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Studying the Effects of Industrial Waste Water on Chemical and Physical Properties of Sandy Soil

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Abstract

The present work highlights on the impact of liquid industrial waste on the chemical and physical properties of sandy soil obtained from Al-Najaf governorate which is located to the south west of Iraq. The soil sample is classified as sandy soil according to unified soil classification system (USCS). The contaminant is liquid industrial waste obtained from Al-Musayyib thermal power plant which is disposed as side product. The soil samples are synthetically contaminated with four percentages 10, 20, 40 and 100 % by the weight of distilled water used in soaking process which is continued for 30 days. The results proved that the contaminant solution has considerably effects on some properties of soil and a slight effects on the others. Increasing the percentages of contaminant, led to a slight increase in both the liquid limit and particle size and significant increase in the optimum moisture content, while there was slight decrease in the specific gravity and maximum dry density. Also, there was considerable changes in the chemical composition of soil samples.

Key Words: Industrial waste water, soil contamination, soil properties, sandy soil.

الخلاصة

هذا العمل يسلط الضوء على دراسة تأثير النفايات الصناعية السائلة على الخواص الكيميائية والفيزيائية لتربة رملية. أخذت عينات التربة من محافظة النجف والتي تقع في الجنوب الغربي من العراق. وتصنف التربة على انها رملية وفقا لنظام تصنيف التربة الموحد (USCS). أما الملوث هو من النفايات الصناعية السائلة والتي تم الحصول عليها من محطة الطاقة الحرارية في المسيب والتي تطرح كناتج عرضي. وتم تلويث عينات التربة صناعيا بأربع نسب ١٠ و ٢٠ و ٤٠ و ١٠٠ ٪ من وزن الماء المقطر المستخدم في عملية الغمر الذي استمر لمدة ٣٠ يوما. وفقا للنتائج التي تم الحصول عليها، فأن الملوث الصناعي له تأثير كبير على بعض خصائص التربة وتأثيرات طفيفة على خصائص أخرى. أن زيادة نسب الملوث في التربة، أدى إلى زيادة طفيفة في كل من حد السيوله و حجم الحبيبات و زيادة كبيرة في محتوى الرطوبة الأمثل، في حين كان هناك انخفاض طفيف في الوزن النوعي والوحدة الوزنية العظمى الجافة. كذلك كان هناك تغييرات كبيرة في التركيب الكيميائي لعينات التربة.

الكلمات المفتاحية: مياه الصرف الصناعي، وتلوث التربة، وخصائص التربة، والتربة الرملية

1. Introduction

All types of human activities produce diverse residues called "wastes", these wastes differ in quantity and quality from place to another depending on the degree of urbanization. The geoenvironmental engineering is devoted to study the diverse effects of wastes on the properties of soil and groundwater (Reddi and Inyang, 2000). Most of industrial wastes were disposed from important industries such as cement, metallurgical, petrochemicals, textiles, food, and chemical and pharmaceutical industries. Industrial solid waste may be divided into hazardous and non-hazardous depending on the inherent dangers associated with its physical and chemical properties. Non-hazardous wastes are those that do not meet the EPA's definition of hazardous waste. Industrial waste may be toxic, ignitable, corrosive or reactive, so it can be recognized as hazardous wastes according to these measures. If improperly managed, this waste can pose dangerous health and environmental consequences and that may affect negatively on the geotechnical properties of soil (Rowe, 2001 and Sharma and Reddy, 2004).

Al-Duwaisan and Al-Naseem (2011) assessed the effects of oil contamination on the geotechnical properties of soil. The results of tests showed significant effects of oil contamination on physical and chemical properties of soil. Rao and Chittaranjan (2012) studied the effects of industrial effluents on plasticity and swelling characteristics of an expansive soil in India. The soil samples were contaminated with textile, tannery and battery effluents at different percentages from 20 to 100%. They noticed a decrease in plasticity and swelling characteristics for soil samples contaminated with tannery and textile effluents, whereas the plasticity and swelling characteristics were increased for soil samples contaminated with battery effluent. Karkush *et al*. (2013) studied the effects of different types of contaminants on the geotechnical properties of soil. Four types of contaminants were used: kerosene, ammonium hydroxide, lead nitrate, and copper sulphate, each of them was added in two percentages 10% and 25% of dry weight of soil sample. The soaking period was 30 days. The results showed that the contaminants had significant effects on the geotechnical properties of the soil, where: LL, PL, maximum dry density and initial void ratio increased with increasing the percentages of contamination, while the specific gravity and optimum moisture content were decreased.

The present work is focusing on determining the effects of industrial waste water on the chemical composition and physical properties of sandy soil contaminated with different percentages of industrial waste water.

2. Field Work

2.1 Materials

The materials used in the present work consisted of sandy soil and industrial waste. The soil samples were obtained from Al-Kufa, which is located to the east of Al-Najaf city/Iraq. The location of soil samples is determined by using GPS (UTM: 33N 0488377, 2302942). While, the contaminant is liquid industrial waste disposed from Al-Musayyib thermal power plant which is consist of hydrocarbons and acidic wastes. The chemical analysis of contaminant is given in Table 1.

Table 1: Results of Chemical Analysis of Contaminant.

Contaminant	Density kg/m^3	pH	Concentration			
			Mineral	%	Mineral	%
Liquid Industrial Waste	1001.3	2.65	Na	0.0228	Fe	0.1517
			NO_3	0.0200	Cu	ND
			SO_3	0.1172	K	0.00841
			SO_4	0.1578	Mg	0.0040
			Zn	0.0071	Pb	0.0000
			Cr	0.0001	Ca	0.2101
			Ni	0.0002	ALK	0.0000
			Cd	ND*	EC	0.3960

* ND means can't determined.

2.2 Drilling and Sampling

Disturbed soil samples were used to measure the effects of contaminant on the chemical and physical properties of soil. The surface layer of soil in Al-Kufa city is medium to dense granular soil with some gypsum, it extended to a depth of 4 to 8m from the natural ground surface. The ground water table varied from (2 to 2.5) m below the ground surface. The soil samples were obtained from depth equal to 1.75m by hand drilling. Then, the soil samples putted in plastic containers and labeled with necessary information. Then, transported to the laboratory.

3. Laboratory Work

To investigate the effects of different percentages of contaminant on the properties of soil samples, the following testing program were conducted on these soil samples.

3.1 Soaking Process

The contaminant was added in four percentages of (10, 20, 40, 100) % by weight of the distilled water used in the soaking process of soil samples for 30 days in plastic covered container. The chemical solution contains a specific percentage of contaminant and completed with distilled water to get the sufficient quantity which is enough to cover soil samples and in order to facilitate the penetration of contaminant into the soil. The soil samples tested in the present study were designated as follows: **k_o** is intact soil sample; **k_1** is soil sample contaminated with 10%; **k_2** is soil sample contaminated with 20%; **k_3** is soil sample contaminated with 40% and **k_4** is soil sample contaminated with 100% of industrial waste.

3.2 Chemical Tests and X-Ray Diffraction

The chemical composition of soil sample is important to understand the geotechnical behavior of contaminated soil sample. The chemical tests were carried out on soil samples before and after contamination. The following chemical tests were conducted according to ASTM and XRD techniques.

a) Chloride content (ASTM D512 A).
b) Three sulfate ions (ASTM D516).
c) pH value (ASTM D4972).
d) Heavy metals (Cu, Ni, Cr, Pb, Cd, Fe).

3.3 Physical Tests

The physical properties tested in the present work were: the particle size distribution of soil samples was conducted according to ASTM (D 422); the liquid limit of soil samples was tested by falling cone method according to (BS: 1377, 1976); the specific gravity for soil samples was tested according to (BS: 1377, 1975, Test 6B) and the maximum dry density and optimum moisture content were determined by using standard Procter test, ASTM (D 698) and modified Procter test, ASTM (D 1557).

4. Results and Discussion

The results of chemical and physical properties of intact soil were compared with those of contaminated soil samples to understand the impacts of the contaminant on these properties.

4.1 Chemical and X-Ray Diffraction Tests

4.1.1 Chemical Tests

The results of chemical tests conducted on soil samples are given in Table 2. The results of chemical tests showed that all soil samples (intact and contaminated) have (SO_3) radical. Sulfates are salts or esters of sulfuric acid H_2SO_4, formed by replacing one or both of the hydrogen's with a metal (e.g., sodium) or a radical (e.g., ammonium or ethyl). Most metal sulfates are readily soluble in water, but calcium and mercuric sulfates are only slightly soluble, while barium, lead, strontium, and mercurous sulfates are insoluble. Sulfates play a significant role both in chemical industries and in biological systems.

According to the results of chemical tests that had been conducted on the contaminant solute, the contaminant is strong acidic solution (pH = 2.65) that will effect negatively on the geotechnical properties of soil. The pH of soil samples decreased as the percentage of contaminant increased because the intact soil have basic property of pH >7 as shown in Table 2. The increase in the percentage of contaminant causes gradual increase in the concentration of sodium ion and iron metal. The reasons of increasing depending on the presence of sodium ion and iron metal in high concentration in the contaminant solute.

Table 2: Results of Chemical Tests for Soil Samples.

Concentration %	Soil Sample				
	k_o	k_1	k_2	k_3	k_4
SO_3	2.48000	2.60220	2.63000	2.64766	2.67821
Cl^{-1}	0.07000	0.07000	0.07000	0.07000	0.07000
CaO	1.74000	1.82000	1.9400	1.67000	1.45000
TDS	4.62000	4.82000	4.90760	4.98580	7.30310
Gypsum	4.78128	5.01786	5.07168	5.10587	5.16501
Na	0.00087	0.00093	0.00103	0.00120	0.00143
Zn	0.00035	0.00037	0.00044	0.00046	0.00049
Cr	0.00141	0.00144	0.00152	0.00157	0.00168
Ni	0.00002	0.00002	0.00002	0.00002	0.00002
Cd	0.00042	0.00042	0.00037	0.00036	0.00036
K	0.00085	0.00094	0.00098	0.00102	0.00116
Fe	0.11430	0.12702	0.12340	0.12570	0.12961
Mg	ND	ND	ND	ND	ND
Cu	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND
pH (unitless)	8.80	8.67	8.40	8.35	8.30

The percentage of total dissolved salts (TDS) increased when contaminant percentage increased due to the effect of grinding soil particles and suspension forming in soil water system. A slight change was noticed in the potassium ion content after soil contamination because of the lower percent of potassium in contaminant solute.The gypsum content in soil is correlating and function of the sulfate ions. The increase in percentage of contaminant causes increase in concentration of sulfate ions. The calcium oxide ions are initially increased when soil contaminated with 10% and 20% of contaminant and after continue with increasing the percentage of contamination, the calcium ions are reduced. This reduction depends on the sulfate ions participation in new reaction with soil mineral.

4.1.2 X-Ray Diffraction Tests

The results of X-ray diffraction tests are given in Table 3. The d-spacing of minerals, which is the distance between different planes of atoms in the crystal lattice are given in Table 3. X-ray tests results have shown major reflections at (3.340, 3.032 and 4.252) A°. This data reveals the presence of quarts, calcite, and orthoclase as major non-clay minerals and heulandites, anhydrite, gypsum and feldspar as minor non-clay minerals. In contaminated soil samples the X-ray diffraction tests markedly decreased the d-spacing due to increasing the percentage of contaminant as shown in Table 3. The decreasing in d-spacing is due to grinding the outer surface of grains due to effect of highly acidic action of contaminant solute (pH = 2.46) on the weak and thin layer that cover the surface of soil grains. The increase in contamination percentage will increase the ions that available to participate with soil ions to create new cementing agent.

Table 3: Results of X-ray Diffraction Tests.

Soil Sample	Major Mineral		Minor Mineral	
	Mineral	d-Spacing A°	Mineral	d-Spacing A°
k_o	Quartz	3.340	Heulandites	2.491
	Calcite	3.032	Anhydrite	2.091
	Orthoclase	4.252	Gypsum	2.456
	-	-	Feldspar	3.850
k_1	Quartz	3.340	Heulandites	2.490
	Calcite	3.032	Anhydrite	2.090
	Orthoclase	4.250	Gypsum	2.450
	-	-	Feldspar	3.848
k_2	Quartz	3.334	Heulandites	2.490
	Calcite	3.027	Anhydrite	2.090
	Orthoclase	4.242	Gypsum	2.450
	-	-	Feldspar	3.848
k_3	Quartz	3.332	Heulandites	2.488
	Calcite	3.025	Anhydrite	2.089
	Orthoclase	4.238	Gypsum	2.451
	-	-	Feldspar	3.837
k_4	Quartz	3.330	Heulandites	2.486
	Calcite	3.023	Anhydrite	2.088
	Orthoclase	4.231	Gypsum	2.450
	-	-	Feldspar	3.836

4.2 Physical Properties of Soil

4.2.1 Particle-Size Distribution

The summary of particle-size distribution tests is given in Table 4. It's clear that the particles of soil samples become finer after contamination that either due to effect of acidic contaminant which caused corrosion the grains of soil during socking period or due to the property of acidic contaminant solute to dissolve the organic matter in soil sample or dissolution of unstable soil particles and leading to produce more fine particles.

Table 4: Results of Physical Tests for Soil Samples.

Soil Sample	Gs	Gravel %	Sand %	Silt and Clay %	LL %	PL %	$k \times 10^{-6}$ m/sec
k_o	2.64	1.97	97.41	0.61	15	NP	10.4
k_1	2.62	1.67	97.00	1.33	15	NP	8.91
k_2	2.61	1.68	96.97	1.35	17	NP	6.66
k_3	2.61	1.33	97.28	1.39	18	NP	4.78
k_4	2.61	1.27	97.33	1.40	21	NP	4.18

4.2.2 Specific Gravity

The results of specific gravity tests are given in Table 4. It can be noticed that the specific gravity decreased with increasing the percentage of contamination for a specific value of contamination percentage, then become constant. This action is due to the low density of the contaminant.

4.2.3 Atterberg's Limits

The results of Atterberg's limits for studied soil samples are given in Table 5. The contaminant causes increasing liquid limit value's with increasing the percentage of contaminant added to the soil sample. This action is due to the decreasing in soil particle's size, which causes increasing surface area of solid particles and the need for additional water content to allow soil to start flow. No plastic limit can be measured due to the non cohesive property of soil samples.

4.2.4 Permeability Tests

The results of constant head permeability tests (CHT) are given in Table 4. The increase in percentage of contamination causes decreasing in permeability of contaminated soil samples consecutively. This reduction is due to increasing the fines of soil particles as result of the effect of acidic contaminants solute.

4.2.5 Maximum Density

The results of standard and modified compaction tests are given in Table 5. The results of tests indicated that maximum dry density decreased in contaminated soil samples. During soaking process, a light weight material generated at the surface of container, which resulted from the chemical reaction between soil sample and contaminant or due to corrosion of weak surface layer of soil particle. This light material has property of black putrid and glutinous material.

The dissolved salts cover soil particles causes decrease in the maximum dry density, it was noticed that contamination of intact soil sample with 10% of industrial waste causes reducing the maximum dry density and optimum moisture content, but increasing the percentage of contaminant above 10% causes decreasing the maximum dry density and increasing the optimum moisture content. This behavior appeared in standard compaction test, which means a relation between compaction effort and percentage of contamination. In modified Procter tests, the maximum dry density decreased slightly with increasing the percentage of contamination, but the optimum moisture content decreased for 10 and 20% of contamination and start to increase for the other two percentages.

Table 5: Results of Compaction Tests.

Modified Procter Test		Standard Procter Test		Soil Sample
ω_{opt} %	$\rho_{d,max}$ gm/cm^3	ω_{opt} %	$\rho_{d,max}$ gm/cm^3	
8.73	1.985	9.76	1.960	k_o
8.11	1.962	9.48	1.916	k_1
8.36	1.950	9.83	1.905	k_2
8.78	1.942	10.40	1.884	k_3
9.14	1.930	10.66	1.880	k_4

5. Conclusions

Contamination of intact soil with acidic liquid make the particles finer than in its natural condition, this because the acidic solute will grinding the outer surface of particle or release the weak layer covered the soil grains which are mostly of bulky shape. The liquid limit of contaminated soil samples increased in compare with the value of intact soil either because the particle gets finer or because the nature of the contaminant liquid soil use large quantity of water to neutralize the power hydrogen of contaminated samples. A slight decrease in specific gravity of contaminated soil samples was noticed. The maximum dry density of contaminated soil samples are decreased with increasing the percentage of contaminant added to the intact soil.

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