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Original Article

Effect of hydrocarbonic pollutants on the stability and soil water repellency intensity: A case study in Bandar Abbas Oil Refinery, Hormozgan province, Iran

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Abstract

Background: The contamination of soil and water with hydrocarbonic pollutants is a major environmental problem. Soil water repellency will interrupt water infiltration, and may decline plant growth and potentially trigger soil erosion. The aim of this study was to investigate the effect of soil and water contamination by oil on soil water repellency, where the soil has been oil-contaminated due to mismanagement of the lands surrounding the refineries, and many of the trees in the area have dried up.

Methods: Water drop penetration time test (WDPT) was performed on contaminated soils. To investigate the effect of the surface water contamination on soil, handmade soil samples were collected and successive dry/wet cycles were applied to them by contaminated and non-contaminated waters. Subsequently, soil water repellency tests, including molarity of ethanol droplet (MED), water and ethanol sorptivity were performed on soil samples. The soils were passed through a 2 mm sieve after being air-dried and the soil texture was determined by pipette method. The SWR was measured by WDPT in the area contaminated with petroleum compounds and 7 to 10 replicates were assigned to each location. In order to determine the effect of water contamination on the area soil and to measure water repellency in the laboratory, disturbed soil samples (36 samples) with a bulk density equal to 80% of the reference bulk density were prepared.

Results: The results showed that soil oil-contamination causes water repellency, increased WDPT, a significant increase in water repellency index, and a significant decrease in cosθ at the level of 0.001. The effect of water contamination on the indices and cosθ were statistically significant at the 0.001 and 1% levels, respectively. Therefore, contaminated water increased the water repellency of the soil after successive dry/wet cycles.

Conclusion: Significant positive correlations between organic and water repellency indices and significant negative correlations between cosθ and organic indices indicate the effect of oil-contamination of water and soil on creating and increasing the intensity of soil water repellency.

Keywords: Environment, Soil pollution, Water sorptivity, Oil refinery, Bandar Abbas

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Introduction

Hydrophobic compounds are coated on the surface of soil particles (1) and prevent water absorption in the soil (2) by increasing the contact angle between water and soil-air surface (3).

According to a study by Goebel et al (4), low soil moisture content, particularly in combination with high temperatures, can increase soil water repellency (SWR). By decreasing water infiltration, SWR affects hydrological and ecological soil functions (5). The effects are rather perceived as negative, such as increasing surface runoff and erosion, impeding plant growth, creating irregular infiltration patterns, and also, preferential flow in forest soils (6), as well as a redistribution of rainwater in the forest floor (7, 8) and in the mineral soil (9). SWR also indirectly affects soil CO_2 efflux, by exerting an influence on soil moisture distribution (10, 11). SWR is especially relevant in arid and semi-arid areas, where water resources may be especially limited and the distribution of rainfall is strongly seasonal (12).

The intensity and persistence of SWR depends on the energy of the soil surfaces with water (13) and the surface tension of the soil liquid (14). Bachmann and van der Ploeg (15) reported a strong relationship between the reduction of the surface charge of solid surfaces and the increase in contact angle. The results of Chau et al (14) also showed that the intensity of SWR does not indicate the persistency of water repellency; however, the contact angle (water repellency severity index) is more strongly correlated with soil moisture content (1).

In hydrophilic soils, the contact angle of the soil particle surface with water is approximately zero degree (16). In subcritical hydrophobic soils, the contact angle is between 0 to 90 degrees. In these soils, water slowly enters the soil (17). In real hydrophobic soils, the contact angle reaches more than 90 degrees preventing water from entering the soil (18). It should be noted that this grouping is true for uniform and linear geometric soil surfaces, but due to the complex structure of soil aggregates and pores surfaces, the actual values of the critical contact angle vary by 90 degrees (19). Some researchers have recently reported that in porous environments, water infiltration will not be performed if the effective contact angle is more than 50 degrees (20).

Many factors are involved in creating and altering SWR (21), some of which include fungal species, land use, forest fires, grasslands, and root exudates of some plant species (22). One of the most important factors in water repellency is the organic coatings on the particles surface and the soil pore wall (23).

A variety of organic compounds are involved in the phenomenon of SWR. The effluent of some plants and refineries can be effective in creating hydrophobic soil (24). Petroleum hydrocarbons are among the organic materials affecting water repellency (25). Researchers have found that oven drying of hydrophobic soils (contaminated with petroleum compounds) eliminates the interaction between polar groups of organic molecules and water molecules (26) and causes soil surfaces to be exposed to a chain of alkyl molecules that reduce water absorption. Moreover, in the air-dried state, some compounds, such as humic acids are moisture-resistant due to contraction (27).

Fluid component of petroleum compounds and evaporation of volatile oil compounds, affect aggregates and pore space (28). Roy and McGill (29) found that the presence of petroleum in the soil is an important factor in causing water repellency. Their studies in 2001 also showed that biogenic lipids, such as phospholipids, long-chain fatty acids, terpenes, and waxes, are compounds produced by plants, insects, and soil microorganisms, and have an effective role in creating unstable water repellency (10 seconds < Water drop penetration time test [WDPT] < 10 minutes) (30). However, petroleum hydrocarbons may cause stable water repellency (WDPT > 10 minutes) due to their high soil stability. Petroleum compounds also have long chain alkyl molecules and cyclic molecules with high molecular weight, which cause more severe water repellency (31).

Many hydraulic processes, such as infiltration, surface runoff, creation and increase of preferential water flows, alteration of soil water storage, and soil erosion are affected by water repellency (14). In hydrophobic soils, the soil pores have less matric suction than the pores of hydrophilic soils; furthermore, the water-soil contact angle is high (32). These two factors cause water droplets to be accumulated on the soil surface (33). Erosion occurs as water accumulates on the soil surface and produces runoff. de Dios Benavides-Solorio and McDonald (34) reported that there is a positive relationship between water repellency and soil erosion.

Increased saturated hydraulic conductivity of soil by hydrophobic compounds causes water to pass through the root zone and reduces water use efficiency in agricultural lands (35). Moreover, the oil contamination on the soil surface reduces water infiltration into the soil profile and causes preferential flows (36). Preferential flows transfer contaminants and hazardous elements to groundwater (37). Furthermore, they reduce available water in the soil and increase weeds growth competing with the main crop (33).

Several studies on soil hydrophobicity in the aridic moisture soils have been published. For example, Hewelke and Oktaba (12) have reported that SWR typically shows temporal variations, which are strongly related to the seasons. It has also been established that the water repellency is present in some forest and shrub communities, but fire can enhance, reduce, or even create it (38). Furthermore, severity of fire-induced SWR, depends on the burning temperature (39), vegetation type and land use (40), and soil properties (40).

Evidence suggests that the soil of the area has been contaminated with petroleum compounds for years. Over time, vegetation in the area has also been affected and some of susceptible trees have dried up. The existence of hard calcareous layers in the cross-section of some soils at a depth of 50 to 80 cm as well as high amounts of lime in the soils of the area are also hypotheses for the destruction of vegetation. However, since some trees are less sensitive to the presence of lime in the soil compared to crops, calcareous compounds cannot be the main reason for the vegetation destruction. The purpose of this study was to investigate the role of water and soil oil-contamination in reducing available soil water and drying of green space trees nearby Bandar Abbas refinery.

Material and Methods

Study Area

This study was conducted in the area around Bandar Abbas Oil Refinery Co., which is located in the west 30 km away from Bandar Abbas city. This company is one of the 9 Iranian petroleum refining companies, that started with a capacity of 232 000 b/d (barrel per day) and was increased to 320 000 b/d in July 2008 with attempt and endeavor of specialized and committed domestic manpowers. In 2012, by increasing 30 000 barrels of condensate to distillation and visbreaker units feedstock due to an innovative capacity improvement project without any expenditure and investment, this company was achieved to upgrade its capacity to 350000 b/d.

The 700-hectare plot of land is a part of the green space around the oil refinery and Morvarid residential town as the refinery staff's residential complex affected by oil refinery waste contamination.

The soil of this region has aridic moisture and a hypothermic thermal regime. Given that the area is near Bandar Abbas Oil Refinery, in long term, it has been contaminated by the refinery oil waste. Nine oil-contaminated locations with different levels of contamination and 9 non-contaminated locations were selected. Samples were taken from each location to a depth of 30 cm. Moreover, water samples were taken to determine the effect of water oil contamination on SWR from oil-contaminated wells.

Samples

A total of 18 points for soil sampling, were randomly selected, where 15 points were selected with different degrees of visible oil pollution, around Bandar Abbas refinery, Kaveh Steel Co., Al-Mahdi Aluminum and Special Economic Zone and three points were selected as controls (Table 1). Control points were selected based on their similarity to contaminated sites in terms of basic soil characteristics such as texture, organic matter, structure, lime content, etc.

Combined sampling was performed so that the central point and four surrounding points were sampled at 5-meter intervals. These 5 samples were then mixed together and a composite sample was taken.

Sampling was done from surface soil at a depth 0 to 10 cm. After transfer to the laboratory, the soil samples were dried and passed through a 4 mm sieve without tapping to measure hydraulic and structural properties. To measure texture and chemical properties, soil samples were compacted and passed through a 2 mm sieve.

Table 1. UTM coordinates of the soil sampling points

Sampling Point	X	Y
1	3007735.34	406713.40
2	3006690.45	406409.67
3	3007319.00	408131.00
4	3007719.89	408838.67
5	3007838.00	409927.00
6	3007050.82	411366.96
7	3006696.96	409442.61
8	3006504.91	407764.17
9	3005522.65	407016.18
10	3004865.00	407703.00
11	3005668.35	409092.35
12	3006060.61	409843.72
13	3005310.27	411835.66
14	3004486.40	411121.18
15	3004882.32	410069.15
16 (Control)	3004222.16	409734.95
17 (Control)	3003993.44	408611.00
18 (Control)	3003526.39	407604.51

Soil texture was determined by pipette method (41). The residual acid titration method with half-normal sodium hydroxide (reversible titration) was used to measure the soil calcium carbonate equivalent. Soil organic matter was measured by wet oxidation or Walkley–Black method as reported by Nelson and Sommer (42).

The TOC-Analyzer (Primacs model, Skular Co.) was used to measure the total organic carbon (TOC) in contaminated and non-contaminated water. To measure total poly-hydrocarbons (TPHs) in contaminated soils, Soxhlet and two normal-hexane and dichloromethane extractors, at a ratio of 1:1, were used as reported by Briedis et al (43). High performance liquid chromatography (HPLC) was used to measure water TPHs after liquid extraction.

Measurement of WDPT and water repellency intensity using MED, water and ethanol sorptivity and Capilary Rise Method methods

The SWR was measured by WDPT in the area contaminated with petroleum compounds and 7 to 10 replicates were assigned to each location.

In order to determine the effect of water contamination on the area soil and to measure water repellency in the laboratory, disturbed soil samples with a bulk density equal to 80% of the reference bulk density were prepared. In 13 cycles, they became dry and wet with contaminated and non-contaminated water to approach normal conditions.

The four treatments included: 1- Non-contaminated soil treated with non-contaminated water (O0W0), 2- Non-contaminated soil treated with contaminated water (O0W1), 3- Contaminated soil treated with contaminated water (O1W1), and 4- Contaminated soil treated with non-contaminated water (O1W0). Then, the molarity of ethanol droplet (MED) test was performed as follows. Using this test, the contact angle of soil-ethanol can be calculated based on the surface tension of ethanol solutions. In this method, using ethanol 96%, 51 ethanol solutions were made with concentrations of 0 to 8 M. Droplets were then placed on the soil samples surface with a dropper and the infiltration time was recorded by a timer. The molarity of the solution absorbed into the soil in 10 seconds (MED) was used as an indicator for SWR. Ethanol surface tension variation curve against molarity of ethanol solutions at 25°C and its equation fitting (Eq. 1) were used to calculate the solution surface tension for contact angle of 90° (γND) in soil samples. Critical surface tension (γC) and soil-water contact angle (θ) were also calculated using Eqs. 2 and 3, respectively:

$$\gamma ND = 58.49-(6.846\times Me)+(0.512\times Me2)-(0.0139\times Me3)+(13088\times e-Me) \quad (1)$$

$$\gamma C = \gamma ND / 4 \quad (2)$$

$$\cos\theta = \sqrt{((\gamma C \,/\, \gamma W\,)) - 1} \tag{3}$$

In Eq. (1), *Me* is the molarity of the ethanol droplet infiltrated by the soil in 10 seconds.

In Eq. (2), γW is the surface tension of water at 25°C (equal to 72.01 Mn m^{-1}).

In water and ethanol sorptivity method, ethanol sorptivity by soil was measured using a micro-infiltrometer (4 mm in diameter). The samples were then dried in the oven and ethanol sorptivity by soil was measured. Then, the cumulative infiltration curves against time and the cumulative infiltration curves against the square root for water and ethanol were separately plotted. Using the volume curve of water and ethanol infiltrated against time, the slope of the linear part of the curve over the time interval of 30 to 130 s was obtained as steady flow volume or Q (L^3/T). Water or ethanol sorptivity was then calculated using Eq. (4).

$$S = \sqrt{\frac{Q \times Ea}{4 \times 0.55 \times rt}} \tag{4}$$

Where *Ea* is the porosity filled with soil air (for oven-dried soil samples, it was equal to the total porosity) and *rt* is the tip radius of the micro-infiltrometer (L). The SWR index was calculated by Eq. (5). In this equation, *SW* and *SE* (L/T 0.5) show water and ethanol sorptivity, respectively, and *R* is the SWR index.

$$\gamma c = \frac{\gamma ND}{4} \tag{5}$$

Data analysis

For statistical analysis, linear regression between water repellency (WDPT) and soil oil contamination (TPHs) was investigated using SAS 0.9 software. To evaluate the effect of water contamination on SWR parameters using MED, water and ethanol sorptivity, and Capilary Rise Method (CRM) methods due to the use of two oil-contaminated and non-contaminated water treatments (in dry/wet cycles of soil samples), two-factorial design with four levels of soil contamination (TPHs equal to zero, less than 3%, between 3% and 6%, and more than 6%) and 2 levels of water contamination were analyzed. Moreover, the means were compared using Tukey's test at a statistical significance level of 5%.

Results

Soil properties

According to Table 2, the area soils have medium to coarse texture and high lime content. Organic matter and TOC were also higher in the contaminated soils compared to the control soil. The total amount of soil poly-hydrocarbons in the control samples was not measurable. Therefore, significant amounts of this parameter in contaminated soils are related to hydrocarbon compounds in petroleum wastes of contaminated soil.

Table 3 shows that the presence of petroleum hydrocarbons (TPHs > 3%) has a significant effect on cosθ in water and ethanol sorptivity method ($P < 0.001$). The results also showed that water contamination had a significant effect on cosθ in the soil ($P < 0.01$).

Figure 1 shows the effect of oil-contamination on SWR persistence; the relationship between WDPT with TPHs/Clay and TOC in contaminated soils. Figure 2 also shows the effect of TOC of the soil on water-soil contact angle calculated by the MED method.

Correlation between water repellency and soil properties

There was a positive correlation between OM, TOC, and TPHs with water repellency index (R), which was statistically significant ($P < 0.0001$) (Table 4). There was a significant negative correlation between calculated organic indices and cosθ ($P < 0.0001$).

Discussion

This study was designed to determine the effect of hydrocarbonic pollutants on the stability and SWR intensity.

According to the results of this study, the petroleum waste in the soil around Bandar Abbas refinery has increased water repellency in the soil by increasing water-soil contact angle. Organic molecules of petroleum sludge form layers on aggregate surfaces, increasing WDPT and water repellency index (44, 45). By increasing the concentration of hydrocarbon compounds in soil, the

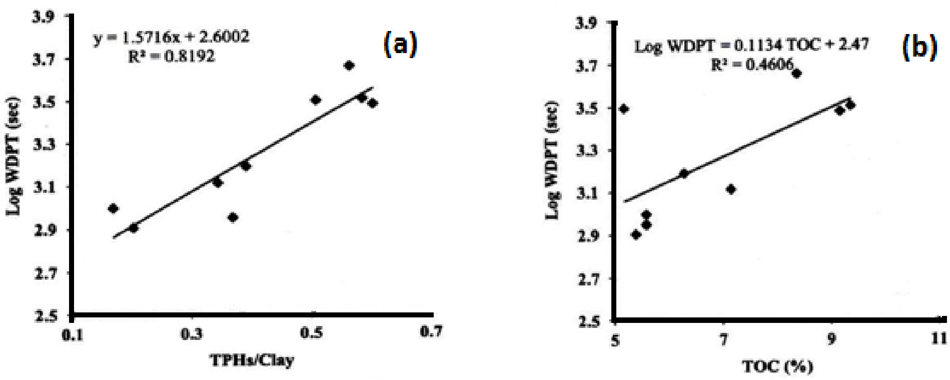

Figure 1. The effect of oil-contamination on SWR persistence; the relationship between WDPT with TPHs/Clay (a) and TOC (b) in contaminated soils.

Table 2. Some physical and chemical properties of soil and water in the areas around Bandar Abbas Refinery

Treatment	Soil Sample no.	Texture	Clay (%)	Silt (%)	Sand (%)	ECC (%)	OM (%)	TOC (%)	TPHs (%)
Non-contaminated soil (control)	1	Sandy loam	15.6	3.5	81.3	49.5	0.90	1.26	-
	2	Loamy	18.6	37.1	44.1	49.0	0.39	0.33	-
	3	Sandy loam	16.0	10.4	73.5	49.6	0.51	1.07	-
	4	Clay loam	34.6	28.7	36.5	47.2	0.52	1.09	-
	5	Clay loam	34.8	28.6	36.5	46.9	0.59	0.37	-
	6	Loamy	20.2	29.8	49.9	48.1	0.59	1.10	-
	7	Sandy loam	28.2	19.1	52.5	48.5	2.55	2.01	-
	8	Loamy	20.9	28.9	50.1	48.7	0.62	1.10	-
	9	Sandy loam	17.6	18.8	63.5	49.5	0.96	1.21	-
Oil-contaminated soil	1	Sandy loam	10.6	20.5	68.9	47.6	5.73	5.60	3.97
	2	Loamy	17.2	18.7	44.0	43.2	13.91	9.40	8.01
	3	Sandy loam	13.6	13.5	72.8	49.0	9.58	6.30	4.76
	4	Sandy loam	9.6	61.5	82.8	46.0	15.68	8.40	5.66
	5	Sandy loam	15.2	24.4	60.3	48.8	4.57	5.40	2.65
	6	Loamy	16.8	37.4	45.7	46.3	5.74	5.60	2.41
	7	Loamy	20.5	36.4	43.0	47.2	9.08	7.16	5.69
	8	Loamy	19.7	43.4	36.8	45.6	14.33	9.20	9.44
	9	Sandy loam	14.9	10.8	74.1	49.2	5.33	5.20	6.91
Contaminated water	1	-	-	-	-	-	-	68	0.3 (mg/L)

Note: ECC: Equivalent calcium carbonate, OM: Organic matter, TOC: Total organic carbon, TPHs: Total poly-hydrocarbons.

Table 3. Comparative evaluation of the mean effect of different levels of soil and water contamination on R and Cos θ in water and ethanol sorptivity tests

Water Repellency Index	Water		Soil			
	Contaminated	Control	TPHs < 3%	3% < TPHs < 6%	TPHs > 6%	Control
R	10.123^{b}	6.167^{a}	7.311^{ab}	11.876^{bc}	17.260^{b}	3.633^{a}
Cosθ	0.17^{b}	0.29^{a}	0.16^{ab}	0.11^{b}	0.07^{b}	0.35^{a}

Note: Different letters represent a significant difference at the level of 5%.

intensity and persistence of water repellency also increase. The petroleum sludge in soils around Bandar Abbas oil refinery bonds with soil particles over several years (10 to 15 years), causing adhesion and hardening of the soil layers. The presence of pebbles in the soils of the area has also contributed to the hardening of the soil layers due to the oil-contaminated mortars.

Over time and due to more successive dry/wet cycles, volatile hydrocarbon fractions have evaporated and high-mass molecules and oil compounds have remained in the soil, causing cementation and adhesion in the soil. This process has enhanced water repellency and stability of hydrocarbon compounds in the soils of the region.

Based on the results of this study, it can be suggested that due to the impact of hydrocarbons on the soil structure and increased coarse porosity, the saturated hydraulic conductivity measured in the laboratory as well as the soil ability to transfer water and solute in saturated conditions have increased, as mentioned in the literature review (46, 47). Therefore, in saturated conditions, water and nutrients are removed from the plants root, as mentioned by Suh et al (46) and Anderson et al (48).

Prior studies have noted the importance of hydrocarbons in the reduction of soil water retention by filling capillary pores (49) and reducing their volume and intensifying water repellency (50). In spite of the increase in coarse pores and volumetric soil moisture content, as well as the increase in Dexter's soil physical quality index, the ability of the soil to retain and provide water for the plant decreased (51). Moreover, high petroleum contamination (TPHs > 6%) significantly reduced the amount of soil

Table 4. The correlation between water repellency indices and soil organic indices

	OM	TOC	TPHs	Cos (Water and Ethanol Sorptivity)	R
OM	1				
TOC	0.92**	1			
TOC	0.85**	0.91**	1		
Cosθ (water and ethanol sorptivity)	-0.74**	-0.84**	-0.73**	1	
R	0.67**	0.75**	0.79**	-0.69**	1

** Significance at the level of 0.01.

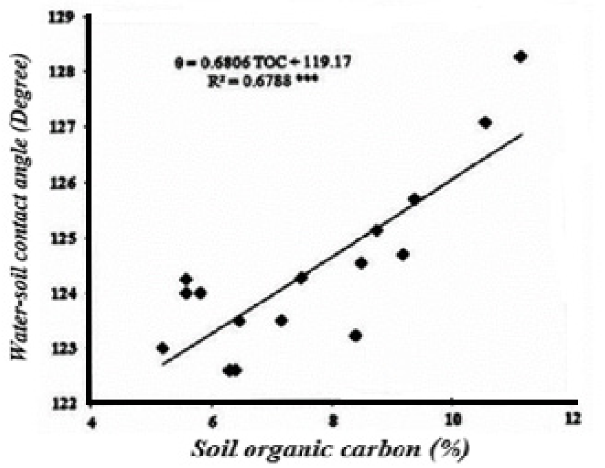

Figure 2. The effect of total organic carbon of the soil on water-soil contact angle calculated by the MED method.

water available to the plant. The results of soil moisture characteristic curve showed that the accumulation of hydrocarbons in the soil had the greatest impact on the soil pores. Changing the pore size distribution and affecting high energy moisture characteristic of the curve have affected soil water retention.

Petroleum contamination affects the size and stability of soil aggregates, increases the weight and geometric mean of stable aggregates in water (52). Furthermore, by reducing the soil mechanical dispersible clay, it increases the stability of soil structure (53). High petroleum contamination (TPHs > 6%), as a critical level of contamination in the area around Bandar Abbas oil refinery, significantly altered the physical, chemical, and hydraulic properties of the soil, and also, reduced the water retention and water available to the plant. Therefore, high petroleum pollution could be one of the reasons for destructing vegetation in the region.

The effect of water and soil oil-contamination on the intensity and persistence of SWR

Figure 1 shows that by increasing the total poly-hydrocarbons of the soil, WDPT (as an indicator of water repellency persistence) increases logarithmically. By dividing TPHs by clay content, the effect of texture on water repellency is expressed by petroleum contaminants independent of soil texture (Figure 1a). Moreover, Figure 1b shows that by increasing the TOC, the SWR increases logarithmically. Non-contaminated soil is due to the presence of petroleum compounds. The results of studies have shown that clay particles reduce the effect of organic compounds on water repellency due to having a very specific surface area (5).

Mirbabaei et al (54) reported a significant positive correlation between log WDPT and organic matter content in the soils of the northern part of Iran. Hallett et al (25) also found that SWR increased linearly by increasing anthracene concentration (a type of polycyclic aromatic hydrocarbon) in the soil. The results of MED analysis showed that the contact angle has increased; however, water contamination had no statistically significant effect on increasing critical surface tension (γND) of the soil.

Figure 2 indicates that by increasing TOC, the water-soil contact angle increases using MED method ($P < 0.001$), indicating the effect of carbonaceous compounds on SWR. Roy and McGill (30) reported that by increasing petroleum concentration in contaminated soils and by increasing soil organic carbon, the water-soil contact angle and MED index increased. The statistical analysis showed that the effect of soil and water oil-contamination on SWR index increased. High concentrations of oil-contamination in soils with medium and high contamination (TPHs > 3%) caused a significant difference in water repellency index in these soils with the control soil. Oil-contaminated water seems to increase water repellency after dry/wet successive cycles in these soils.

Correlation between water repellency and soil properties

There was a significant negative correlation between calculated organic indices and cosθ ($P < 0.0001$).

According to Table 4, the correlation coefficients are between organic matter and SWR indices. This finding indicates the significant effect of carbonaceous compounds on SWR compared to the total soil organic matter. Researchers have reported that only a fraction of organic matter have a greater impact on SWR. For instance, humic acids in alkaline pH and fulvic acids dissolve in almost every acidity in water, and they alter the surface tension of water and reduce the penetration of water droplets into the soil. Therefore, fulvic acids and humic acids play an important role in SWR (5).

Vogelmann et al (55) reported a positive correlation between organic matter content and SWR index. Organic matter and hydrophobic compounds does not affect ethanol sorptivity by soil, and it depends on the size distribution and geometry of the soil pores and shows the actual penetration rate of a fluid; however, water sorptivity in the soil is also a function of the presence of organic compounds in the soil. Therefore, by increasing the amount of hydrophobic organic matter, soil water sorptivity decreases and the water repellency index increases. They also obtained a significant correlation between the organic matter and the calculated water-soil contact angle. Furthermore, the correlation coefficient between TPHs and SWR index is higher than the other two organic factors, indicating the effect of petroleum hydrocarbons, including alkanes, long-chain aliphatic compounds and organic polymers on increasing SWR intensity (56).

Conclusion

Significant positive correlations between organic and water repellency indices and significant negative correlations between cosθ and organic indices indicate the effect of oil-contamination of water and soil on creating and increasing the intensity of SWR.

This research, however, has thrown up many questions in need of further investigation, considering the well water contamination of the region and the application of successive dry/wet cycles on the well water, it was found that the petroleum contamination of well water did not have a significant effect on changing the hydraulic properties of the soil and only increased SWR indices. Therefore, the main cause of changes in hydraulic properties and soil water retention were soil contamination.

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Ethical issues

The authors hereby certify that all data collected during the study are as stated in the manuscript. This manuscript is the original work of the authors, and no data from the study has been or will be published separated elsewhere. This article was extracted from a PhD thesis approved by the Soil Science Department, Faculty of Agriculture, Islamic Azad University, Isfahan branch (Approval thesis code: 17548128799729513991). It has no ethical issues.

Competing interests

The authors declare that they have no conflict of interests.

Authors' contributions

All authors contributed and involved in the problem suggestion, experiments design, data collection, and manuscript approval.

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