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Effect of Oil Refinery Sludge on Plant Growth and Soil Properties

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ABSTRACT

A pot experiment was carried out to determine the effect of Oil Refinery Sludge (ORS) on Vinca rosea (*Catharanthus roseus*) and soil chemical composition. Mean dry matter yield of Vinca rosea ranged between 1.80-3.65 g (Uthmaniyah Oil Refinery, UOR) and 1.47-3.65 g (Ab-Qaique Oil Refinery, AOR) in different sludge treatments. The dry matter yield decreased significantly with increasing application of oil refinery sludge. The decrease in yield was significant in UOR and AOR sludge than the control treatment. Soil salinity (ECe) and sodicity (SAR) showed slight increases with the application of oil refinery sludge. Mineral elements of plants such as N and P decreased significantly with the application of ORS than the control treatment. The Oil Refinery Sludges (ORS) were rich in total plant nutrients and organic matter but low in the available form of plant nutrients. The application of ORS, being rich in organic matter, can improve the productivity of sandy soils provided supplemented with inorganic (NPK) fertilizers. However, further studies are needed to investigate the use of ORS as a potential source of organic matter and to minimize the associated environmental hazards with its land disposal.

Key words: Oil refinery sludge, plant height, dry matter yield, soil salinity, organic matter, nitrogen, phosphorus, land productivity

INTRODUCTION

Kingdom of Saudi Arabia is one of the leading oil producing and exporting countries in the world. The crude oil contains a number of organic compounds which are removed as solid wastes from the oil refinery and defined as sludge. Generally, the crude oil sludge and other waste products are disposed as land fills which are likely to creates some health and environmental hazards. Baek *et al*. (2005) investigated the phytotoxic effects of crude oil and oil components on the growth of red beans (Phaseolus nipponesis OWH1) and corn (*Zea mays*). They found that crude oil-contaminated soil (10,000 mg kg^{-1}) was phytotoxic to corn and red beans. Sayles *et al*. (1999) showed that oil-contaminated soil treated with aerobic biodegradation was less toxic to lettuce and oat root elongation. Hanson *et al*. (1997) reported that *Acinetobacter* sp. A3-treated soil permitted better germination and growth of mung beans, as evidenced by better plant length, weight and leaf chlorophyll content. Achuba (2006) studied the effect of crude oil contaminated soil at various sub-lethal concentrations (0.25, 0.5, 1.0 and 2.0%) on the growth and metabolism of cowpea (*Vigna unguiculata*) seedlings. The results showed that crude oil induced environmental stress in the seedlings was indicated by the increase in free sugar, total protein and amino acids and a decrease in chlorophyll contents of the leaves of 12-day-old seedlings.

Issoufi *et al*. (2006) evaluated seedling growth of six crop species in crude oil contaminated soils in a greenhouse. Based upon percent emergence and plant biomass production in contaminated soil, *Z. mays* and *G. max* seedlings showed the greatest potential to enhance remediation. John and Effiong (2008) in a greenhouse experiment studied the effects of decomposed refuse from two dumpsites (A and B) on the growth of maize in Uyo, Southeastern Nigeria. Mean maize plant height, fresh and dry weights among the different treatments were significantly ($p<0.05$) different among the various levels of the applied refuse. Maize plants grown on soil fertilized with refuse A and B produced better fresh and dry matter yields than those on the experimental soil alone, indicating some improvements in the soil fertility with the application of these decomposed refuse. Ekwuribe *et al.* (2008) in a field experiment determined the effect of oil palm sludge on cowpea nodulation and weed control. They observed that as the level of oil palm sludge increased, the length of root showed remarkable decrease in length irrespective of cultivars or season. Besalatpour *et al.* (2008) tested the germination and subsequent growth of seven plants including tall fescue, agropyron, puccinellia, white clover, canola, safflower and sunflower in a soil with three petroleum contamination levels. The presence of Total Petroleum Hydrocarbons (TPHs) in the soil had no effect on seed germination of agropyron, white clover, sunflower and safflower, although canola and white clover seedlings were sensitive to these contaminants and failed to produce dry matter yield (DMY) at the end of the trial period. There were 52 and 56% decrease in germination of tall fescue and puccinellia seeds, respectively, in C-2 treatment as compared to C-0 (control) treatment. No reduction was found in DMY of puccinellia in contaminated soils (C-1 and C-2), while the presence of TPHs in C2 decreased DMY of sunflower and safflower by about 50 and 73%, respectively.

An extensive survey of literature showed that not much scientific work has been done on oil refinery sludge and other similar waste products on plant growth and soil properties under local environmental conditions. The main objective of this study was to investigate the composition of oil refinery sludge and its effects on plant growth and soil properties under local environmental conditions to minimize the environmental hazards from its open land disposal.

MATERIALS AND METHODS

A pot experiment was carried out in greenhouse at Agricultural Research and Veterinary Experimental Station, King Faisal University, Al-Ahsa during 2008-2009.

Treatments:

Soil	= 1 (Sandy)
Oil refinery sludge	= 2 (Uthmaniyah and Ab-Qaique oil refineries)
Crop	= 1 [Vinca rosea (Catharanthus roseus)]
Application rates	= 4 (0, 10, 20 and 30 Mg ha^{-1})
Replications	= 3
Total No. of pots	= 1×2×1×4×3 = 24
Statistical design	= Completely randomized design

Methodology: The experimental soil (sandy soil) was collected from Research Station, King Faisal University located about 20 km on south-east side of main town Hofuf on Al-Ahsa-Qatar Highway. The soil was non-saline non-sodic with pH of 7.78, electrical conductivity of saturation paste extract (EC_e) of 1.25 dS m^{-1}, sodium adsorption ratio (SAR) of 2.56 and field capacity of 8.5% by weight. The percentage of soil separates were 95, 3 and 2% as sand, silt and clay, respectively.

Table 1: Chemical composition of oil refinery sludge

	UOR		AOR	
Parameters	Total	Available	Total	Available
Organic matter	36.11	-	33.7	-
Nitrogen	420	-	432	-
Phosphorus	250	2.85	267	3.7
Potassium	252	73	266	47
Sodium	760	-	933	-
Calcium	10.93	-	10.3	-
Magnesium	0.25	-	0.28	-
Copper	2.65	0.8	0.9	0.6
Iron	545	7.4	485	7.9
Manganese	13	-	12	-
Zinc	10.3	1.0	6.1	1.2

All parameters are expressed as mg kg^{-1} except organic matter, Ca and Mg which are expressed as percentage. UOR: Uthmaniyah oil refinery; ARQ: Ab-Qaique oil refinery

Experimental soil was air-dried, passed through 2 mm sieve and filled in plastic pots with a diameter of 25 cm and a depth of 30 cm. A total of 6 kg soil was filled in each pot leaving the upper 5 cm for irrigation application.

Collection of oil refinery sludge: The Oil Refinery Sludge (ORS) was collected from two oil refineries (Uthmaniyah Oil Refinery is located about 45 km west side of Hofuf on the main Al-Ahsa-Riyadh Highway and Ab-Qaique Oil Refinery (AOR) is located about 50 km on north side of Hofuf on the main Hofuf-Dahran Highway from Al-Ahsa, Eastern Province, Kingdom of Saudi Arabia). The ORS samples were labeled as Uthmaniyah Oil refinery (UOR) and Ab-Qaique Oil Refinery (AOR). The chemical composition of sludge samples is given in Table 1. The experimental plastic pot size was 25 cm (diameter)×30 cm (height). The ORS sludge was applied at the rate of 0, 10, 20 and 30 Mg (ton) ha^{-1}. The quantity of sludge for each treatment came to 0, 50, 100 and 150 g pot^{-1}. The sludge was applied and mixed thoroughly in the upper 10 cm depth of soil. A soaking irrigation was applied before planting to bring the soil moisture to field capacity.

Cultivation of experiment: Five seeds of Vinca rosea (Catharanthus roseus) were sown in each pot. The experiment was carried out in spring 2009. The seeds were sown on February 15, 2009 and harvested after 20 weeks on July 15, 2009. Seed germination was recorded. The total number of plants per pot was kept to 2-plants at 4-6 leaves stage with a height of 4-5 cm. All the pots were weighed at the time of planting. The pots were successively weighed before each irrigation and the irrigation was applied to maintain initial weight of each pot in different ORS treatments. Groundwater from the experimental station was used for irrigating the pots. The well water has an electrical conductivity (EC) of 1.85 dS m^{-1} and sodium adsorption ratio (SAR) of 2.58. The bulk density of soil was 1.65 g cm^{-3}. The irrigation interval was about 2 days.

Soil samples: Initial soil samples were taken in triplicate from the experimental soil before starting the experiment. Post harvest soil samples were taken from each pot from 0-25 cm depth of soil. The soil samples were analyzed for pH, ECe, Ca, Mg, Na, K, Cl, HCO_3 and sodium adsorption ratio (SAR) to monitor the effect of ORS application on soil properties. The soil analysis was done by following the analytical procedures described in USDA, Handbook No. 60 (USDA, 1954).

Water sample: Irrigation water samples were collected fortnightly and analyzed chemically by following methods described in APHS, AWWA and WEF (1995). Mean values of water quality parameters were: pH = 7.48, EC = 1.85 dS m^{-1} and SAR of 2.58.

Plant growth measurements: Plant growth parameters include plant height and dry matter contents. The whole plants were harvested from each pot at the flowering stage on July 15, 2009, weighed, dried in an oven at 65°C and calculated the dry matter yield per plant.

The data were analyzed statistically by ANOVA according to SAS Institute (2003).

RESULTS AND DISCUSSION

Chemical composition of oil refinery sludge: Mean chemical composition of Oil Refinery Sludge (ORS) was determined (Table 1). The ORS contains high concentration of total plant nutrient elements and organic matter contents (33.17-36.11%), but the available form of P, K, Cu, Fe, Mn and Zn essential elements for plant growth is low. The ORS, containing high percentage of organic matter, can prove to be a potential source to improve the water holding capacity and productivity of sandy soils.

Plant height: Mean plant height decreased significantly with the application of ORS (Table 2). The plant height decreased significantly with an increase in the application rates of ORS than the control treatment [$LSD_{0.05}$ of 2.718 (UOR), 4.236 (AOR)]. The results showed that application of ORS did not improve plant height which could be attributed to low nutritional status of oil refinery sludge (Table 1).

Dry matter yield: Mean dry matter yield decreased significantly with the application of oil refinery sludge in different ORS treatments than the control treatment (Table 3). This significant decrease in dry matter could be due to the presence of very low available form of plant nutrient in the ORS and the adverse effects of hydrocarbon compounds present in ORS. Overall, the results

Table 2: Effect of oil refinery sludge on plant height (cm) of vinca rosea

Treatments	Oil refinery sludge	
ORS (Mg ha^{-1})	UOR	AOR
0 (Control)	32.33a	32.33a
10	28.98b	28.02ab
20	25.92c	26.08b
30	22.56d	25.81

Values in a column followed by the same letter are not significantly different by $LSD_{0.05}$

Table 3: Effect of oil refinery sludge on dry matter (g/plant) yield of vinca rosea

Treatments	Oil refinery sludge	
ORS (Mg ha^{-1})	UOR	AOR
0 (Control)	3.65a	3.65a
10	2.43b	2.16b
20	2.03b	1.80c
30	1.80c	1.47c

Values in a column followed by the same letter are not significantly different by $LSD_{0.05}$

Table 4: Effect of oil refinery sludge on plant composition

Treatments	N	P	K	Ca	Mg	Na
(Mg ha^{-1})	(mg kg^{-1})		(%)			
UOR						
Control (0)	10792	752	1.98	0.98	0.82	2.70
10	5840	682	1.25	0.98	0.62	2.64
20	6524	675	1.38	0.86	0.51	2.38
30	6610	572	1.92	0.89	0.51	2.10
AOR						
Control (0)	10792	752	1.98	0.98	0.82	2.70
10	4976	754	1.62	1.05	0.68	2.99
20	5995	635	1.94	1.08	0.64	2.02
30	8508	610	1.95	1.10	0.55	1.98

Table 5: Effect of oil refinery sludge on soil properties

Treatments	EC	pH	SAR	Cl	HCO_3
(Mg ha^{-1})	(dS m^{-1})		(mg L^{-1})		
UOR					
Control (0)	4.66	7.39	3.72	1482	110
10	4.03	7.25	4.24	1409	86
20	4.68	7.20	4.54	1706	68
30	4.69	7.19	4.40	1706	55
AOR					
Control (0)	4.66	7.39	3.72	1482	110
10	4.15	7.48	3.74	1462	92
20	4.66	7.44	4.09	1736	81
30	5.96	7.35	4.30	1860	62

suggested that the ORS is a useful source of organic matter but not that of available plant nutrients.

Effect of ORS on plant mineral composition: Mean mineral plants composition showed that nitrogen and phosphorus decreased significantly with the addition of ORS than the control treatment (Table 4). However among the different ORS treatments, the N, K, Na and Ca concentration in plants showed an increasing trend, while P and Mg showed a decreasing trend with the corresponding increase in ORS application. The slight decrease in P contents of plants could be due to the fixation of soil-P by the Ca ion from ORS. Because, in the cleaning process of crude oil tankers, CaO is used as a catalyst to expedite the cleaning process. High Ca contents of plants are associated with high Ca contents of ORS which ranged from 10.30-10.93% (Table 1).

Effect on soil chemical properties: Men soil salinity and sodicity increased slightly due to the addition of ORS (Table 5). The soil pH was not affected by ORS application and almost remained constant. The Cl contents of soil increased significantly as compared to the control treatment which may be due to the release of Cl contents from the ORS. The HCO_3 concentration decreased significantly than the control treatment which could be attributed to the chemical reaction of bicarbonate in ORS with the high CO_2 contents released during plant growth in the soil.

Generally, it is expected that addition of organic materials to sandy soils (coarse textured) promotes plant growth and improved the soil productivity by enhancing its fertility status. But in the present study, the ORS application did not improve plant growth parameters such as plant height and dry matter yield. Both these plant growth parameters decreased significantly with the addition of ORS. The study results do not agree with the findings of John and Effiong (2008), who found that maize plants grown on soil fertilized with two types of refuse produced better fresh and dry matter yields than those on the experimental soil alone, indicating some improvements in the soil fertility with the application of these decomposed refuse. Similarly, Hanson *et al.* (1997) reported that Acinetobacter sp. grown in treated soil permitted better germination and growth of mung beans, as evidenced by better plant length, weight and leaf chlorophyll content. This could be due to the fact that the refuse used by these investigators was rich in plant nutrients thus resulting in improved plant growth parameters. However, the oil refinery sludge used in this study contained very low concentration of available plant nutrients.

However, the study findings were comparable with those of Ekwuribe *et al.* (2008), who determined in a field experiment that as the level of oil palm sludge increased, the length of root showed remarkable decrease in length irrespective of cultivars or season. Similarly, Besalatpour *et al.* (2008) tested the germination and subsequent growth of seven plants in a soil with three petroleum contamination levels. They found that canola and white clover seedlings were sensitive to these contaminants and failed to produce dry matter yield (DMY) at the end of the trial period due to plant mortality.

CONCLUSIONS

Application of Oil Refinery Sludge (ORS) decreased significantly both the plant height and fresh biomass. Soil salinity increased slightly with the addition of oil refinery sludge. The oil refinery sludges used in this study were rich in organic matter. Also, the total concentration of different plant nutrients (N, P, K, Cu, Mn, Zn, Fe) was high in the Oil Refinery Sludge (ORS) but the available form of these plant nutrients was very low. However further studies are needed to determine the potential use of refinery sludge in agriculture with special emphasis on changes in physio-chemical properties of soils and plant growth. The ORS is a potential source of organic matter for improving the productivity of sandy soils provided supplemented with inorganic (NPK) fertilizers under arid climatic conditions.

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