map of distribution of the expansive soil in KSA [30].

Once soil samples were collected from Al-Ghat, a multitude of basic tests were done in order to characterize, classify and identify the severity nature of the selected clay. The basic soil tests consist of: Gradation tests (Sieve Analysis and Hydrometer), Atterberg limits (Liquid limit, Plastic limit), and all these tests were done according to ASTM standards. Table 2 summarizes the basic soil tests results and Table 3 summarizes the chemical composition. Numerous approaches in classifying the severity nature were developed (as depicted in Table 4) all these approaches depend on the liquid limit, plasticity index, and shrinkage limits. According to all these classifications, Al-Ghat clay shale is classified as medium to highly expansive clay.

Table 2: Physical properties of the soil [30].

SOIL PROPERTIES	Al-Ghat
Liquid Limit (%)	62
Plastic Limit (%)	30
Plasticity Index (%)	32
Shrinkage Limit (%)	17
Linear Shrinkage (%)	31
% Finer than 200 µm	87.3
Maximum Dry Density (Standard Proctor) (g/cc)	1.63
Optimum Moisture Content (%)	24.68
USCS Classification	CH

Table 3: Chemical composition of the soil [30].

Chemical Composition (%)	Al - Ghat
K+	1.1
K2O	1.3
Al	7
Al2O3	13.3
Si	9.8
SiO2	21
Ca+2	1.4
CaO	2

Table 4: Index properties in classifying the severity nature.

Degree of Expansion	Liquid Limit% Chen	PLASTICITY INDEX% PI Holtz and Gibbs
Very High	>60	≥ 32
High	40-60	23-45

Medium	30-40	12-34
Low	<30	≤ 20

Chemicals Used

Analytical grade calcium hydroxide, Ca(OH)2 represents lime in the study. The amount of lime was fixed at 6% (by dry weight of the soil) considering initial lime consumption, optimum lime content and concern associated with lime leachability [33]. The details of salt used to spike the soils are presented in Table 5. Firstly, the metallic solutions were prepared in 10000ppm concentration, by using the distilled water the solution was diluted to the required concentration of the solution, i.e., 100ppm as shown in Table 5.

Table 5: Salts used for the preparation of metal ion solution.

Metal Ion	Salt used
Lead	Lead Nitrate, Pb(NO3)2

RESULTS AND DISCUSSION

Shear Strength

Shear strength of soil was evaluated using direct shear box apparatus as per ASTM D 3080[34]. The direct shear test is the oldest and simplest form of shear test arrangement. A diagram of the direct shear test apparatus is shown in Figure 2. The test equipment consists of a metal shear box in which the soil specimen is placed. The size of the specimens is 10cm x10 cm across and 2 cm high. The box consists two parts split horizontally into halves. Normal force on the specimen is applied from the top of the shear box. Shearing force applied by moving the upper part of the box relative to the other to cause failure in the soil specimen. The device used in this study was Wykeham Farrance strain-controlled, a constant rate of shear displacement is applied to one-half of the box by a motor that acts through gears. The constant rate of shear displacement is measured by a horizontal dial gauge. The resisting shear force of the soil corresponding to any shear displacement can be measured by a horizontal proving ring or load cell. Change of the height specimen (and thus the volume change of the specimen) during the test can be obtained from the readings of a dial gauge that measures the vertical movement of the upper loading plate. Figure 2 shows a photograph of strain-controlled direct shear test equipment. Shearing was performed with a strain rate of 0.3 mm/min up to peak point strength. Samples were kept fore 1 day after mixing with different dry density and water content, statically compacted samples in one layer.

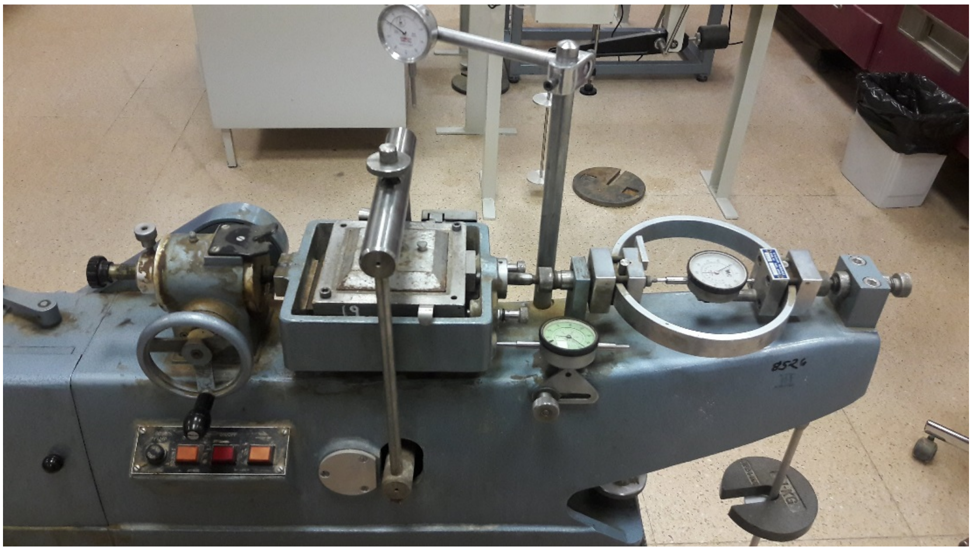

Fig. 2: Direct shear apparatus

The cohesion intercept, C, and angle of friction, ∅, were determined and discussed in Table 6. A series of 16 direct shear tests were carried out for two different conditions of soil (includes repeatability of test for three times and the average of tests were taken to have consistency and assurance of results). Figure, 3 shows the soil sample after testing and the change in sample texture can be examined visually. In every case, the cured lime-soil mixtures displayed a larger angle of friction, ∅, than the untreated soil, among three metal elements lead was prominently dominating. The formation of aforementioned cementitious products in the soil-stabilizer matrix are responsible for increase in the internal friction and shear strength of the stabilized soil.

Fig. 3:Soil sample after testing (Direct shear).

Table 6: Peak Stress and Strain values (0%lime and 6%lime)

Sample	∅		C	
	0%Lime	6%Lime	0%Lime	6%Lime
Al-Ghat soil	34.8	38.9	67.4	112.8

Al-Ghat soil + Pb	35.6	41.6	70.6	117.6

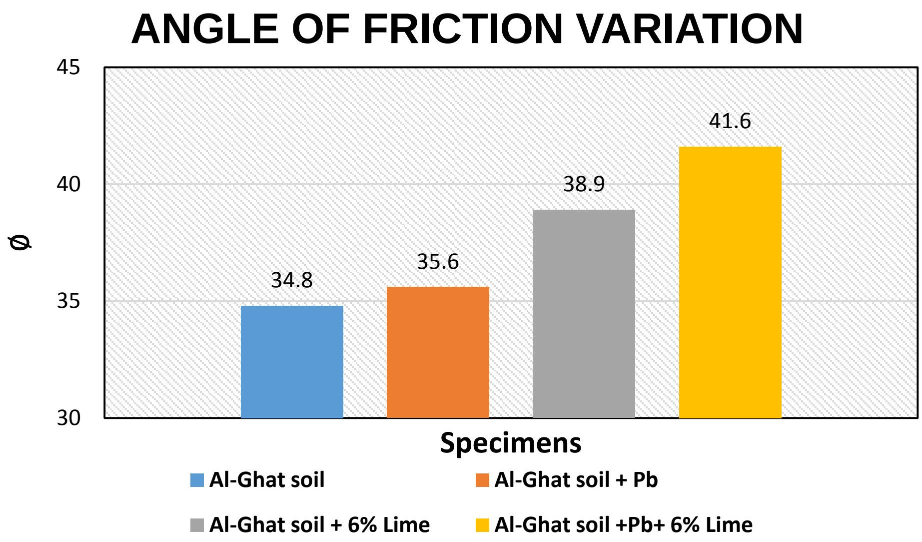

Fig. 4: Angle of friction of different soil samples.

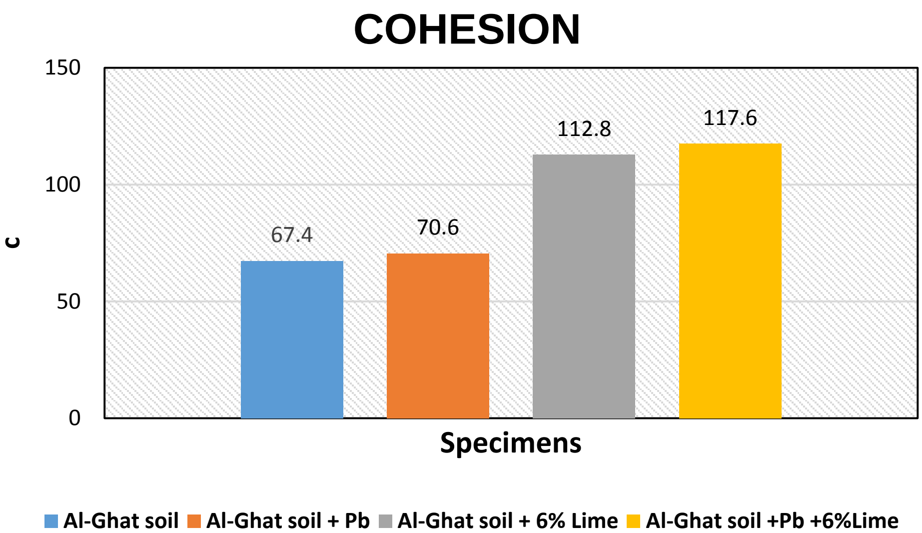

Fig. 5: Cohesion of different soil samples.

Fig. 4 and Fig. 5 gives a clear understanding of effect of lime on soil as angle of friction increased by 10-15% .and cohesion was increased more than 80%.

Organic content:

Influence of organic matter on the geotechnical properties of clays:

The influence of organic matter on the strength- and deformation properties of clay are discussed. It is shown that the geotechnical properties of clay are largely influenced by the amount of organic substance. Progressive failure and creep deformation are obvious at an organic content of 2-3% [35]. When the organic content is of the order 3-4%, the shear strength is considerably influenced. It is obvious that very small amounts of organic matter largely affect the remolded strength. The investigation indicates a close relationship between the processes involved in creep deformation caused by shear and compression. The studies show that the classification of clays with reference to the organic content is reasonable for geotechnical purposes as concerns the limit between clays and muddy clays (2%) while the limit between muddy clays and muds (6%) should be of the order of 4% to illustrate a specific effect of the organic content. The result obtained from laboratory test are shown in Table 7 and it is evident that the result obtained has significant influence on shear strength as discussed in above section of direct shear test results.

Table 7: Organic content of Al-Ghat soil.

Porcelain dish number	A
MP = Mass of empty, clean porcelain dish (grams)	84.5405
MPDS = Mass of dish and dry soil (grams)	118.2224
MPA = Mass of the dish and ash (Burned soil) (grams)	117.0138
MD = Mass of the dry soil (grams)	33.6819
MA = Mass of the ash (Burned soil) (grams)	32.4733
MO = Mass of the organic matter (grams)	1.2086
OM = Organic matter, %	3.5883

CONCLUSION

To safeguard ground water effectively and economically; the landfill liner and cover should be made with locally available materials, which can attain low permeability and high strength.

With addition of lime there is a net increase in porosity.

- With addition of lime the release of silica and alumina phases from the clay particle surfaces to aid in bridging the individual clay particles due to the formation of relatively strong pozzolanic bonds.

- Using clay as a liner for backfill of contaminant produce from industries this study will give a clear understanding of soil- metallic contaminant behavior.

- Further, this study emphasizes and delivers the issues identified with the utilization of locally accessible materials as a suitable choice for the construction of baseliners for landfills (both domestic and industrial).

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