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Original Research Article

Influence of crude and emulsified crude oil on some properties of clay soil

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Abstract

A study was conducted to evaluate a modified and direct applied method of crude oil as conditioner after emulsification oil with irrigation water (oil: water emulsion). Clay soil was used to investigate the effect of three factor, the first factor: Pulverization soil index (P), (measured by mean weight diameter of soil clods) with two indices, high (p_1) and low (p_2) with mean weight diameter (MWD) (17.026 and 10.511 mm) respectively; the second factor: crude oil applied method (C) with three treatment, control 0% (c_0), crude oil 0.5 % w/w mixing with irrigation water (c_1) and (c_2) treatment, crude oil 0.5 % w/w mixing with water and emulsified by add artificial emulsifying agent (Anionic surfactant: Sodium Dodocyl Sulphate coconut fatly acid; third factor: initial moistening (W) with two treatment, field capacity (w_1) and saturation percent (w_1) mention to water volume which used to applied in C_0, $C_1$and C_2 treatment to soil. The results showed that the most of hydrocarbon compounds (with percent 82 %) accumulated in 0 – 15 cm depth, while about 18 % of total hydrocarbon compounds penetrate to 15 – 30 cm. Emulsification crude oil with water increased significantly the diffusion and penetration of hydrocarbon compounds at C_2 treatment from 0 – 15 cm depth to 15 – 30 cm depth up to duplication compared with c_2 with c1 treatment with percent 68 % and 36 % for 0 – 15 cm and 15 – 30 cm depth, respectively. It was observed that increasing pulverization index from p_2 to p_1 and initial moistening level from field capacity (w_1) to saturation percent (w_1) causes slight increasing of penetrated hydrocarbon compounds percentage at 15 – 30 cm depth for about 2 % and 3 %, respectively. The results showed c_1 and c_2 treatment causes significant increase in mean weigh diameter (MWD) and soil porosity (f %) associated with significant decreasing in soil bulk density (Pb) compared with C_0 treatment, with significant superiority of c_2 treatment which, its effect reached to whole of soil depth 0 – 30 cm over c_1 treatment which, its effect restricted chiefly at 0 – 15 cm depth, also the results showed a slight decrease in MWD and soil bulk density with slight increase in soil bulk density as increasing initial moistening level from w_1 to w_2 level and at decreasing pulverization index from p_1 to p_2 level, this impact be happen chiefly in 0 – 15 cm depth at C_0 treatment

Key word: Crude oil, Pulverization index, mixture, Emulsifying agent, (Oil: water) emulsion.

INTRODUCTION

Crude oil and its derivatives were used as hydrophobic conditioners to improve physical and hydrological properties of soil and reducing loss of soil by erosion process since half century ago. Crude oil and its derivatives applied improve soil structure through bonding soil particles together which increased mean weight diameter (MWD) of soil aggregates (De Boodt and Bisschop, 1974 and Gabriels et al., 1975). Petroleum hydrocarbons coated soil aggregates surface and changed these surfaces from hydrophilic to hydrophobic which lead to increasing the constant angle value between water – solid phase and effect on the driving force of capillary movement of water, this impact make soil aggregates more stable against deterioration effect of rapid wetting, which resulted an improvement in soil properties represented in increasing soil porosity and decreasing bulk density (Hartmann et al., 1983; Al – Dubaki, 1983 and Al – Doori, 2002). Several studies showed that hydrocarbon compounds have negative effect on biological activity on soil chiefly at heavy levels by reduced soil microbes number and enzymes activity in soil (Voets et al., 1977; Tayer, 1976; Al – Ansari et al., 1998). Abdul kareem (2002) suggested that safety level of hydrocarbon compounds in soil shouldn't exceed 0.5 % w/w. Most petroleum hydrocarbons are low infiltration in soil due to the high viscosity and highly absorptivity of these materials by soil (Ivshina et al., 1998); therefore all pervious application methods of hydrocarbons to soil aimed to reduced deteriorated effect of these compounds on soil and plant through decreasing the concentration of hydrocarbons on surface and microsites of soil by spraying method to soil clods surface (Hillel, 1980); and by use mechanical mixing soil with mixture of water and hydrocarbons (Al – Ansari et al., 1998, Al – Atab, 2001 and Abdulkareem, 2002), or a diluted mixture of petroleum hydrocarbon with organic solvents spreaded to soil (Al – Maleky , 2005 and Al – Saraji, 2006). However, above mentioned methods are restricted to small area land, in addition to that, petroleum hydrocarbons unlikely to form stable mixture with water. Duck (1966) reported that water and oil are immiscible liquids cannot form stable and homogenous emulsion due to high surface tension and capillary tension of water which make stress between oil droplets to produced large oil drop then the emulsion become unstable. Martin (1980) reported that water and oil may be mixed to produced stable mixture by addition emulsifying agents (surfactants) which reducing the interfacial tension between the liquids, he also reported that surfactant molecules consist of at least two groups , one soluble in soil (hydrophobic group) and other soluble in water (hydrophilic group) so interfacial film formed between oil droplet and surrounding water, which prevent coalescence of oil droplet due to similar charges on the droplets . Hermann et al. (2001) indicated that the stability and homogeneity of Oil: Water (O / W) emulsion increased with decreasing the oil droplet diameter to at least 2 micrometer depending on suitable concentration of emulsifying agent (surfactant) in mixture volume. The present study aimed to evaluate the effect of application of crude oil emulsion in irrigation water (oil: water emulsion) as modified method on soil surface at different pulverization index and moistening level on penetration and distribution of oil through soil profile and their effects on some soil physical properties (MWD, soil bulk density and total porosity).

MATERIALS AND METHODS

This study was conducted at college of Agriculture farm univ. of Basrah Karmat Ali location on alluvial clay soil (clayey, mixed, calcareous, hyperthermic, typic torrifluvents). Samples of soil surface (0 – 30) cm were collected then physical and chemical properties of soil were determined according to Black et al. (1965) and Page et al. (1982), (Table 1). Two experiments were carried out, the first aimed to evaluate the effect of crude oil treatments, pulverization soil index factor and initial moistening level factor on some physical properties, (MWD, soil bulk density and soil porosity). The first factor: Pulverization soil index. (P) (measurement of mean weight diameter of soil clods) with two treatment, high (p_1) and low (p_2) pulverization indices, at these treatment the soil which used was collected from the form at 0 – 30 cm depth after double cross plower by mild board plow followed with once and twice harrow disk traffic for p_1 and p_2 respectively, with MWD equal to 17.026 and 10.511 mm for p_1 and p_2 successively , which be rating in Table (2) by using set of sieves, the soil samples may be passed through, according to the method described in (Hillel , 1980). (Table 2)

The second factor, crude oil applied method with three treatments, control 0% (c0), crude oil 0.5% w/w (for dry soil) mixing with water (c_1) and crude oil 0.5% w/w (for dry soil) mixing with water and emulsified by add artificial emulsifying agent (Anionic Surfactant).

(Sodium Dod0cyl Sulphate coconut fatty acid) (SDS) by addition and mixing with equivalent volume of surfactant to arriving SDS concentration in the mixture to 7mM, according to Hermann et al., (2001), the properties of crude oil which used described in Table (3). The third factor, initial moistening level (W), with two treatments, field capacity (w_1) and saturation percent (w_2) mention to water volume added directly for (C_0) treatment or mixed with crude oil for c_1 and c_2 treatments. Soil columns which used as experimental unit by using plastic cylinder with 20 cm diameter and 30 cm soil column length, glass wool was used, and hold in the bottom of each cylinder, 11 kg of dry soil used to filling and packing thereby the total experimental units equal 24 unit (Table 3).

Resulting from multiplication of factorial combination: 3 crude oil treatment X2 pulverization indices X2 initial moistening level X3 replication. After the factorial treatment have been done, soil columns let to be dried to complete the coalescence process, which all water surrounding oil droplets lose in order to make continuous film of oil around soil aggregates or soil clods (Martin, 1981). Then all soil columns were treatment with six of

Table 1. Some physical and chemical properties of soil for 0 – 30 cm depth

Soil Properties		Measurement units	The value
Bulk density		Mgm^{-3}	1.22
Particle density		Mgm^{-3}	2.66
Porosity		%	54.10
MDW		mm	0.42
Sand		gkg^{-1}	54.90
Silt			337.70
Clay			607.40
Texture class			Clay
Field capacity		$gmgm^{-1}$	0.33
Saturation percent			0.50
pH			7.41
Organic matter		gkg^{-1}	3.61
Total carbonate			326.78
EC_e		dSm^{-1}	5.29
Soluble ions	Ca^{2+}	$mmoleL^{-1}$	10.01
	Mg^{2+}		7.02
	Na^{+}		25.22
	K^{+}		2.38
	$SO4^{2-}$		23.22
	Cl^{-}		46.34
	CO_3^{2-}		0.00
	HCO_3^{-}		2.47
Irrigation water			
EC_w		dSm^{-1}	1.80
pH_w			7.00

Table 2. Rating method of MWD soil clods as indices for soil pulverization factor

Sieves ranges (mm)	M i: average of sieves range (mm)	Wi : weight of residual soil (kg) on the sieves		Xi: average of percentage ratio = (wi*mi / ∑wi)	
		P_1*	**P_2****	**P_1**	**P_2**
120 – 90	(120+90) / 2 = 105	0	0	0	0
90 – 70	(90+70) / 2 = 80	1.17	0	0.967	0
70 – 50	(70+50) / 2 = 60	3.160	1.590	1.940	0.971
50 – 30	(50+30) / 2 = 40	17.470	6.770	7.22	2.757
30 – 10	(30+10) / 2 = 20	20.580	16.510	4.255	3.364
10 – 2	(10+2) / 2 = 6	40.080	52.500	2.486	3.207
< 2	2 / 2 = 1	15.280	20.840	0.158	0.212
∑wi		97.740	98.220		
		MWD =∑xi		17.02 mm	10.51 mm

*P1 high pulverization index treatment
**P2 low pulverization index treatment

Table 3. Some characteristics of crude oil from Southern Rumiala s field / Basrah – Iraq

The characteristics		The value
Specific weight at 21.1 Cº		0.8562
Water content (v/v %)		Nill
Sulphric content (w/w %)		1.90
Carbon content (w/w %)		4.48
Wax content (w/w %)		3.10
The pouring point (Cº)		-15.00
Viscosity (cSt)	at 21.1 Cº	10.96
	at 37.8 Cº	6.436
Initial boiling point (Cº)		40.00
Total distillation ratio (v/v %)		48.50

wetting – drying cycles by allow soil to dry nearly to 60% of field capacity content, then soil columns be moistening to arrive up water content to field capacity level, then disturbed and undisturbed soil samples were taken from 0 – 15 and 15 – 30 cm depth. Soil aggregates stability as representing by Mean Weight Diameter (MWD) determined by using wet sieving method (Black et al., 1965); Bulk density and total soil porosity were determined by standard procedures as explained in Black et al., (1965). For determination the effect difference between crude oil and crude oil emulsion with influence of other studying factor , pulverization index and initial moistening level on penetration deeply and homogeneity distribution of oil compound in soil depth , the second experiment was carrying out by using the same procedures , steps and treatments in the first experiment (above mentioned) just without control treatment (c_0) , and without wetting – drying cycles , then the soil columns was air – dried soil samples were taken from 0 – 15 and 15 – 30 cm depth and kept at frigid temperature. Total hydrocarbon compounds of crude oil were extracted by a mixture of methanol – benzene according to IOC / WMO, (1982) method by using Soxhlets Discontinuous extraction, then spectroflurophotometer was used to determination the concentration of total hydrocarbon compounds.

RESULTS AND DISCUSSION

The influence of studying factors on hydrocarbon compounds distribution at soil depth

The results in Table(4) referred to the distribution of total residual hydrocarbon compounds through 0 – 30 cm depth, which showed there was significant reducing ($P < 0.05$) in hydrocarbon concentration average at crude oil emulsion treatment (c_2) comparison with crude oil treatment (c_1) with reduction percentage 2.64%, this result can be attributed to the effect of emulsification process to increase the penetration and distribution of oil through soil depth, where of decreasing the concentration of oil in soil sites, which may be enhancing bioremediation of oil compound by soil microorganisms (Voet et al., 1973; Tyler, 1976). Generally, most of hydrocarbon compounds were concentrated at 0 – 15 cm depth with significant superiority comparison with 15 – 30 cm depth with average 3053.6 and 1085.8 Mg kg^{-1} respectively, this result can be attributed to the highly viscosity and sportively of oil to soil particles surface (Ivshina et al., 1998), as well as, where water infiltrated through 0 – 15 cm depth may be fluxed through different size pores, thus be great total surface area which able to trap oil in this depth chiefly at crude oil treatment (c_1) which recorded concentration averages 3413.73 and 781.13 Mg kg^{-1} for 0 – 15 and 15 – 30 cm depth respectively, with decreasing ratio 77.12 % for 15 – 30 cm depth comparison with 0 – 15 cm depth, whereas the penetrating hydrocarbon compounds increasing through soil depths at crude oil emulsion (c_2), which got averages 2693.53 and 1390.5 Mg kg^{-1} for 0 – 15 and 15 – 30 cm depth respectively, so that decreasing ratio of oil concentration at 15 – 30 cm depth comparison with 0 – 15 cm depth lowered to 48.37 %, this result can be attributed to the characteristics of stable crude oil emulsion be formed of soil droplets less than 2 micrometer, which able to penetrate and distribute through soil depths and soil pores overly. Table (4) also showed that, three was significant effect ($P < 0.05$) of interaction between initial moistening, factor and soil depth on hydrocarbon compounds concentration, the field capacity treatment (w_1) at 0 – 15 cm depth showed highest concentration average (3123.80 Mg kg^{-1}) with superiority over water saturation treatment (w_2) (2983.45 Mg kg^{-1}), while w_2 treatment at 15 – 30 cm depth surpass significantly W_1 treatment, the reason of this result because of excess water volume which used at saturation (w_2) than field capacity (w_1) might be enhanced the movement and distribution of crude oil either mixed or emulsion to soil depth overly. The hydraulic conductivity in soil might be significantly increased directly proportional with increasing water content from field capacity level to saturation level

Table 4. The influence of studying factors on distribution of total hydrocarbon compound (Mg kg^{-1}) through soil depth

Crude oil treat. (C)	Soil depths cm (D)	Initial moist. level (W)				Oil *depth interact. (C*D)	Average of crude oil (C)
		Field capacity (W_1)		Saturation (W_2)			
		High pul. (P_1)	Low pul. (P_2)	High pul. (P_1)	Low pul. (P_2)		
C_0	0 – 15	—	—	—	—	—	—
	15 – 30	—	—	—	—	—	
C_1	0 – 15	3463.20	3522.70	3264.30	3404.70	3413.73	2097.43
	15 – 30	773.20	713.70	810.83	826.80	781.13	
C_2	0 – 15	2714.10	2795.20	2619.70	2645.10	2693.53	2042.00
	15 – 30	1393.40	1210.10	1510.40	1448.00	1390.50	
		R . L . S . D for tetruinteraction (C * D * W *P) = ns				R . L . S . D (C * D) = 53.67	R . L . S . D (C) = 39.76
(W *D) interaction		Field capacity (W_1)		Saturation (W_2)		(D) average	R . L . S . D (D) = 35.74
D1 = 0 – 15 cm		3123.80		2983.45		3053.63	
D2 = 15 – 30 cm		1022.60		1149.00		1085.80	
(W) average		2073.19		2066.22		R . L . S . D (W*D) = 20.29	
		R . L . S . D (W) = ns					
(D * P) interaction		High P (P_1)		Low P (P_2)		R . L . S . D (P*D) = 35.74	
D_1 = 0 – 15 cm		3015.33		3091.93			
D_2 = 15 – 30 cm		1121.96		1049.40			
(P) average		2068.63		2070.79			
		R . L . S . D (P) = ns					

because all soil pores became full with water and highly conductor (Hillel, 1980). The results also showed that there was significant interaction effect between pulverization soil index and soil depth on hydrocarbon compounds concentration; in soil depth 0 – 15 cm, low pulverization index (P_2) showed the highest concentration (3091.93 Mg kg^{-1}) exceeded high pulverization index (p1) (3015.33 Mg kg^{-1}), while in 15 – 30 cm depth, p_1 treatment showed concentration (1121.96 Mg kg^{-1}) with superiority over p_2 treatment (1049.40 Mg kg^{-1}), this result might be obtained as a results of variable in pore size distribution between p_1 and p_2 treatment so that infiltration rate of oil / water mixture or oil / water emulsion through soil depth may be affected with pores size distribution specially macropores and mesopores which be found in p1 treatment higher than in p_2 treatment ; these results agreed with the results which was obtained by Siri – Prieto et al., (2007); Al – Atab (2001).

The influence of studying factor on soil structure

The results in Table (5) showed the influence of studying factor and its interaction on soil structure representing at Mean Weight Diameter (MWD) of soil aggregates, which appeared significant effect ($P < 0.05$) for crude oil factor (C) on MWD. Crude oil emulsion treatment (c_2) got highest MWD with average (0.404 mm) and then crude oil treatment (c_1) with average (0.381 mm) with significant superiority for c1 and c2 over control treatment (c0) with the increasing ratio 15.79 % and 9.10 % respectively, this results can be attributed to the role of hydrocarbon compounds to do hydrophobic coating around soil aggregates make them more stable against deteriorated effect of rapid wetting during irrigation process (DeBoodt and Bisschop, 1974; Al – khafaji, 1985; Holomes et al., 2002). Consequently, this impact can be improved MWD at emulsified crude oil treatment (c_2) got significant increasing comparison with other treatment due to a mention reason which related to high penetration and distribution of oil emulsion through more of soil pores so that more of soil aggregates were coated that lead them stable against deteriorated effect of rapid wetting during wetting – drying cycles. Table (5) also showed the was a significant effect of interaction between crude oil factor (C) and soil depth on MWD, the lowest MWD value be found at c0 treatment in 0 – 15 cm depth, with high and significant difference in MWD value between this depth comparison with 15 – 30 cm depth. While, at crude oil treatment (c_1) the difference in MWD values between 0 – 15 and 15 – 30 cm depth reported significant decreasing in 15 – 30 cm depth comparison with 0 – 15 cm depth, whereas, at crude oil emulsion (c_2) the difference between these soil depth 0 –15 and 15 – 30 cm in MWD values reported least range, the reasons of these results might be resulted from that the deteriorated effect of rapid wetting. Which caused soil aggregates deterioration must be happened with highest rate in 0 – 15 cm depth at c0 treatment because there is no any conditioner added to this treatment. While, at c_1 treatment the higher accumulation of oil compound in 0 –

Table 5. The influence of studying factors on MWD value (mm)through soil depths

Crude oil treat. (C)	Soil depths cm (D)	Initial moist. level (W)				Oil *depth interact. (C*D)	Average of crude oil (C)
		Field capacity (W_1)		Saturation (W_2)			
		High pul. (P_1)	Low pul. (P_2)	High pul. (P_1)	Low pul. (P_2)		
C_0	0 – 15	0.340	0.336	0.341	0.328	0.336	0.349
	15 – 30	0.369	0.337	0.363	0.340	0.362	
C_1	0 – 15	0.388	0.398	0.383	0.400	0.392	0.381
	15 – 30	0.389	0.346	0.380	0.363	0.370	
C_2	0 – 15	0.406	0.400	0.412	0.398	0.404	0.404
	15 – 30	0.410	0.405	0.399	0.400	0.403	
		R . L . S . D for tetruinteraction (C * D * W *P) = 0.01				R . L . S . D (C * D) = 0.004	R . L . S . D (C) = 0.003
(W *D) interaction		Field capacity (W_1)		Saturation (W_2)		R . L . S . D (C*W) = 0.005	
C_0		0.355		0.343			
C_1		0.380		0.381			
C_2		0.405		0.401			
(W) average		0.380		0.376		R . L . S . D (W) = 0.004	
(D * P) interaction		High P (P_1)		Low P (P_2)		(D) average	R . L . S . D (D) = ns
D_1 = 0 – 15 cm		0.372		0.385		0.378	
D_2 = 15 – 30 cm		0.378		0.382		0.378	
(P) average		0.378		0.382		R . L . S . D (D*P) = o.oo36	
		R . L . S . D (P) = 0.0025					

R . L . S . D ($P < 0.05$) ; D = Soil depth ; P (Pulve.) = Pulverization index ; C : crude oil treatment

15 cm depth than in 15 – 30 cm depth lead soil aggregates in surface depth more stable than in subsurface depth against the above action; Whereas, the increasing of the penetration and distribution of oil compound through soil depth even 15 – 30 cm depth lead soil aggregates of whole soil column more stable. Table (5) showed a significant effect of initial moistening factor upon MWD, the average of MWD significantly decreased from field capacity treatment (w_1) with value 0.380 mm to saturation percent (w_2) with value 0.376 mm, this result might be resulted from the variation in soil aggregates deterioration percent which directly proportional with rate of immersion and wetting of soil aggregates, which was higher at saturation percent than at field capacity level (Hillel, 1980). Consequently, the highest difference in MWD values between W_1 and W_2 treatment showed at 15 – 30 cm depth more than at 0 – 15 cm depth (table 5) because the variation in the rate of immersion and wetting between W_1 and W_2 treatments so higher at 15 – 30 cm depth than at 0 – 15 cm depth, this result agreed with the result which was obtained by Freeman et al., 1976. The results also showed that the highest differences between W_1 and W_2 treatment in MWD values appeared at control treatment (c_0), the values 0.355 and 0.343 mm respectively (table 5), while the differences between w_1 and w_2 treatments which interaction with either c_1 or c_2 treatment reduced less than significant threshold. The results also showed there was significant effect of pulverization index factor (P) on MWD values, high pulverization index treatment (p_1) reported significant decreasing comparison with low pulverization index (p_2) (table 5), this result might be resulted from the percent of macro and meso pores in soil at P_1 treatment which higher than at p_2 treatment, so that the rate of immersion and frontal wetting advance in p_1 more than p_2 treatment , this impact increased the soil clods and soil aggregates must be deteriorated (Al – Alab, 2001). The results also showed that the difference between p_1 and p_2 treatments in MWD values altered with soil depth, p_2 treatment reported higher and significant increasing comparison with P_1 at 0 – 15 cm depth, as if be compared with the same treatment (p_1 and p_2) at 15 – 30 cm depth because the water flux was faster through top layer than in deep layer during irrigation (Al – Saud et al., 1993).

The influence of studying factors on soil bulk density (Pb) and Porosity

Results in Table (6 and 7) showed a significant effect ($P < 0.05$) of crude oil factor (C) on soil bulk density and soil porosity percentage (f %), crude oil emulsion treatment (c_2) got lowest soil bulk density average (1.252 Mgm^{-3}) associated with highest soil porosity average (52.90 %) , then crude oil treatment (c_1) which reported soil bulk density average (1.332 Mgm^{-3}) associated with soil porosity average (49.90 %) , while the highest soil bulk

Table 6. The influence of studying factors on soil bulk density (Mgm-3) through soil depths

Crude oil treat. (C)	**Soil depths cm (D)**	**Initial moist. level (W)**				**Oil *depth interact. (C*D)**	**Average of crude oil (C)**
		Field capacity (W_1)		**Saturation (W_2)**			
		High pul. (P_1)	**Low pul. (P_2)**	**High pul. (P_1)**	**Low pul. (P_2)**		
C_0	0 – 15	1.473	1.424	1.457	1.470	1.457	1.420
	15 – 30	1.397	1.370	1.393	1.377	1.384	
C_1	0 – 15	1.347	1.313	1.350	1.290	1.385	1.332
	15 – 30	1.237	1.357	1.397	1.363	1.338	
C_2	0 – 15	1.267	1.270	1.250	1.230	1.254	1.252
	15 – 30	1.230	1.237	1.260	1.267	1.249	
		R . L . S . D for tetruinteraction (C * D * W *P) = 0.023				R . L . S . D (C * D) = 0.0116	R . L . S . D (C) = 0.008

(P *W) interaction	Field capacity (W_1)	Saturation (W_2)	(P) average	R . L . S . D (P) = ns
P_1	1.325	1.352	1.338	
P_2	1.329	1.333	1.331	
(W) average	1.327	1.342	R . L . S . D (P * W) = 0.01	
	R . L . S . D (W) = 0.0095			

(D * W) interaction	(W_1)	(W_2)	Depth average	R . L . S . D (D) = ns
D_1 = 0 – 15 cm	1.349	1.341	1.345	
D_2 = 15 – 30 cm	1.304	1.343	1.324	
	R . L . S . D (D * W) = 0.0095			

(C * W) interaction	(W_1)	(W_2)	R . L . S . D (C * W) = 0.0116
C_0	1.417	1.424	
C_1	1.313	1.350	
C_2	1.251	1.252	

(D * P) interaction	(P_1)	(P_2)	R . L . S . D (D * P) = 0.01
D_1 = 0 – 15 cm	1.357	1.333	
D_2 = 15 – 30 cm	1.319	1.328	

R . L . S . D ($P < 0.05$); D = Soil depth; P (Pulve.) = Pulverization index; C: crude oil treatment

density average (1.42 Mgm^{-3}) associated with the lowest soil porosity average (0.466 %) was obtained at control treatment (c_0), the reason of this results might be resulted to the same reasons above mentioned which related to the effect of oil compounds to created hydrophobic surface around soil aggregates lead them more stable against deteriorated effect of rapid immersion and wetting , where by the soil structure deterioration reduced and lead to increased soil porosity and decreased soil bulk density consequently (Hartmann et al., 1983; Akpoveta et al., 2012; Al – Maleky, 2005). While, the higher penetration of crude oil emulsion through soil depth making excess of soil aggregates and soil clods be coated with oil compounds and became stable excessively more than other treatment (c_0 and c_1). Tables (6 and 7) showed there was significant effect of interaction between crude oil factors (C) and soil depth on soil bulk density and soil porosity, whereas the higher differences between soil depth 0 – 15 and 15 – 30 cm depth obtained at control treatment (c_0), these results might be resulted from that the deteriorated effect of rapid immersion and wetting during wetting – drying cycles on soil structure could be occurred at 0 – 15 cm depth more than in 15 – 30 cm depth due to the higher of water flux in upper depth while, the difference in soil bulk density and soil porosity values between 0 – 15 and 15 – 30 cm depths were reduced when crude oil added especially at crude oil emulsion (table 6 and 7) these results can be attributed to ability of oil in c_2 treatment to penetrate and distribute through soil depth and soil pores overly, this impact make the structure of the most soil stable. Whereas, in spite of the most oil was concentrated at 0 – 15 cm at crude oil treatment c_1 (table 4) but this property lead to reduce the deteriorated effect of frontal wetting advance on soil structure might be obtained at 0 – 15 cm depth, when the most of soil aggregates and soil pores must coated with oil and their surface became hydrophobic; this effect must be reached also to 15 – 30 cm depth due to high concentration of oil compounds at 0 – 15 cm depth at c_1 treatment must be narrowed the pores and channel of soil and lead to delayed the velocity of frontal wetting advance

Table 7. The influence of studying factors on total soil porosity (f %) through soil depths

Crude oil treat. (C)	Soil depths cm (D)	Initial moist . level (W)				Oil *depth interact. (C*D)	Average of crude oil (C)
		Field capacity (W_1)		Saturation (W_2)			
		High pul. (P_1)	Low pul. (P_2)	High pul. (P_1)	Low pul. (P_2)		
C_0	0 – 15	46.40	44.60	44.70	45.20	45.20	46.60
	15 – 30	48.50	47.50	48.20	47.60	47.90	
C_1	0 – 15	50.60	49.40	51.50	49.30	50.20	49.90
	15 – 30	49.00	53.50	48.80	47.50	49.70	
C_2	0 – 15	52.30	52.40	53.60	53.00	52.80	52.90
	15 – 30	53.20	53.80	52.40	52.50	53.00	
		R . L . S . D for tetruinteraction (C * D * W *P) = 1.00				R . L . S . D (C * D) = 0.40	R . L . S . D (C) = 0.30
(P *W) interaction		Field capacity (W_1)		Saturation (W_2)		(P) average	R . L . S . D (P) = ns
P_1		50.20		49.20		49.70	
P_2		50.00		49.90		49.90	
(W) average		50.10		49.50		R . L . S . D (P * W) = 0.40	
		R . L . S . D (W) = 0.30					
(D * W) interaction		(W_1)		(W_2)		Depth average	R . L . S . D (D) = ns
D_1 = 0 – 15 cm		49.30		49.50		49.40	
D_2 = 15 – 30 cm		50.90		49.50		50.20	
		R . L . S . D (D * W) = 0.40					
(C * W) interaction		(W_1)		(W_2)		R . L . S . D (C * W) = 0.50	
C_0		46.70		46.40			
C_1		50.60		49.30			
C_2		52.90		52.90			
(D * P) interaction		(P_1)		(P_2)		R . L . S . D (D * P) = 0.40	
D_1 = 0 – 15 cm		49.80		50.40			
D_2 = 15 – 30 cm		50.00		49.70			

R . L . S . D ($P < 0.05$); D = Soil depth; P (Pulve) = Pulverization index; C: crude oil treatment

at second depth (15 – 30 cm), this result agreed with the result which was obtained by (Toogood, 1977; Aiyad, 2004). Table (6 and 7) also showed that the increasing initial moistening level from field capacity (w_1) to saturation percent (w_2) caused significant increasing at soil bulk density average from 1.327 to 1.342 Mgm^{-3} respectively, associated with the significant decreasing at soil of from 50.10 % to 49.50 % respectively, this result agreed with result was obtained by Al – Shamy, 2013; who indicated that increasing irrigation level to saturation percent must be increased the velocity of immersion and frontal wetting advance which caused deterioration soil aggregates to primary particles which moved and filled the soil pores there by soil bulk density must be increased and soil porosity decreased consequently. The results also showed the effect interaction between initial moistening treatment w_2 with high pulverization index p_1 got significant increasing in soil bulk density from 1.325 Mgm^{-3} at w1 to 1.352 Mgm-3 at w_2 associated with significant decreasing soil porosity from 50.20 % at W1 to 49.20 % at w2 treatment (table 6 and 7). While, at low pulverization index treatment p_2, the variation in soil bulk density or soil porosity values with increasing moistening level from w_1 to w_2 obtained least variance less than significant threshold, these results might be resulted from that the large soil clods can be deteriorated more than small soil clods by influence of the high rate at immersion and rapid wetting (Kuht and Reintam, 2004; Gomez et al., 2004). The results also showed (table 6 and 7) that the effect of immersion and rapid wetting on deterioration of soil aggregates and clods which increased with increasing initial moistening level to w_2 (saturation percent) must be reached to the whole depth of soil even 15 – 30 cm depth so that there is no significant difference in soil bulk density or soil porosity between 0 – 15 and 15 – 30 cm depth, while, at w1 (field capacity) treatment, the result showed significant difference between 0 – 15 cm and 15 – 30 cm depth in soil bulk density and soil porosity because the deteriorated effect of immersion and rapid wetting might be restricted specially at first soil depth (0 – 15 cm). The results also showed there was significant interaction effect between crude oil factor (C) and initial moistening factor (W) on soil bulk density and soil porosity (table 6 and 7), whereas, the highest soil bulk density value associated with lowest soil porosity obtained at control treatment (c_0) which interacted with w_2 or w_2 treatments, but c_2 treatment which interacted with w_1 and w_2 treatments obtained lowest soil bulk density associated with highest soil porosity, while, treatment combinations between c_1 treatment with w_1 and w_2 treatment have intermediate values compared with above treatment combinations at c_2 and c_1, these results might be referred that deteriorated effect of immersion and rapid wetting on soil structure and then on soil bulk density and soil porosity must be reduced significantly even at high moistening level (w_2) if crude oil added as conditioner specially crude oil emulsion . Table (6 and 7) also showed that there was a significant effect of interaction between soil depth and pulverization index (P) on the soil bulk density and soil porosity values, the higher and significant difference were obtained between P_1 and P_2 treatments at 0 – 15 cm depth, while, at 15 – 30 cm depth, the differences between P_1 and P_2 treatments in soil bulk density and soil porosity were reduced less than significant threshold, this results might be referred that the highest effect of deteriorated effect of immersion and rapid wetting might be occurred at the surface soil depth (0 – 15 cm) which enhanced by presence and dominance of macropores and large soil clods at p_1 than p_2 treatment which caused increasing in soil bulk density associated with decreasing soil porosity as the same reasons above mentioned .

CONCLUSION

The results obtained from this study lead to the following Conclusion:

1 – The emulsification of crude oil created stable emulsion (oil in water) lead to increase the penetration of oil droplets in soil depth even to 15 – 30 cm depth for twice compared with crude oil without emulsify-cation.

2 – The increasing of initial moistening level (from field capacity to saturation percent) and pulverization index (from 10.511 to 17.026 mm) lead to increase the deteriorated effect on the studying soil physical properties (MWD of aggregates, soil bulk density and soil porosity) but addition of crude oil treatments caused significant improvement on these properties, chiefly crude oil emulsion which obtained higher effect reached for whole soil depth.

RECOMMENDATION

The emulsification of crude oil can be used as modified, preferable and directly method for soil surface application at field conditions for a large scale of land with irrigation water under wide range of field practices representing at moisture regimes (field capacity to saturation percent) and at disking operation degree (pulverization indices from 10.511 to 17.026 mm for MWD of soil clods).

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