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GEOTECHNICAL PROPERTIES OF SOIL SUBJECTED TO LONG-TERM EFFLUENT CONTAMINATION

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Abstract:-This research describes the results of a scientific examination focusing whether effluent thermal power plant can absorbed by semi contaminated soil and can affect the geotechnical properties of natural contaminated soils. Undisturbed soil samples used for this experimental study are treated with thermal power plant effluent and discussed its effect on the engineering properties after a maturing period of 7 days, 50 days, 100 days and 150 days. The results shown more changed in geo-environmental properties for testing soil with the soaking period. Knowledge of the effect of chemicals on the geotechnical properties of contaminated soil is essential to reduce the problems that geotechnical engineers faces while placing new structures on sites with contaminated soils. This will facilitate the invention and introduction of site specific technologies.

Key Words: Thermal power plant effluent, geotechnical properties, geo environmental properties, contaminated soil.

Introduction:

The particular kinds of metal contaminants available in a polluted soil is directly related to the action that happened at the location. The variability contaminant amounts and the physical and chemical forms of pollutants as well based on actions and disposer method for polluted wastes on the area. Additional circumstances which could affect the form, amount, and dissemination of metal contaminants include soil and ground-water chemistry and regional commuting processes [1]. In this part, totality heavy metal amount and its impacts on soil properties were assessed in soil samples obtains from semi polluted site at depth (3m) with known long-term pollution matters. The chemicals included in west from the landfill are subjected to many different transformation and collapsed conditions they flow with the soil and into the deep strata. The effectiveness of every one soil to attenuate effluent varies, and not all features or formulations are equally taken out or decreased in concentration. A few of the contaminants could possibly adsorbed with the soil media within the movement of effluent across the soil [2]. The long-term results of metals and sometimes pollutants subjected to the soil are extremely hard to evaluate, as there exists less investigations and this means less stats. In this study, the soil samples have been selected from sites with known pollution problems where heavy metals and other contaminants have been exhausted by effluent for more than 20 years. This area is especially influenced with the discharge of liquid effluents provided by thermal power plant waste. At this place heavy metals can be found in equilibrium in the soil solution and knowing that the existence of chemicals correlates generally to their happening and dissimination in the soil solution, these ecosystems supply a great media for analyzing the impact of heavy metals on soil properties [3]. The providence of heavy metals in soil possibly be controlled by physical and biological technics performing inside the soil. Metal ions inside the soil solution from these different kinds of mixture in several amounts can potentially either stay in solution or move within the outflow water or be pickup by plants developing located on the soil or be reserved by the soil in sparingly soluble or insoluble forms. The organic matter of these soil include more like to heavy metals cations that will form control structures thus causing decreased in nutrient content [4]. Every kinds of effluent include directly or indirectly impacts on soil characteristics. Soil-effluent connection modifies soils activity plus can lead to partial or total suppression of pollutants. Soil-effluent activities are able to resultant in soil properties like, effective grain size of soil particles, liquid limit, plastic limit, shrinkage limit, specific gravity, hydraulic conductivity, compaction properties, consolidation and strength properties of soil. The improvement of soil features can lead to different geotechnical matters for instance: landslides, ground subsidence, settlement, erosion, progressive failure, underground structural stability, foundation durability and corrosion. The polluted water attacks foundation structures. It effects the workability and durability of concrete if applied in preparing concrete [5]. (Gratchev I. and Towhata I., 210) examined the consequence of sulfuric acid (H_2SO_4) with pH=3 on compressibility characteristic of clays in Jaban. This sulfuric acid pass into the soil specimen with for various amounts of time, directly from1 to 9 months. It's actually showed that clay mineralogy and soil arrangement created a considerable result toward the compressibility of clays at low pH [6]. (George M., 2014) studied the seepage from the MSW landfill pass through the two types of test soils first type was low compressible and second type was high compressible. The soils are subjected with synthetic chemicals at different amounts and described its result toward the engineering properties after a time period of 7 days, 50 days, 100 days and 150 days. The outcomes indicated that the long term results of the cation amount can lead to more decreasing in Diffuse Double Layer (DDL) thickness. At higher ionic amount, there is a fewer tendency of cations to diffuse away from the soil particles and tendency in decreasing DDL thickness can be decreased [7].

Materials and Methods

Liquid effluent

Due to the existing the drainage disposal, the treated effluent collected directly from treatment station of thermal power plant and analyzed in laboratory. With percolation of effluent from drainage into the soil, many processes will be happening to this effluent like physico-chemical decomposition process, ion exchange reactions, chemical alterations, oxidation, hydrolysis etc. and these actions may be caused changing in natural soil properties. The effluent chemical analysis are given in Table 1. Effluent chemical analysis were applied according to (Standard Method for the Examination of Water and Wastewater) [8].

Table 1: Chemical properties of liquid effluent

Liquid effluent		Mineral content mg/l			
PH	6.58	Cl^-	99.97	Ca	24.6
Alkalinity	52	SO4	200	Na	113.7
Total Hardness mg/l	170	NO3	0.50	K	3.44
Calcium Hardness mg/l	112	Cd	ND	Mg	14.89
*BOD5 mg/l	111	Fe	1.962		
COD mg/l	50	Cr	ND		
EC µs/cm	880	Ni	0.23		
TDS mg/l	800	Pb	0.000		
TSS mg/l	40	Cu	0.034		
Temp. c^o	7.6	Zn	0.005		

Soil Samples:

To study the effect of effluent absorption the undisturbed sandy clay with silt soil samples used were kindly provided by the naturally semi contamination soil samples. The particle size distribution curve for teased soils are shown in (Fig. 6).The naturally semi contamination soil samples were obtained from the site within (50) m distance from the drainage channel which is located at Al -Musayyib thermal power plant/ Iraq which was collected the industrial effluent for 20 years ago at depth (3) m from one borehole No. (BHu2).

Experimental Procedure

Four of model tests were conducted in the developed laboratory set-up with test soil semi polluted to study the leaching process. Test soils were undisturbed samples driven in to the perforated test steel Shelby tube (10) cm diameter and (30) cm high contains circular holes along its circumference with space between holes (2) cm and the diameter for each is (1) mm. Circumference perforations were made on the portion of the steel Shelby tube where it is having contact with the soil. Effluent was transferred to the soil through this perforated Shelby tube also from the top and bottom of the tube. Perforations facilitate the uniform passage of the effluent to surrounding soil. Perforated steel Shelby tube were placed in plastic containers covered with the tide plastic cover to prevent vaporization of the fluid, this containers were filled with thermal power plant effluent. These specimens models soaked with different time period as (7, 50, 100 and 150) days. So, the specimens named as (S7d, S50d, S100d and S150d) respectively. Later on when (7) days passed, this time period that recommended acceptable for chemical equilibrium, the effluent was taken out of the container, and the container was re-filled with the original effluent to keep the chemical concentration constant during the soaking period.

Results and Discussion

1) Chemical Tests

The chemical characteristics of the four soil samples under study are shown in (Table 2).

Table 2: Physical properties for soil samples

Test	BHu2 (3m)	S7d	S50d	S100d	S150d	Standard Specification
PH	7.72	7. 70	7.67	7.60	7.57	BS 1377:1990 [9]
EC µs/cm	950	1047	1421	1524	1747	EC meter [2] [10]
Temp. c^o	29.4	28.7	29.2	29.3	29.6	
Org. %	2.99	3.16	3.22	4.39	4.40	BS 1377:1990 [9]
TDS mg/l	427	478	487	570	799	
Cl^- mg/l	105	145	175	196	200	
SO_4 mg/l	797	842	896	978	1028	
NO_3 mg/l	23.8	26.4	29.4	29.8	29.8	Spectrophotometer [11]
Cd mg/l	219	219	219	219	219	Atomic Absorption Spectroscopy (AAS). [12]
Fe mg/l	34508	35759	36278	36668	37004	
Cr mg/l	56.5	56.5	56.5	56.5	56.5	
Ni mg/l	221	223	225	227	227	
Pb mg/l	ND	ND	ND	ND	ND	
Cu mg/l	24.6	24.7	24.7	24.9	24.9	
Zn mg/l	65.0	74.7	86.3	93.3	95.6	
Ca mg/l	44852	45700	47593	48846	49653	Methods of Soil Analysis. Part 3. [13]
Na mg/l	13597	13794	13872	13937	13972	
K mg/l	8692	8712	8792	8858	8895	
Mg mg/l	3197	3250	3365	3382	3397	

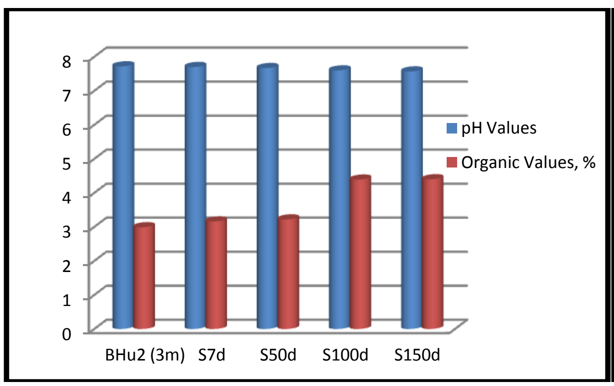


Fig. 1. Variation of pH and Organic values

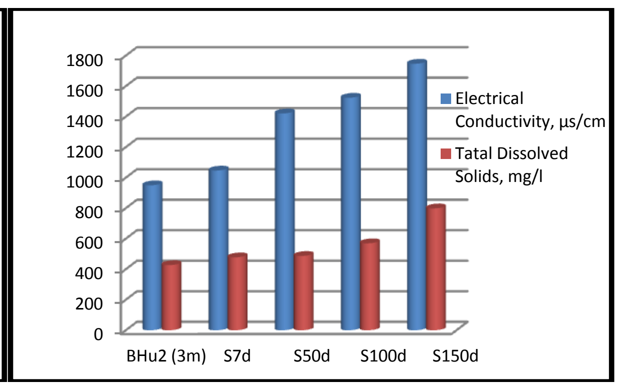


Fig. 2. Variation of EC and TDS

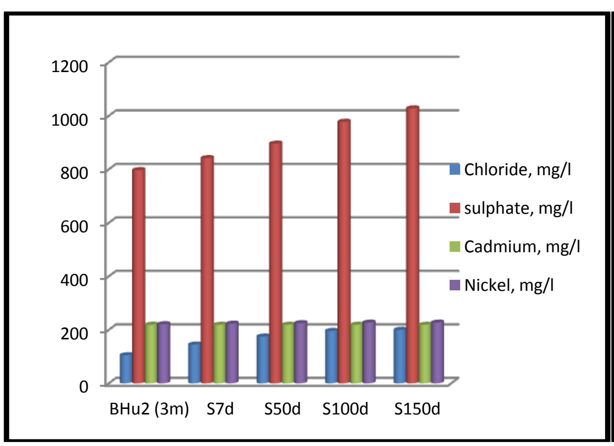


Fig. 3. Variation of Cl, So_3, Cd and Ni Concentrations

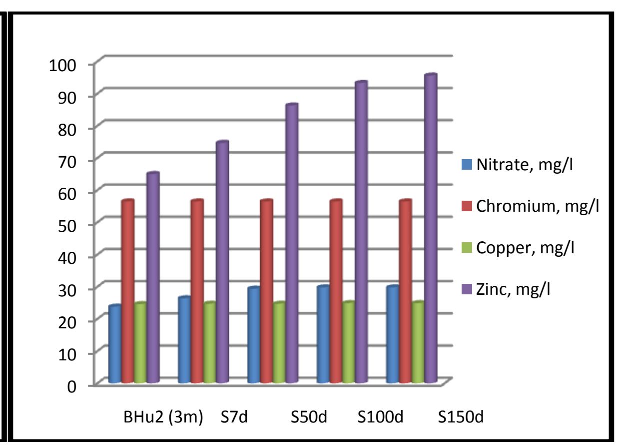


Fig. 4. Variation of No_3, Cr, Cu and Zn Concentrations

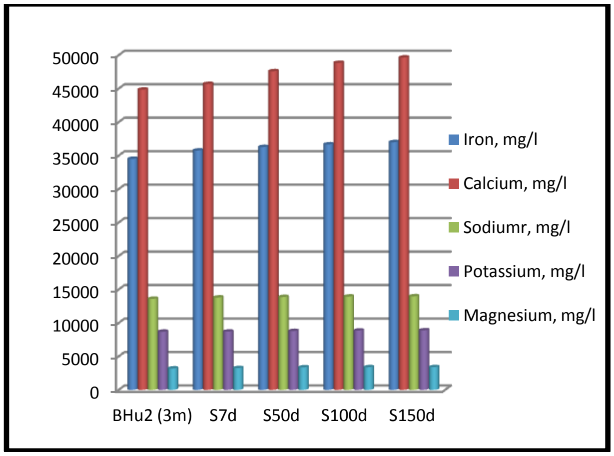


Fig. 5. Variation of Fe, Ca, Na, K and Mg Concentrations

As shown in (Fig. 1), the level of organic matter is high in polluted soil due to some anthropogenic providers, OM might possibly include more amount of contaminants. Therefore typical accumulation of OM can raise the possibility of deposition of high amount of heavy metals towards the surrounding soil [14] . The results appear in (Fig. 1) indicated the reduction in pH values with duration of soaking, also (Fig. 2) viewed the increasing in both EC and TDS values. Same discovering by (Panahpour et al., 2011) who investigated influence of garbage leachate on soil properties, salinity and soil organic matter in east of Isfahan. Results of this study showed reduction in pH value for soil treated with the MWL and raising in soluble salts TDS and also organic matter value. Therefore, acidic media caused increasing the ability of soil to absorb some nutrient elements such as phosphorus, iron, zinc, copper and manganese, and organic materials [15]. Also the results presented in (Fig. 3,4 and 5) stated the increasing in chemical concentrations of metals. This results agreed with (Seyede Batoul Kiayee, 2013), who discovered that the cumulating of micronutrients and heavy metals from MWL usage will be resulted directly via the presence of micronutrients and heavy metals in MWL or indirectly via maximizing solubility of the indigenous insoluble soil heavy metals as decreasing soil pH [16].

2) Physical Tests

The physical characteristics of the reference and soaked soil samples under study are shown in (Table 3). The grain size distribution for referenced and soaking soil samples are presented in (Fig. 6).

Table 3: Physical properties for soil samples

Test		**BHu2 (3m)**	**S7d**	**S50d**	**S100d**	**S150d**	**Standard Specification**
G.S.D	Clay %	46	45	43	52	55	ASTM D 422 [17]
	Silt %	8	5	7	8	9	
	Sand %	46	50	50	40	36	
Gs		2.65	2.57	2.55	2.53	2.53	ASTM D 854-00 [17]
γ_{wet} kN/m^3		20.3	19.6	19.4	19.3	18.6	ASTM D 293 [17]
γ_{dry} kN/m^3		16.2	15.6	15.5	15.4	14.8	
ω %		25.06	25.04	25.20	25.53	25.35	ASTM D 2216 [17]
L.L. %		34.62	34.81	39.95	44.07	45.92	ASTM D 4318 [17]
P.L %		23.72	21.17	24.62	25.25	25.56	
P.I %		10.90	13.64	15.33	18.82	20.36	

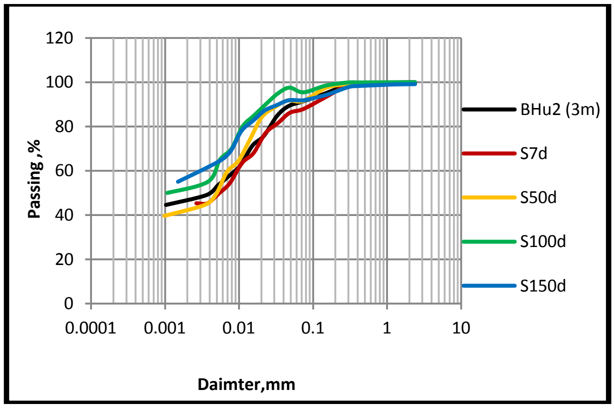


Fig. 6. Grain size Distribution

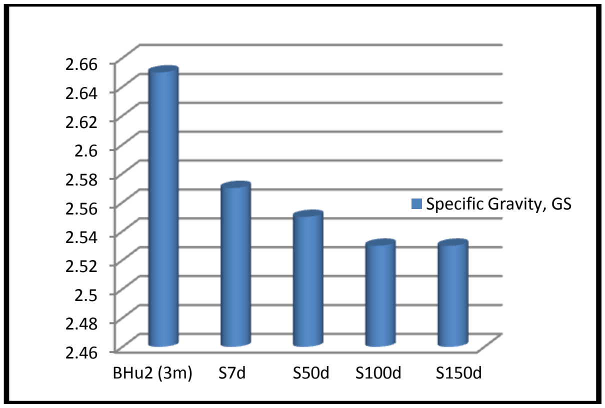


Fig. 7. Variation of Specific Gravity

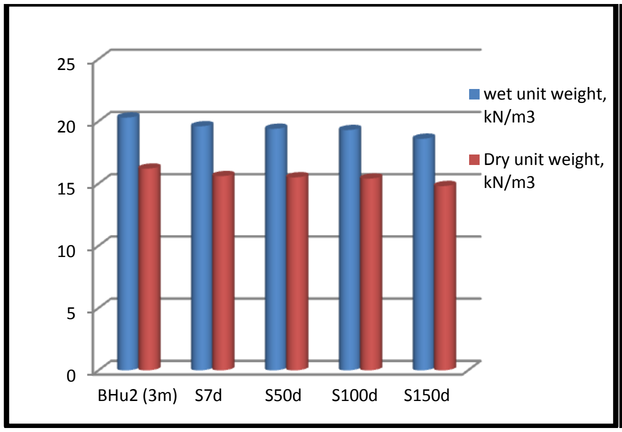


Fig. 8. Variation of Wet and Dry unit weight

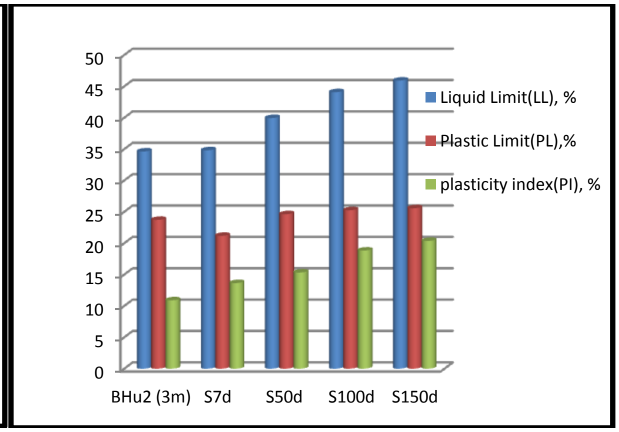


Fig. 9. Variation of Atterberg's Limits

There was slight decrease in specific gravity , wet and dry unit weight with increasing the period of soaking as shown in (Fig. 7 and 8) respectively.

The results of Atterberg's limits for studied soil samples are presented in (Fig. 9) shown slight increase in liquid limit, plastic limit and plasticity index with increasing the period of soaking. A number of past researches found raising in the index characteristics, plastic limit and liquid limit, while more researches found reduction of the index characteristics by subjected of industrial effluent in soil. (Resol D.A. 2008) discovering the raising in liquid limit for fine grained soil with the raising of contaminant amount due to reduction in sizes of soil grained, that will lead to maximize the surface area of solid particles and need more water content to let soil to flow [18]. (Goswami D. and Choudhury B.N., 2013) showed the raising in liquid limit (L.L) of the lateritic soil are primarily from raise clay material of the lateritic soil. The liquid limit activity of a montmorillonite soil is managed clearly by diffuse double layer forces and that of kaolinitic soil by shearing resistance at grain position [19]. The partnership within small particle portion and the engineering activity of the soil relies on its quantity and the physical-chemical features as well as on the relative quantity and properties of the waste as an unpolluted liquid in landfill location. The power thermal effluent was acidic and high electrical conductivity, thus, it will be produce additionally variations in the soil-water arrangement and the ability of water retaining. The perfect knowledge of the clay colloid as the most chemically active portion of the soils might actually evaluate the main information for the important variation. The clay materials consists of the solid clay grain itself plus its sphere of effect in the surrounding water or aqueous solution. Within this sphere of effect, exchangeable ions are in a state of dynamic equilibrium. These ions are attracted to the net negative surface charge of the grain, but they also need to diffuse away under their own inherent kinetic power. Environmental or adsorbed waters are under the effect of electrochemical forces happened due to the clay material and have been influenced by several leachates, causing various in soil consistency [20] .

3) Mechanical Tests

3.1 Consolidation Tests

A Study of the effect of soaking period on the compressibility and swelling behavior of partial polluted soil is important. The effluent component has many chemical properties, and these chemicals can cause excessive settlements and lead to serious consequence. (Table 4) summarizes the components of consolidation test for the soils tested in various test series. Also the results of consolidation test assimilated in Fig. 10.

Table 4: Consolidation results for soil samples

Test		BHu2 (3m)	S7d	S50d	S100d	S150d	Standard Specification
Consolidation	Cv m^2/year	0.801	0.665	0.650	0.498	0.376	ASTM D2435 [17]
	Cc	0.147	0.224	0.227	0.228	0.324	
	Cr	0.017	0.019	0.020	0.023	0.023	
	k m/sec	$4.9*10^{-11}$	$5.0*10^{-11}$	$4.9*10^{-11}$	$4.4*10^{-11}$	$5.0*10^{-11}$	
	e_o	0.634	0.643	0.644	0.648	0.705	
	e_f	0.429	0.358	0.442	0.414	0.407	
	mv m^2/MN	0.196	0.268	0.245	0.283	0.444	
	D kPa	5097	3468	4904	3540	2250	

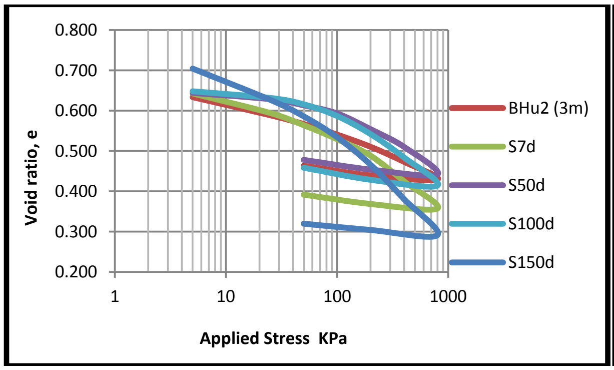


Fig. 10. e – log σ curve

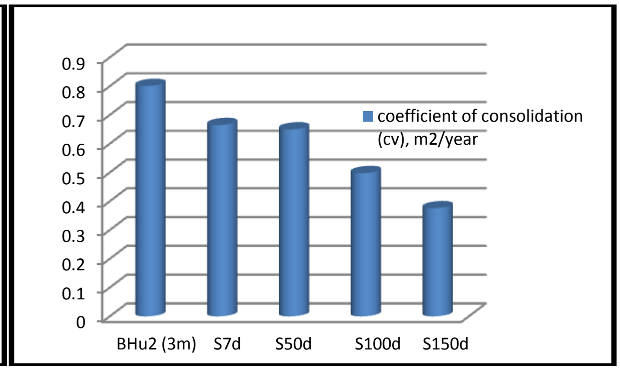


Fig. 11. Variation of Coefficient of Consolidation

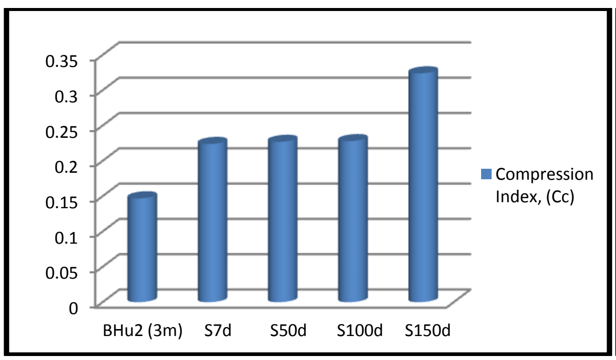


Fig. 12. Variation of Compression Index

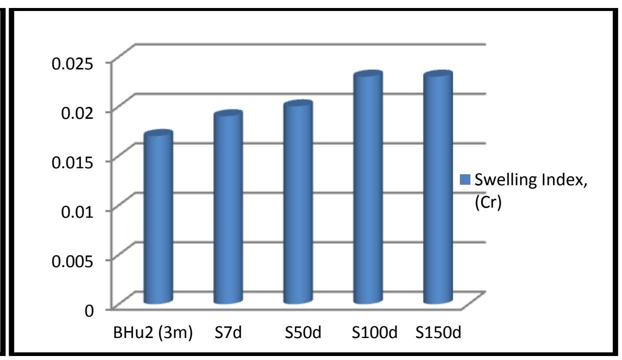


Fig. 13. Variation of Swelling Index

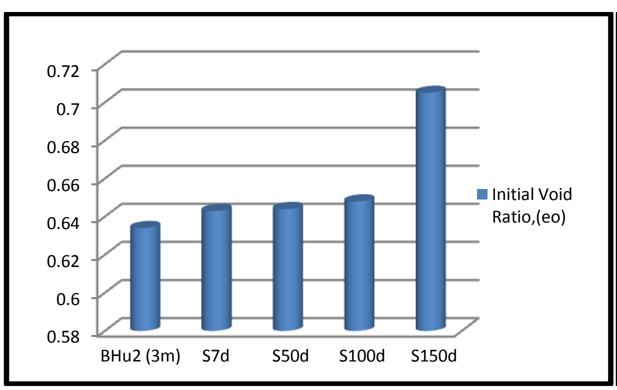


Fig. 14. Variation of Initial Void Ratio

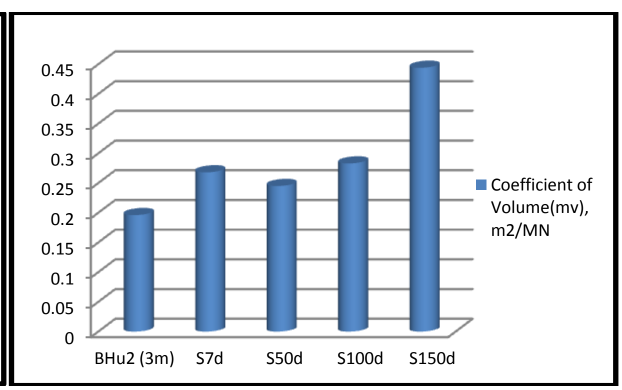


Fig. 15. Variation of Coefficient of Volume

Clay mineralogy, soil matrix, contains cementation, plus the period of acidic pollution look like important components identifying the level that basically variations in the clay's consolidation characteristics could happen throughout leakage. From the results presented in (Fig. 12), its notes the increment in the compression index (c_c). It can be established that compressibility of clay is controlled by mechanical and physicochemical features. As well, the outcomes procured in this part show that the physicochemical features would have additionally clear effect on the consolidation characteristics of clays in case of lowering pH values for the pore fluid. As the samples for every analyzed soil are supposed to have had the exact microfabric prior to acidic leakage, it could be hypothesized that the noticed variations in compressibility have been typically from the soil–water–acid action [6]. According to (Gratchev I. and Towhata I., 2016), the significant raising in the compressibility was noticed for the Kansai clay after the compression index (Cc) of the undisturbed samples increased by (50)%. This could be due to the dissolved of existence calcium carbonates via acidic fluid [21].
(Talukdar D. K. and Saikia B. D., 2013) proved that values of compression index maximize when the concentration of crude oil contamination raise in soils. The lubricating influence of crude oil allows the sliding of soil grains and this can be induced the maximizing in the compression index [22]. The swelling index (c_r) increased may be due to the organic content increment in soaking soils as shown in (Fig. 13). The maximizing in initial void ratio values (e_o) as shown in (Fig. 14) with time period may be due to the reduction in dry unit weight which created large void space between soil particles as shown in (Fig. 8). So, (Ijimdiya T.S., 2013) showed in his study the possible cause for the primary rise in the void ratio at 2% oil content may be as the result of the major lowering of the amount of fines as they were bonded to create pseudo-sand and sand sized grains that will produced bigger void places in the soil structure [23]. The possible cause for the raising in (mv) showed in (Fig. 15) may perhaps be the result of rearrangement of the newly bonded soil grains into the tiny voids happened as the soil was compressed [23] caused by increasing in void ratio as shown in (Fig. 14), so, with this increment and the permeability remain approximately constant with time period as shown in (Table 4), also the coefficient of vertical consolidation (c_v) decreased in soaked soils as presented in (Fig. 11).

3.2 Unconsolidated Undrained Triaxial Test (UU)

Effect of chemicals on the strength parameters is assessed by conducting unconfined undrained triaxial strength on soils with varying maturing period. The result is illustrated in (Table 5) and (Fig. 16, 17, 18, 19 and 20)

Table 5: Triaxial test results

Test	BHu2 (3m)	S7d	S50d	S100d	S150d	Standard Specification
Cu kPa	27.81	34.04	68.31	72.43	72.68	
φu	0.012	0.099	0.012	0.059	0.074	

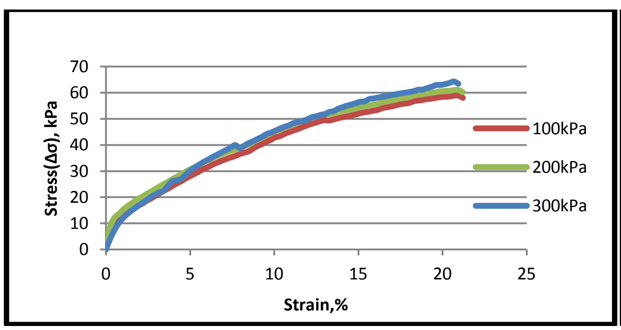


Fig. 16. stress-strain curves BHu2(3m)

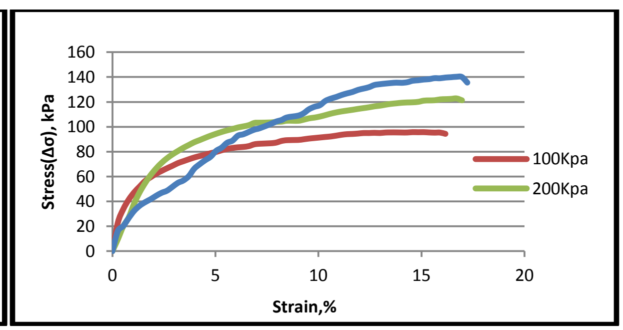


Fig. 17. stress-strain curves S7d

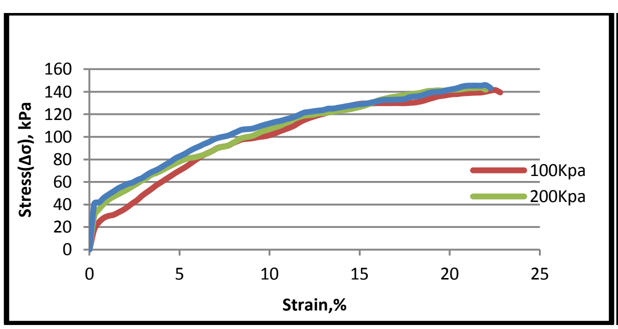


Fig 18. stress-strain curves S50d

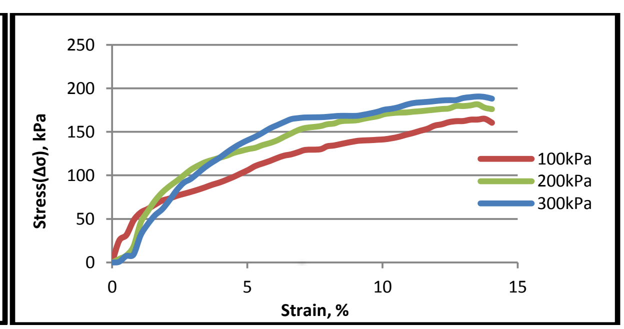
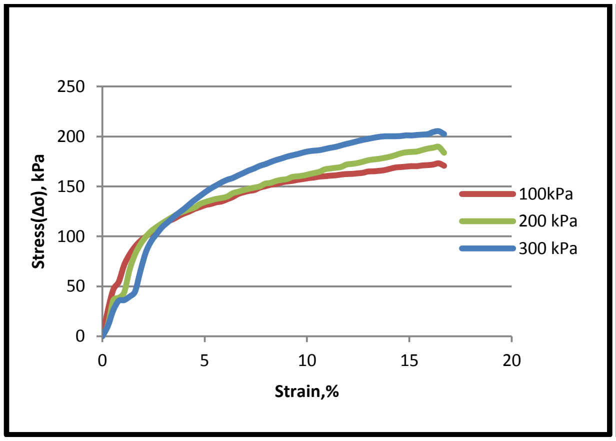


Fig. 19. stress-strain curves S100d



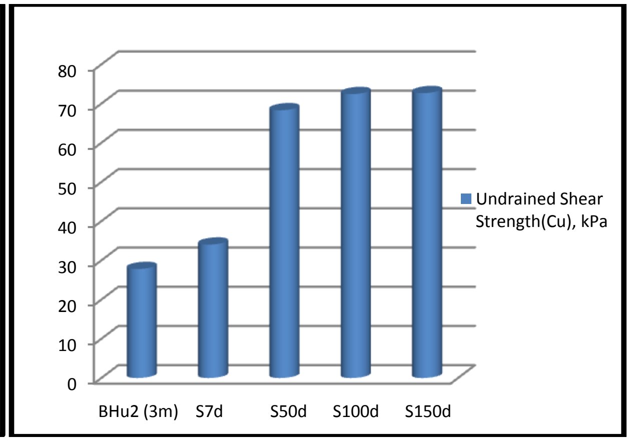


Fig. 20. stress-strain curves S150d

Fig. 21. Variation of Undrained Shear Strength

Principally, two processes regulate the undrained strength in clays, that (a) cohesion or undrained strength resulting from the net attractive powers plus the case of grain system as managed via the inter particle forces, or (b) cohesion resulting from the viscous shear resistance of the double layer water [24]. As shown in (Fig. 21), the undrained strength increased with the soaking period. Similar behavior was observed by (George M., 2014) who find the unconfined compressive strength of examined soils was raised with the addition of chemicals within 7 days to 150 days of time period due to the change in the thickness of Diffuse Double Layer (DDL) [7]. (Goswami and Choudhury, 2013) conclude that the maximize in clay amount of lateritic soil when the interaction with the effluent happened it has been noticed the maximized in the cohesion while the friction angle minimized [19]. (Rao and et al., 2012) resulted the raising in UCS values with raising of Textile effluent amount could be due to the interaction between clay materials and dyes existed in Textile effluent [25].

Conclusions:

Here it is intended to study the effect of extra absorption chemical concentration on the engineering properties of soil.

1- The results obtained from this study referred to more changes in the geo-environmental properties for semi contamination soil with the increased of soaking period.

2- The pH of soil decreased in soaking soil due to the acidity nature for the effluent. Its notes increased in organic value due to some anthropogenic sources. The increased in the electrical conductivity of contaminated soil may be due to the further dissolved salts in the effluent.

3- The increased in chloride, sulphate, nitrate, iron, copper, zinc, and chromium concentration is due to effluent chemical properties. This change in chemical properties of surrounding soil may be lead to foundation problems like the corrosion of concrete due to the sulphate increment.

4- Specific gravity, dry and wet density decreased with increased of soaking period due to the effluent physical properties.

5- There was slight increased in liquid limit, plastic limit and plasticity index for studied soil samples with increasing the period of soaking.

6- According to the results of consolidation test, the initial void ratio, compression index, swelling index, coefficient of volume was increased with soaking period in compared with referenced semi contaminated soil while coefficient of vertical consolidation was decreased, and permeability remain approximately constant.

7- The results of triaxial test shown the raising in the value of undrained shear strength in polluted soil due to change in double layer thickness.

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