Pollution, 5(2): 287-300, Spring 2019
DOI: 10.22059/poll.2018.266690.525
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

Liquid Effluent Discharge and Control Management of Surrounding Soil

Hussein, H. M.[1,2], Ayub, S.[1*] and Siddiqui, A.A.[1]

1. Department of Civil Engineering, Aligarh Muslim University
Aligarh, 202002, India
2. Al-Esra'a University College, Iraq, Baghdad

Received: 13.10.2018 Accepted: 17.01.2019

ABSTRACT: The effluent generated from a thermal power plant waste is a mixture of several chemicals and to identify the effect of these chemicals on soil, a case study on naturally contaminated sites at Al-Musayyib region, Hilla city in Iraq has been carried out. Soil and water samples were collected from the sites and analyzed to identify the pollutants and their effect on soil characteristics. Laboratory experiments were formulated to model the field around a channel collecting effluent for about 20 years and the pollutant transport pattern through the soil using soaking process was studied. Experiments were also conducted to study the effect of pollutants on engineering properties of the soil. For environmental management, permeable reactive barriers are used as stabilization and solidification technology to control the pollution through the soil. In this study, the suitability of locally available materials like activated granular carbon was also investigated as reactive media in permeable reactive barrier. The results have shown higher change in geo-environmental properties of soil with the soaking period and it has also been proved that granular carbon improves the geo-environmental properties of polluted soil.

Keywords: contaminated soil, soaking period, thermal power plant, granular carbon.

INTRODUCTION

Difficult environmental issues linked with urban expansion have a developing impact towards the environment. Contaminated liquid, if discharged directly or indirectly into a water system with no suitable remedial measures will have a negative impact on the surrounding soil. These contaminants getting into the mainstream water system could be a complex activity and need employing specific limitations and managing techniques. Containment applications are secure and extremely cost-effective techniques useful to manage contaminants available in the subsurface. Containment is established by applying physical, hydraulic, or chemical bounds that eliminate the external transfer of pollutants (Zahid et al., 2017). In case of soils polluted by heavy metals, the physical and chemical structure of the heavy metals in soil clearly decides the choice of the suitable remedial technique. Details regarding the physical properties of the field, type and concentration of pollution at location are needed to allow reliable evaluation of field pollution and treated solutions. After the place has been recognized, the intended element in soil need to be established (Wuana & Okieimen, 2011). Hilber & Bucheli (2010) provided a

* Corresponding Author Email: sohailayub@rediffmail.com

short overview of the state-of-the-art in activated carbon (AC) amendment to such sites. Nearly half of the studies in soils and 68% of the studies in sediments showed reduced pollutant availabilities of more than 50% after activated carbon amendment. The reasons for observed low reductions (less than 50%) may include low exposure time, insufficient equilibrium time for coke breeze, biochar, and granulated activated carbon, overloading of activated carbon material, different uptake pathways of benthic organisms, and pollutant reductions outside the dynamic range of toxicity endpoints. (Crane & Crane, 2013) evaluated the addition of Powdered Activated Carbon (PAC) with cement to enhance the Stabilization and Solidification (S/S) of materials contaminated with organic compounds. Adsorption of organic contaminants onto PAC can reduce leaching of organic contaminants. Laboratory studies were carried out on aged and contaminated soil samples from manufactured gas plant sites to compare the performance of S/S treatment with simultaneous addition of PAC and cement against cement addition after preconditioning with PAC to enhance contaminant adsorption. The contaminants were monoaromatics such as benzene, toluene, ethylbenzene, and xylenes, called as BTEX and Naphthalene (a 2-ring PAH). Performance was evaluated by quantifying the leaching of BTEX and naphthalene with the synthetic precipitation leaching procedure, and by measuring unconfined compressive strength in amended soil samples. Amending the test soils with 1% PAC over a period of 15 to 25 weeks resulted in reduced leaching of BTEX and naphthalene measured with the Synthetic Precipitation Leaching Protocol (SPLP). Allowing a 20-week PAC preconditioning time in the test soils significantly enhanced the ability of added quicklime, Portland cement, and Class C flay ash to reduce contaminant leaching and to increase unconfined compressive strength. Simultaneous addition of PAC and cement showed only modest improvements in leaching and strength compared with adding cement without PAC. (Oyegbile & Ayininuola, 2013) examined the effect of short term crude oil spillage on geotechnical properties of lateritic soil e.g. Atterberg limits, compaction and shear strength triaxial test by mixing 10% of crude oil with soil sample and storing inside container for six months while the tests were performed on 7, 14, 21, 28, 56, 84,112,140 and 168 days. The results indicated reduction in maximum dry density, moisture content, liquid limit, plastic limit, cohesion and internal friction angle within short term period. (Zhi et al., 2015) presented the effect of diesel oil on engineering properties (water content, Atterbergs limits, swelling pressure, unconfined compressive strength and electrical resistivity) for commercial Kaolin clay mixed with 10% tap water. The samples were kept in air tight plastic bags over a period of 48 hrs and then mixed with different ratio of oil (0,4,8,12,16 and 20%) and left to equilibrate for more than 8 days. The remolded samples were then prepared through static compaction method and sealed in air tight plastic bags and kept in the humidity room under 22^{o}C for (7, 14, 28, 90, 120, and 210) days. The results showed that there is reduction in all tested engineering properties with the increase in oil content in the soil. The result indicated that the unconfined compression strength was increased with the increase in curing period. The aim of the present study was to identify the impact of waste discharge from thermal power plant on the geotechnical and geo-environmental properties of the soil at Al-Hilla Governorate located to the south west of Iraq. The study was focused to examine whether effluent from the thermal power plant can be absorbed by semi contaminated soil and if it affects the geotechnical properties of natural contaminated soils after a maturing period of 7, 50, 100 and 150 days. The pollution was controlled through leachate permeable reactive barriers used as an emerging technology for environmental management. The suitability of activated granular carbon was also investigated as reactive media in permeable reactive barrier.

MATERIAL AND METHODS

The treated effluent was collected directly from treatment station of thermal power plant and analyzed in the laboratory. The percolation of effluent from drainage into the soil may cause a change in natural soil properties due to processes like physico-chemical decomposition process, ion exchange reactions, chemical alterations, oxidation, hydrolysis etc. The organic matter in the effluent may also cause potential pollution problems due to the requirement of a large quantity of oxygen for degradation. The effluent was analyzed according to the Standard Method for the Examination of Water and Wastewater (Lenore et al., 2015) and the results are given in Table 1.

The naturally contaminated undisturbed sandy clay and silt soil samples were obtained from Al -Musayyib thermal power plant in Iraq. The site was chosen within 50 m distance from the drainage channel receiving industrial effluent since last 20 years at depth 3 m from one borehole no. (BHu2).

The test samples of soil were undisturbed samples driven into the perforated test steel Shelby tube 10 cm diameter and 30 cm high containing circular holes along its circumference with space between holes as 2 cm and the diameter for each is 1 mm using. Laboratory experiments were started after 7, 50, 100 and 150 days of soaking period and the specimens were named as S7d, S50d, S100d and S150d respectively. After every 7 days (recommended time period that is acceptable for chemical equilibrium), the effluent was taken out of the container, and it was re-filled with the fresh effluent to keep the chemical concentration constant during the soaking period.

In order to study the remediation of contaminated soil, naturally contaminated soil (BHu2) in the borehole was mixed with granular carbon (5 and 10% by dry weight) passing through 1.17mm sieve. These mixed samples were represented as C5% and C10% respectively. The mechanical properties for naturally contaminated soil were obtained with undisturbed and remolded face (BHu R) that matches with the field density and natural moisture content for comparison purposes.

RESULTS AND DISCUSSION

The chemical characteristics of the polluted, soaked and treated soil samples under study are shown in Table 2. Fig.1 shows that the pH values of all contaminated soils were decreased due to the acidic nature of effluent. Fig. 2 shows rise in organic percentage values in contaminated soil due to the high value of organics in the effluent and due to some anthropogenic sources.

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	50	Fe	1.962		
COD	mg/l	111	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		

Table 2. Chemical properties for tested soil samples

Test	Polluted soil	Soaking period in day				Granular carbon remediation		Standard Specification
	BHu2	**S7d**	**S50d**	**S100d**	**S150d**	**C 5%**	**C10%**	
pH	7.72	7. 70	7.67	7.60	7.57	7.80	7.85	BS 1377:1990
EC µs/cm	950	1047	1421	1524	1747	472	189	EC meter
Temp. c^{o}	29.4	28.7	29.2	29.3	29.6	28.9	29.5	
Organics %	2.99	3.16	3.22	4.39	4.40	5.19	6.05	BS 1377:1990
TDS mg/l	427	478	487	570	799	378	111	
Cl^{-} mg/l	105	145	175	196	200	85	79	
SO_4 mg/l	797	842	896	978	1028	511	468	Spectrophotometer
NO_3 mg/l	23.8	26.4	29.4	29.8	29.8	10.4	9.8	
Cd mg/l	219	219	219	219	219	200	131	Atomic Absorption Spectroscopy (AAS).
Fe mg/l	34508	35759	36278	36668	37004	32883	31938	
Cr mg/l	56.5	56.5	56.5	56.5	56.5	51.6	45.6	
Ni mg/l	221	223	225	227	227	213	185	
Pb mg/l	ND	ND	ND	ND	ND	ND	ND	
Cu mg/l	24.6	24.7	24.7	24.9	24.9	21	17.85	
Zn mg/l	65.0	74.7	86.3	93.3	95.6	59.3	47.1	
Ca mg/l	44852	45700	47593	48846	49653	11852	11051	Methods of Soil Analysis. Part 3.
Na mg/l	13597	13794	13872	13937	13972	11048	7440	
K mg/l	8692	8712	8792	8858	8895	8260	6466	
Mg mg/l	3197	3250	3365	3382	3397	2690	1374	

Higher chemical concentrations lead to an increase in electrical conductivity (Fig.3) and total dissolved salts (Fig.4) for soil samples. Higher EC values shows the existence of high dissolved inorganic materials in the specimens (Ouhadi & Goodarzi, 2002). This is in agreement with Panahpour et al. (2011) who investigated the influence of garbage leachate on soil reaction, salinity and soil organic matter in the east of Isfahan. Results of this study showed that the MWL added to the soil caused a decrease in soil pH but an increase in TDS and also percent organic matter. Thus acidic pH increases the ability to absorb some nutrient elements such as phosphorus, iron, zinc, copper manganese, and organic materials (Panahpour et al., 2011).

The presence of inorganic anions (carbonate, phosphate, and sulfide) in the soil water can influence the soil's ability to fix metals chemically. These anions can form relatively insoluble complexes with metal ions and cause metals to desorbed and/or precipitate in their presence (Evanko & Dzombak, 2013). The results presented in Figures 5, 6(a) and 6(b) shows an increase in chemical concentration of metals with the soaking period. The major chemicals in the effluent are identified as chloride, sulphate, nitrate, iron, nickel, cadmium, chromium. Maximum adsorption was found to be 38.9% in 7 days, 66.67% in 50 days, 86.67% in 100 days and 90.48% in 150 days for chlorides. Similarly, a high adsorption was observed for Zinc as 14.92% in 7 days, 32.77% in 50 days, 43.54% in 100 days and 47.08% in 150 days. These results are in agreement with Kiayee (2013), who discovered the accumulation of micronutrients and heavy metals from MWL application. Deka & Sarma, (2012) improved the amount of lead, manganese and iron as relevant to high value of organic matter, pH and conductivity in soil. The rise in iron and manganese concentration in soil minimizes the concentration of cadmium or lead dissolved in polluted soil (McKenzie, 1980).

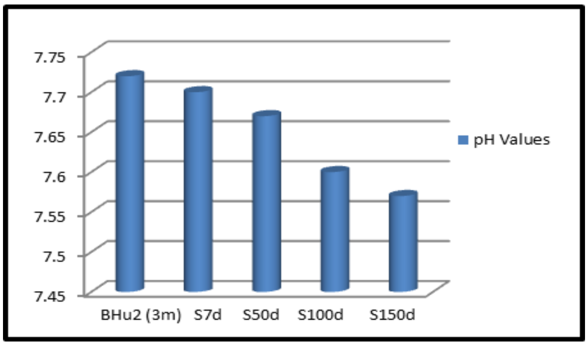

Fig. 1. Variation of pH values

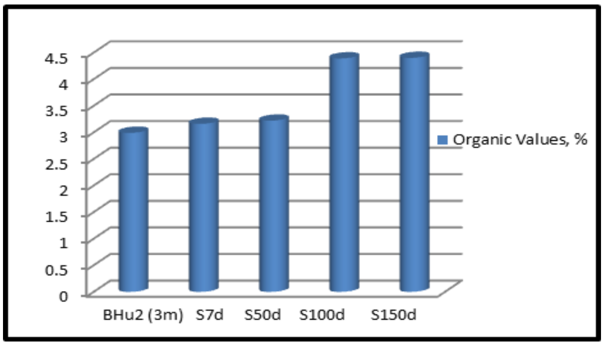

Fig. 2. Variation of Organic materials values

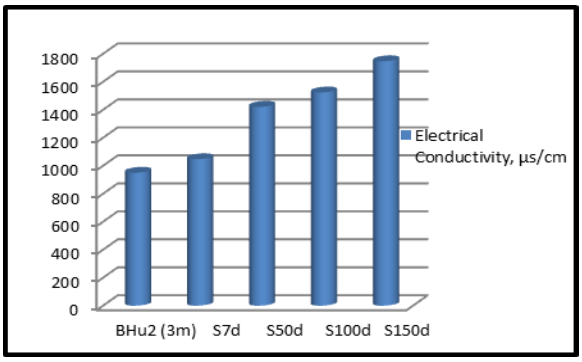

Fig. 3. Variation of EC values

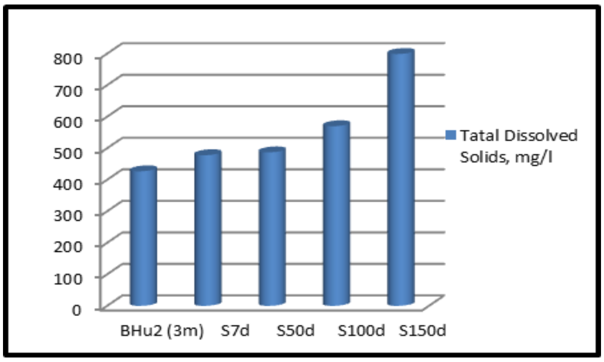

Fig. 4. Variation of TDS values

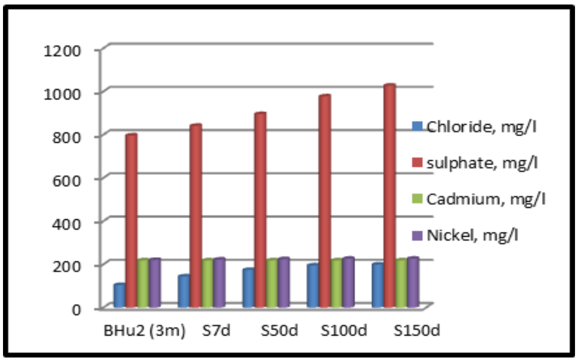

Fig. 5. Variation of Cl, SO_4, Cd and Ni Concentrations

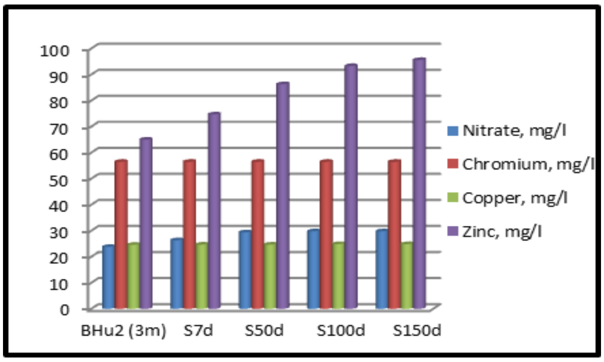

Fig. 6(a). Variation of NO_3, Cr, Cu and Zn Concentrations

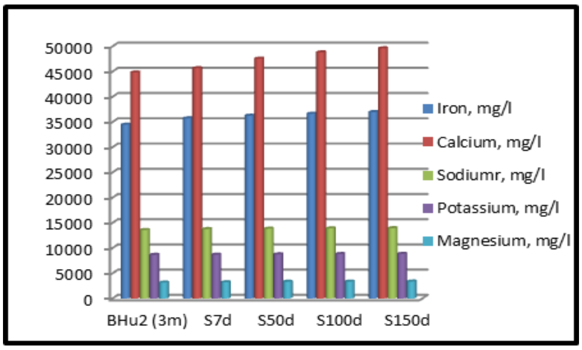

Fig. 6(b). Variation of Fe, Ca, Na, K and Mg Concentrations

The addition of 5and 10% of granular carbon material leads to an increase in pH values (Fig.7) and organic percentage (Fig.8). Electrical conductivity and total dissolved salts were decreased as presented in Figs. 9 and 10. Maximum reductions in treated soil were observed in calcium (73.5-75.3), nitrate (56.3-58.8), magnesium (15.8-57.0), sodium (18.7-45.2), sulfate (35.8-41.2), and cadmium (8.6-40.1) as shown in Figs. 11, 12, 13, and 14 respectively. The minimization in chemical concentrations as a result of adding granular carbon lead to an improvement in the chemical properties of the polluted soil due to its strong sorption properties. Activated carbon's porous structure allows it to adsorb materials from the liquid and gas phase. Its pore volume typically ranges from 0.20 to 0.60 cm^3/g, and has been found to be as large as 1 cm^3/g. Its surface area ranges typically from 800 to 1500 m^2/g but has been found to be in excess of 3,000 $m^2/$ g. The surface area contains mostly micropores with pore diameters smaller than 2 nm (Leimkuehler, 2010).

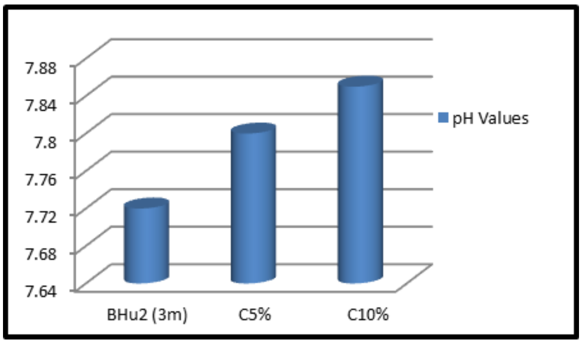

Fig. 7. Variation of pH values

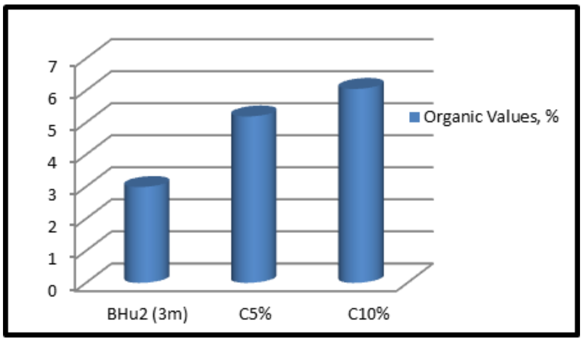

Fig. 8. Variation of Organic materials values

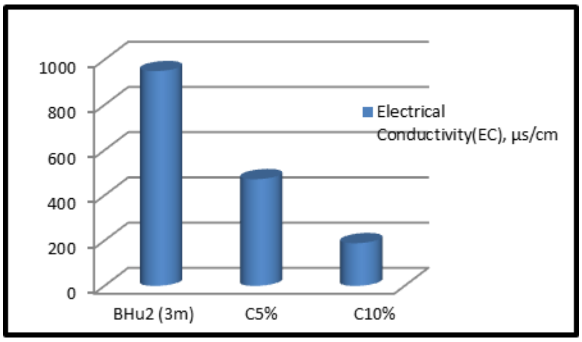

Fig. 9. Variation of EC values

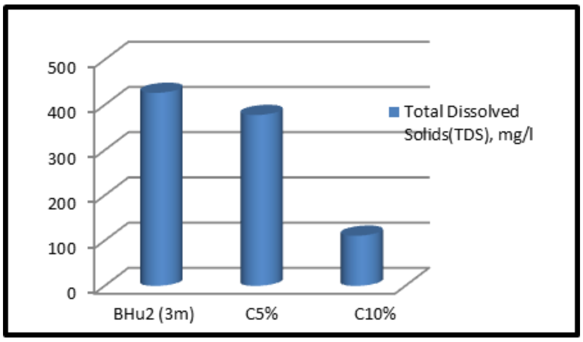

Fig. 10. Variation of TDS values

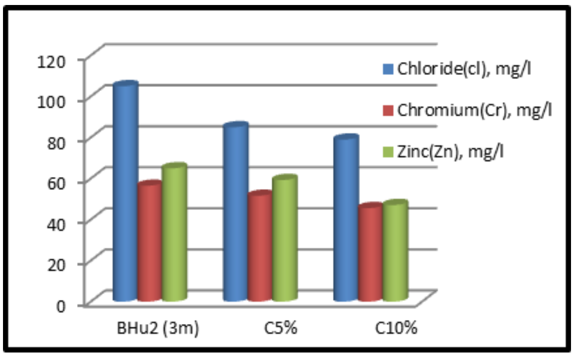

Fig. 11. Variation of Cl, Cr and Zn

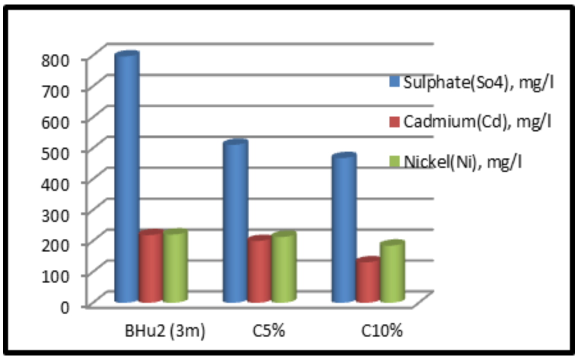

Fig. 12. Variation of So_4, Cd and Ni

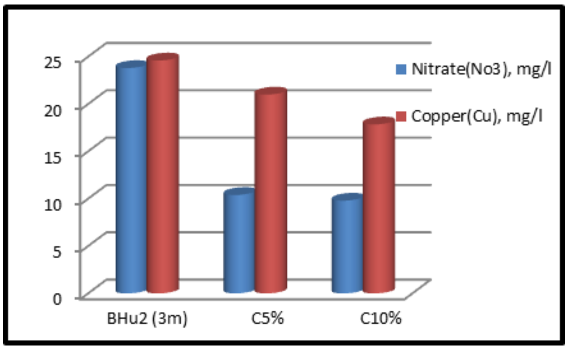

Fig. 13. Variation of No_3 and Cu

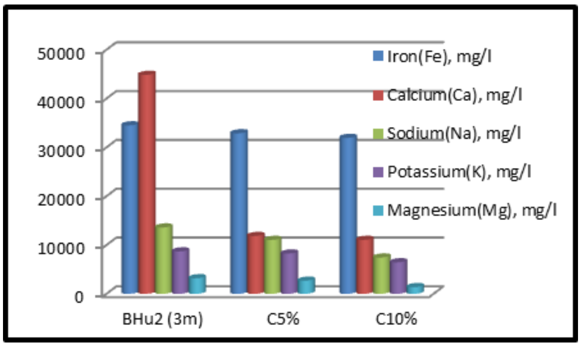

Fig. 14. Variation of Fe, Ca, Na, K and Mg

The physical characteristics of the polluted, soaked and remediated soil samples under study are shown in Table 3. The grain size distribution for the reference and soaked soil samples are presented in Fig. 15.

The increase in ageing causes a decrease in specific gravity, dry and wet density index in tested soils as shown in Figs. 16 and 17. This may be attributed to the acidic nature of the effluent. Liquid limit, plastic limit and plasticity index of soil samples were increased with the chemical concentration and ageing as shown in Fig. 18. This may be explained by the acidic nature of the thermal power effluent and higher electrical conductivity causing more changes in the soil-water structure and water holding capacity. This is in agreement with Resol (2008) who showed an increase in liquid limit with increasing contaminant concentration due to decrease in sizes of fine grained soil causing an increase in the surface area of solid particles and required additional water content to allow soil to flow.

The proctor compaction curves for the reference and treated soil are presented in Fig 19. As shown in Figs. 20, 21 and 22, the specific gravity, dry unit weight and maximum dry density decreases with granular carbon addition to the contaminated soil. This action is due to the low specific gravity of granular carbon. Figure 23 shows that the optimum moisture content increases in treated soils due to the water within creative voids from flocculated structure leading to an increase in water retaining capacity of the soil (Rao & Chittaranjan, 2012).

Table 3. Physical properties for tested soil samples

Test		Polluted soil	Soaking period in day				Granular carbon remediation		Standard Specification
		BHu2	S7d	S50d	S100d	S150d	C5%	C10%	
G.S.D	Clay %	46	45	43	52	55	-	-	ASTM D 422
	Silt %	8	5	7	8	9	-	-	
	Sand %	46	50	50	40	36	-	-	
Gs		2.65	2.57	2.55	2.53	2.53	2.62	2.61	ASTM D 854-00
γd_{max}	kN/m^3	18.1	-	-	-	-	17.2	16.82	ASTM D 698
ωopt	%	17.46	-	-	-	-	18.50	21.00	
γ_{wet}	kN/m^3	20.3	19.6	19.4	19.3	18.6	19.6	18.9	ASTM D2937
γ_{dry}	kN/m^3	16.2	15.6	15.5	15.4	14.8	15.8	15.0	
ω	%	25.06	25.04	25.20	25.53	25.35	24.27	25.24	ASTM D2216
L.L.	%	34.62	34.81	39.95	44.07	45.92	-	-	ASTM D 4318
P.L.	%	23.72	21.17	24.62	25.25	25.56	-	-	
PI.	%	10.90	13.64	15.33	18.82	20.36	-	-	

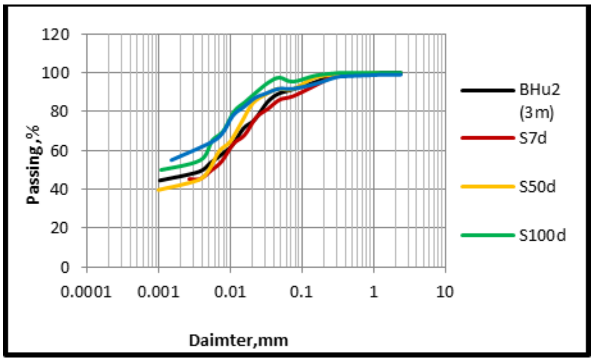

Fig. 15. Grain size Distribution

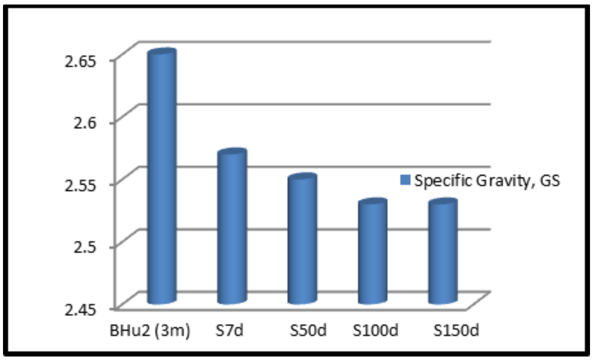

Fig. 16. Variation of Specific Gravity

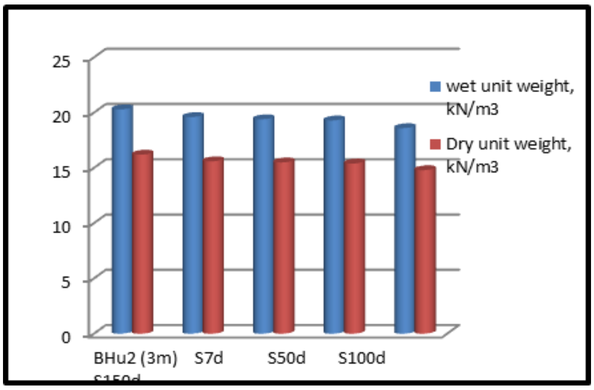

Fig.17. Variation of Wet and Dry unit weight

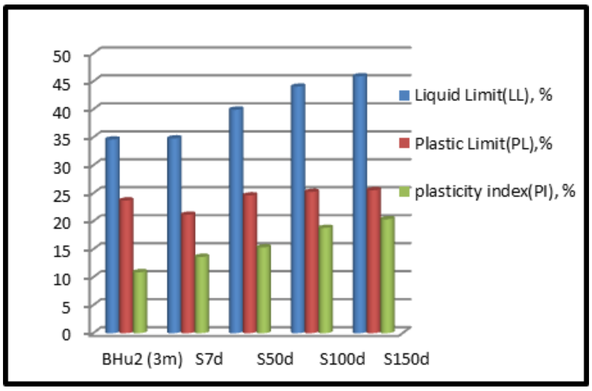

Fig. 18. Variation of Atterberg's Limits

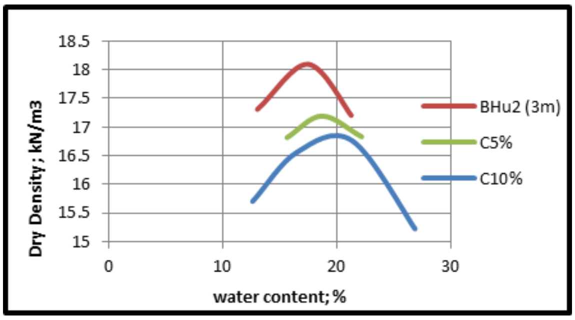

Fig.19. Standard Compaction Test

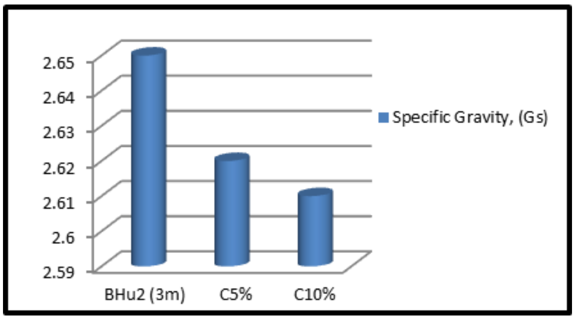

Fig. 20. Variation of Specific Gravity

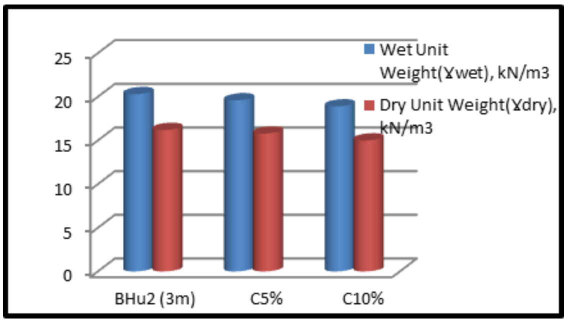

Fig. 21. Variation of Wet and Dry Unit Weight

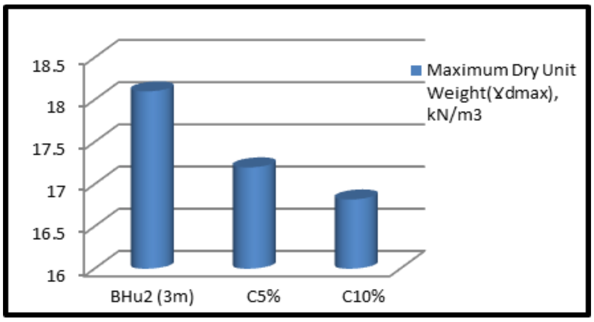

Fig. 22. Variation of Maximum Dry Unit Weight $\gamma_{d_{max}}$

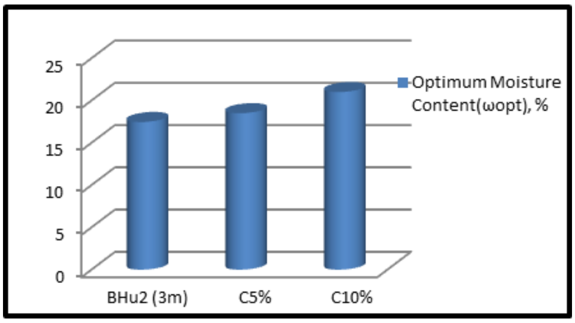

Fig. 23. Variation of optimum moisture content ωopt

In accordance with ASTM D2435, the results obtained from one dimensional consolidation tests conducted on soil samples including the initial void ratio, compression index, swelling index, coefficient of volume compressibility, coefficient of consolidation, and constrained modulus (D) are given in Table 4. The variation of void ratio with pressure for soaked soil samples and treated soil samples is shown in Fig. 24 and Fig. 30 respectively.

Fig. 25 shows the increment in the compression index (c_c). It has long been recognized that compressibility of clay is governed by mechanical and physicochemical factors. However, the results obtained in this part indicate that the physicochemical factors may have more pronounced impact on the consolidation properties of clays when pH values of the pore fluid become low. As the specimens of each tested soil are assumed to have had the same microfabric prior to acidic leaching, it can be hypothesized that the observed changes in compressibility were mainly due to the soil–water–acid interaction (Gratchev & Towhata, 2011).

An increase in swelling index (c_r) may be due to the organic content increment in soaking soils as shown in Fig. 26. The increase in initial void ratio values as shown in Fig. 27 with time may be due to the reduction in dry unit weight creating large void space between soil particles. The possible cause for the rise in coefficient of volume shown in Fig. 28 may be the result of rearrangement of the newly bonded soil grains into the tiny voids as the soil was compressed due to increasing void ratio as shown in Fig. 27 (Ijimdiya, 2013). The permeability remains approximately constant with time as shown in Table 4. The coefficient of vertical consolidation (c_v) decreases in soaked soils as presented in Fig. 29.

Table 4. Consolidation properties for tested soil samples

	Test	Polluted soil	Soaking period in day				Granular carbon remediation		
		BHu2	S7d	S50d	S100d	S150d	BHu R	C5%	C10%
Consolidation	Cv m^2/year	0.801	0.665	0.650	0.498	0.376	0.801	0.416	0.416
	Cc	0.147	0.224	0.227	0.228	0.324	0.147	0.213	0.209
	Cr	0.017	0.019	0.020	0.023	0.023	0.017	0.019	0.018
	k m/sec	$4.9*10^{-11}$	$5.0*10^{-11}$	$4.9*10^{-11}$	$4.4*10^{-11}$	$5.0*10^{-11}$	$4.9*10^{-11}$	$4.1*10^{-11}$	$4.1*10^{-11}$
	e_o	0.634	0.643	0.644	0.648	0.705	0.634	0.681	0.738
	e_f	0.429	0.358	0.442	0.414	0.407	0.429	0.495	0.469
	mv m^2/MN	0.196	0.268	0.245	0.283	0.444	0.196	0.320	0.318
	D kPa	5097	3468	4904	3540	2250	5097	3124	3148

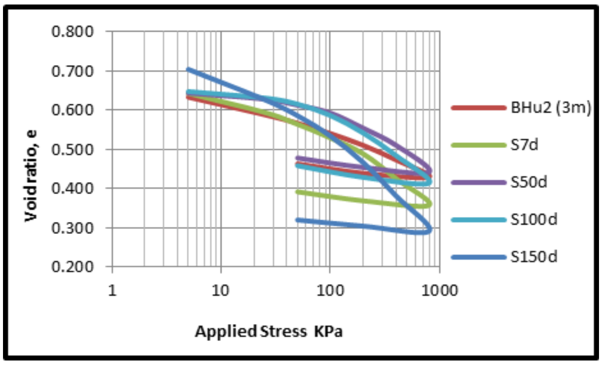

Fig. 24. e – log σ curve

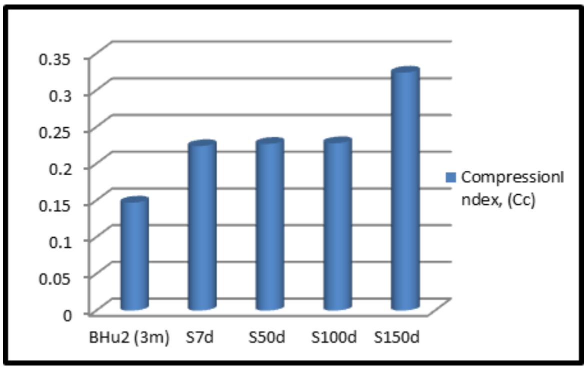

Fig. 25. Variation of Compression Index

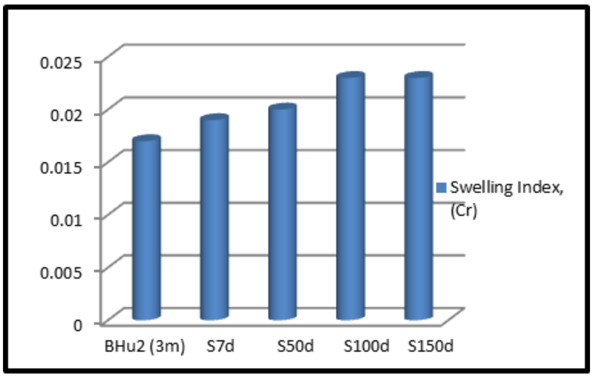

Fig. 26. Variation of Swelling Index

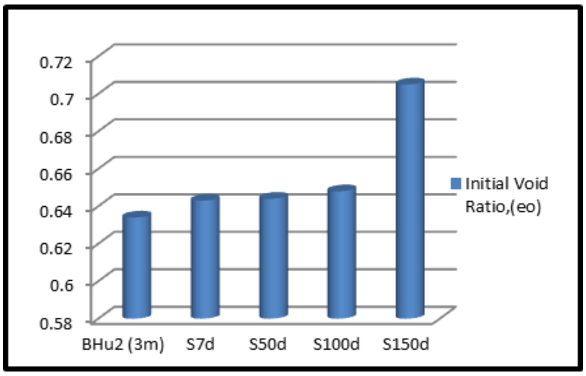

Fig. 27. Variation of Initial Void Ratio

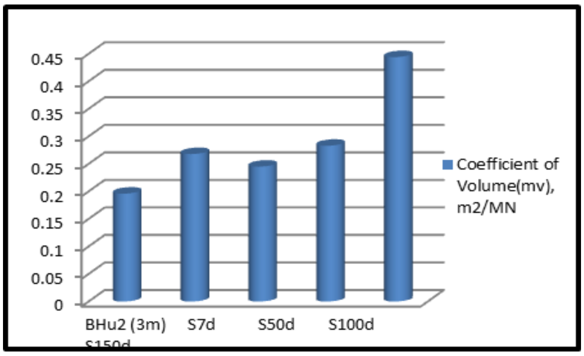

Fig. 28. Variation of Coefficient of Volume

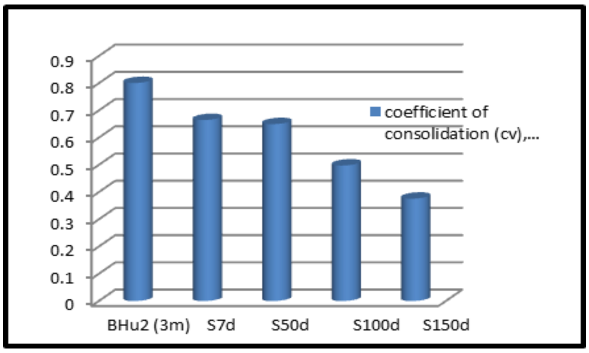

Fig. 29. Variation of Coefficient of Consolidation

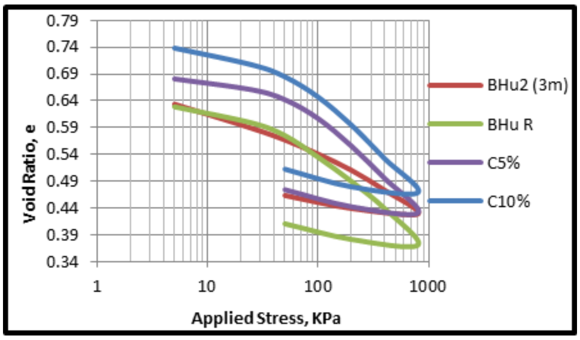

Fig. 30. e – log σ curve

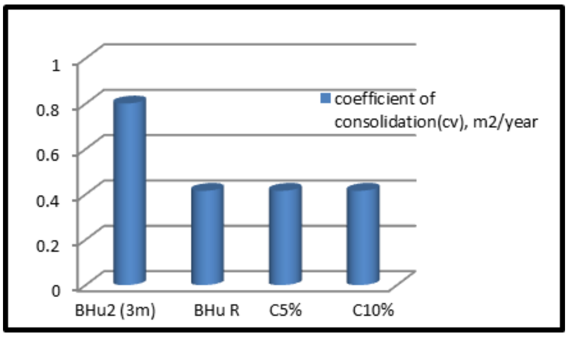

Fig. 31. Variation of Coefficient of Consolidation

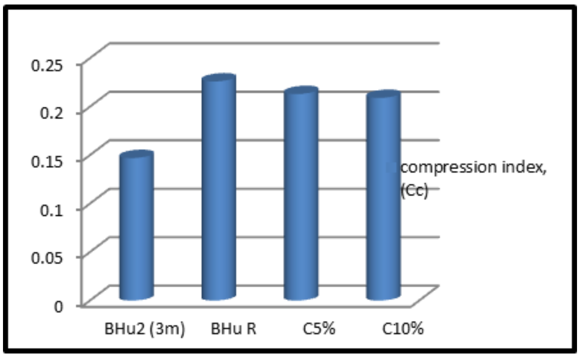

Fig. 32. Variation of Compression Index

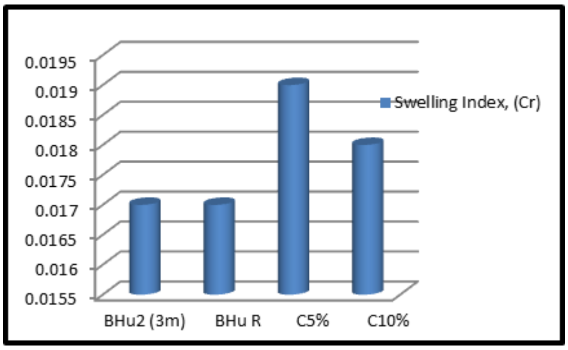

Fig. 33. Variation of Swelling Index

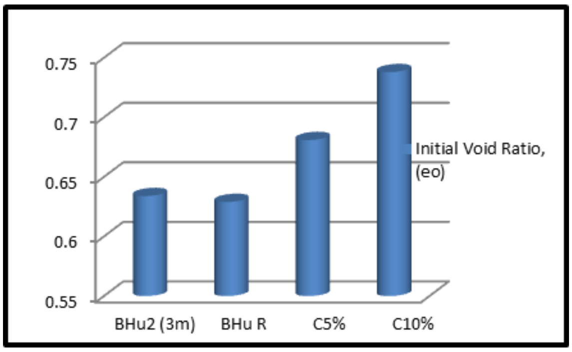

Fig. 34. Variation of Initial Void Ratio

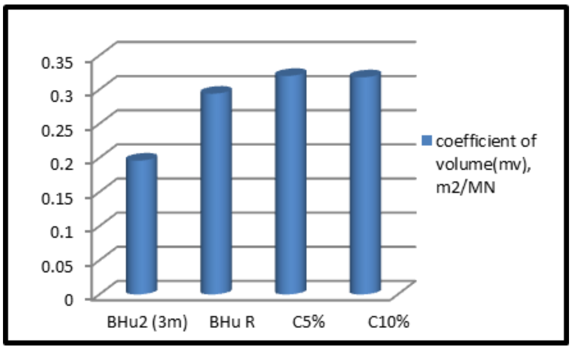

Fig. 35. Variation of Coefficient of Volume

Table 5. Results of Triaxial test

Test	Polluted soil	Soaking period in day				Granular carbon remediation		
	BHu2	**S7d**	**S50d**	**S100d**	**S150d**	**BHu R**	**C5%**	**C10%**
Cu kPa	27.81	34.04	68.31	72.43	72.68	20.25	28.06	39.35
φu	0.012	0.099	0.012	0.059	0.074	0.045	0.036	0.026

As shown in Table 4, there is a difference in results between undisturbed and remolded samples for the same soil. As shown in Fig. 31, the granular carbon has no effect on the coefficient of consolidation (cv) and permeability hence the results remain approximately same after improvement. A slight decrease in compression index may be due to the rise in rigidity of the soil skeleton with the addition of granular carbon (Fig. 32). The little increment in swelling index displayed in Fig. 33 may be due to the higher organic percentage with addition. Similar observation on the behavior of soil modified with GAC was reported by Malusis et al., (2009). As shown in Fig. 35, there was slight increase in coefficient of volume (mv) due to the void ratio increment. An increase in initial void ratio values as shown in Fig. 34 with granular carbon addition may be due to the reduction in dry unit weight which created large void space between soil particles as discussed above.

Table 5 shows the summary of the unconsolidated undrained triaxial test results for the soil samples in accordance with ASTM D2850.

Along with other factors, strength behavior is also significantly influenced by the nature of pore fluid. The shear strength of soil which is controlled by modified effective stress is affected by changes in electrical attractive and repulsive pressures. Many factors are responsible for the net attractive and repulsive forces between clay particles. From several investigations it has been concluded that the primary forces responsible for repulsion between two clay particles are due to the interaction of diffuse double layers, which is directly proportional to the dielectric constant. A number of phenomena are responsible for the existence of electrical attractive forces among clay particles and these forces are inversely proportional to the dielectric constant of the pore fluid (Hussein et al., 2018). Basically, two mechanisms control the undrained strength in clays, namely (a) cohesion or undrained strength is due to the net attractive forces and the mode of particle arrangement as governed by the inter-particle forces, or (b) cohesion is due to the viscous shear resistance of the double layer water (Sridharan et al., 2002).

As shown in Fig. 36, the undrained shear strength of test soils was increased towards maturing period. Similar behavior was observed by George (2014) who found that the unconfined compressive strength of test soils was increased on the addition of chemicals for 7 to 150 days of maturing period which was attributed to the change in the thickness of Diffuse Double Layer (DDL). The results confirmed that the undrained shear strength of test soils increased with increase in carbon percentage as shown in Fig.37. The large increase in inter-particle attraction due to the reduction of diffuse double layer was responsible for the flocculation of the clay mixture. This effect resulted in increased strength of clay mixtures (George, 2014; Ayub et al., 2017).

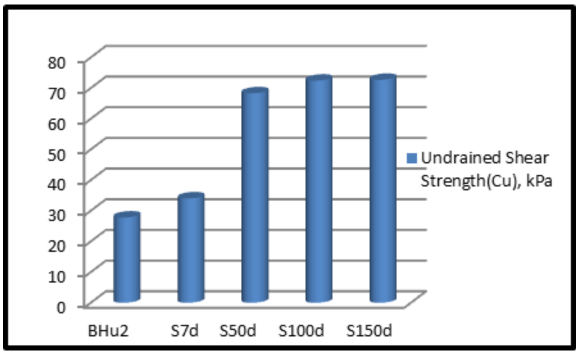

Fig. 36. Variation of Undrained Shear Strength for soaked soil samples

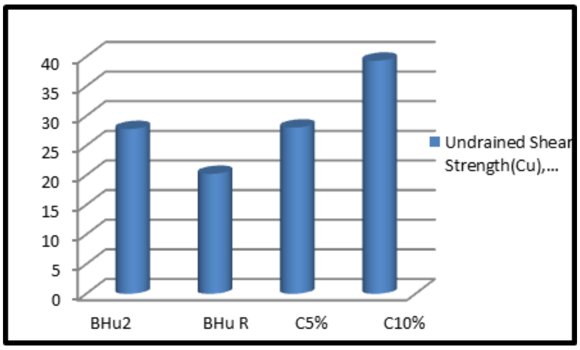

Fig. 37. Variation of Undrained Shear Strength for treated soil samples

CONCLUSIONS

The major conclusions drawn from the above study which can find applications in engineering practice, especially in the field of geo-environmental engineering are presented below.

1. Naturally polluted site at Al-Musayyib region, receiving waste since last 20 years contain high amounts of chloride, sulphate, nitrate, iron, nickel, cadmium, chromium in the soil.

2. Maturing period showed significant change in the chemical concentration and geotechnical properties of soil. The Maximum change in chemical concentration as well as the engineering properties of soil was observed for 150 days of soaking period.

3. The engineering properties were improved and the chemical concentration was reduced to a maximum for the soil treated with 10% granular carbon. The preliminary adsorption studies have shown that this material can be effectively utilized as a reactive material in soil treatment.

ACKNOWLEDGMENT

The author is grateful to Prof. Dr. Abdul Razzaq Al-Majidy (Dean of Al-Esra`a University, Baghdad, Iraq) and Prof. Dr.

Bushra Suhale Al-Busoda (civil engineering department/ Baghdad University/ Baghdad, Iraq) for their valuable suggestions.

REFERENCES

ASTM. (2003). American Society for Testing and Materials, USA," (Different Designation).

Ayub,S., Siddiqui, A.A., and Hussein, H.M. (2017). Impact of geotechnical properties due to industrial and hydrocarbon contaminated soil. Poll Res. 36 (4): 814-821.

BS 1377 British. (1990).Standard Method of Test of Soil for Civil Engineering Purposes, part.1.

Crane, R. E. (2013). Activated carbon preconditioning to reduce contaminant leaching in cement-based stabilization of soils. Master thesis, Western Michigan University, http://scholarworks.wmich.edu/masters_theses/177.

Deka, J. and Sarma, H. P. (2012). Heavy metal contamination in soil in an industrial zone and its relation with some soil properties., Archives of Applied Science Research., 4; 831–836.

DR 2800 Spectrophotometer. (2007). Catalog Number DOC022.53.00725, 2nd ed., standard methods, 356.

Dutta, S. K., Singh, D. and Sood, A. (2011). Effect of soil chemical and physical properties on sorption and desorption behavior of lead in different soils of India, Soil and Sediment Contamination., 20;249-260.

Evanko, C. R. D. and Dzombak, D. A.(2013). Remediation of metals-contaminated soils and groundwater,. Ground-Water Remediation Technologies Analysis Center.

George, M. (2014). Studies on landfill leachate transportation and its impact on soil characteristics. A thesis submitted for the award of the degree of doctor of philosophy, division of civil engineering, school of engineering cochin university of science and technolog.

Glewa S. M. and Al-alwani, M.(2013). Evaluation of the effect of Solid Waste leachate on Soil at Hilla city, Jurnal of Babilon University.,3;894-906.

Gratchev, I. and Towhata, I. (2011). Compressibility of natural soils subjected to long-term acidic contamination., Environ Earth Sci.,64;193–200.

Hussein, H.M., Ayub, S. and Siddiqui, A.A. (2018). Geotechnical properties of soil subjected to long-term effluent contamination. Int. J.Tech. Innovation in Modern Engg. & Science.4 (11); 250-258.

Hilber, I., and Bucheli, T. D. (2010). Activated carbon amendment to remediate contaminated sediments and soils : a review," Global NEST Journal, 12(3);305–317.

Ijimdiya, T.S. (2013). The effects of oil contamination on the consolidation properties of lateritic soil, DAOE ., 2;53–59.

Kiayee, S. B.(2013). Impact of municipal waste leachate application on soil properties and accumulation of heavy metals in wheat (triticum aestivum L)," IJSRES., l;1–6.

Leimkuehler, E. P. (2010). Production, Characterization, and applications of activated carbon., Ph.d thesis, University of Missouri.

Lenore, S. C., Arnold, E. G. and Andrew, D. E. (2015).Standard Methods for the Examination of Water and Wastewater, 20th ed. ISBN 0-87553.

Malusis, M. A., Asce, A. M., Barben, E. J. and Evans, J. C.(2009). Hydraulic conductivity and compressibility of soil-bentonite backfill amended with activated carbon,. J. Geotech. Geoenviron. Eng., 135;664-672.

McKenzie, R.M. (1980). The adsorption of lead and other heavy metals on oxides of manganese and iron., Australian Journal of Soil Research.,18;61 - 73.

Ouhadi, V.R. and Goodarzi, A.R. (2002). Proceedings of the 55th Canadian Geotechnical and 3rd Join IAH-CNC and CGS Groundwater Specially Conferences, Niagara Falls, Canada;20-23.

Oyegbile, O. B. and Ayininuola, G. M. (2013).Laboratory studies on the influence of crude oil spillage on lateritic soilshear strength : a case study of niger delta area of nigeria. Journal of Earth Sciences and Geotechnical Engineering. 3(2);73–83.

Panahpour, E., Gholami, A. and Davami, A. H. (2011). Influence of garbage leachate on soil reaction , salinity and soil organic matter in east of Isfahan, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering.,5(9); 530–535.

Rao, A.V.N. and Chittaranjan, M.(2012). Effect of certain industrial effluents on compaction charactristic, International Journal of Engineering Inventions., 1; 22–28.

Resol, D. A. (2008). Investigating the effects of contamination and washing process on the geotechnical properties of sandy soil," A master thesis., Baghdad University Iraq.

Sparks, D.L. (1996). Methods of Soil Analysis: Chemical Methods. Soil Science Society of America Book Series, part 3;551-603.

Sridharan, A., El-Shafei, A. and Miura, N.(2002). Mechanisms controlling the undrained strength behavior of remolded Ariake marine clays, In Marine Georesources & Geotechnology., 20;21-50.

Wuana, R. A., and Okieimen, F. E. (2011). Heavy metals in contaminated soils : a review of sources , chemistry , risks heavy metals in contaminated soils : a review of sources , chemistry , risks and best available strategies for remediation, International Scholarly Research Network, International Scholarly Research Network ISRN Ecology Volume 2011, Article ID 402647, 20.

Yusuf, A. J., Galadima, A., Garba, Z.N., and Nasir, I. (2015). Determination of some heavy metals in soil sample from illela garage in Sokoto state , Nigeria, Research Journal of Chemical Sciences., 5(2);8–10.

Zahid, W. M., Moghal, A. A. B., Obaid, A. A. K., Al-shamrani, M. A. and Mohammed, S. A. S. (2017). Physico-chemical and geo-environmental behavior of semi arid soils, International Journal of GEOMATE, 12(29); 115–123.

Zhi-bin, L. I. U., Song-yu, L. I. U., and Yi, C. A. I. (2015). Engineering property test of kaolin clay contaminated by diesel oil. J. Cent. South Univ, Springer, 22;4837−4843.