Effect of the added Spent Engine Oil levels and Fermented Sheep Manure on some Properties of Gypsiferous Soil

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Abstract

The increasing discharge of used motor oil into the environment, resulting from the growing use of cars and other engines and their subsequent maintenance, is a significant environmental concern. Therefore, this study aimed to evaluate the effect of used motor oil and fermented sheep manure on the properties of gypsiferous soil. A factorial experiment was conducted using a completely randomized block design under laboratory conditions. The first factor involved the addition of four levels of used motor oil: 0%, 2%, 4%, and 6% (O0, O2, O4, and O6). The second factor involved the addition of three levels of fermented sheep manure: 0, 10, and 20 Mg h^{-1} (M0, M1, and M2). The soil was incubated at 50% of the field capacity for four weeks. After the incubation period, the soil was sampled, and some of its physical and chemical properties were determined. The results showed a significant effect of adding both study factors and their interaction on the studied properties. Adding oil caused a decrease in saturated hydraulic conductivity 29.7%, electrical conductivity 35.3%, soil pH 2.3%, and soil content of Nitrogen 21.4%, Phosphorus16.7%, Potassium 4.4%, and available Zinc 14.3%, while increasing soil content of available Iron 23.2% and Lead 25.5%. Regarding the effect of adding fermented sheep manure, the results indicated a significant opposite effect to that of the first factor, increasing saturated hydraulic conductivity 27.6% and soil content of available Nitrogen 48.7%, Phosphorus 101.8%, Potassium 105.5%, Iron 188.1%, with a clear increase recorded in lead movement and availability in the soil. This suggests the potential use of organic materials as a tool to mitigate the negative effects associated with spent engine oil

Keywords: Gypsiferous soils, spent engine oil, fermented sheep manure, NPK availability, Heavy elements Zn, Fe and Pb.

Introduction

Gypsiferous soils, which contain large amounts of calcium sulfate ($CaSO_4 \cdot 2H_2O$), are common in arid and semi-arid regions and are characterized by their unique, often complex, physical and chemical properties. Gypsiferious soils cover an area of 88,000 km² in Iraq, constituting approximately 28.6% of the country's total area. They extend from south of Sinjar and southeast of Tal Afar to southern Iraq, the western desert, and the southern Badia. Gypsy soils suffer from numerous problems, including poor fertility, weak structure, the presence of impermeable layers, salinity, and the formation of sinkholes. Therefore, their management requires specialized scientific methods to facilitate their use in agriculture[8].

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Soil structure plays a crucial role in soil properties, particularly physical and hydraulic properties. It controls water infiltration, movement, and storage, and is pivotal in determining the soil's physical behavior. Since soil structure is one of the most important physical properties, influenced by the soil's various components and the quality of irrigation water (which in turn affects water absorption and movement within the soil), it directly and indirectly impacts soil properties [2]. Therefore, maintaining a good soil structure with high stability through the addition of organic matter and petroleum and industrial derivatives is a priority in the proper management of gypsiferous soils[8].

Spent engine oil is a common pollutant in auto repair shops and mechanics' workshops, a byproduct of servicing automobile engines and generators after their use [22]. These organic chemical pollutants consist of low and high molecular weight hydrocarbons, aromatic aliphatic hydrocarbons, polychlorinated biphenyls, lubricant additives, and chlorodibenzofurans [25].

It also includes potentially toxic and trace elements found in used engine oil such as aluminum (Al), chromium (Cr), tin (Sn), lead (Pb), manganese (Mn), nickel (Ni), and silicon (Si) [32].

[6] indicated in a laboratory experiment to study the decomposition of cow and sheep manure in gypsiferious soil (15% gypsum), the manure was added at a rate of 1.5% to the soil and the treatments were incubated at a temperature of 30 ± 2 °C for 77 days and the amount of carbon dioxide gas released was measured weekly. The treatments were arranged in the following order in terms of the amount of CO_2 gas collected:

Sheep manure < Cow manure < Control, with the 14-day period being superior in terms of effect.

[14] observed a significant decrease in soil pH and electrical conductivity with increasing application of organic fertilizer (0, 5, and 10 Meg ha^{-1}) and gypsum (0, 2, and 4 Meg ha^{-1}) throughout all stages of bean crop growth. The lowest pH and EC values were significantly recorded at harvest in the treatment with 10 tons of organic fertilizer and 4 tons of gypsum per hectare.

Organic wastes such as compost, animal manure, and plant residues improve the physical and chemical properties of soil, in addition to providing food sources for microorganisms. This accelerates the decomposition of hydrocarbon compounds by increasing the activity of degrading enzymes and microbial decomposition capacity. Studies have shown that the use of organic soil amendments can restore seed germination capacity in contaminated soils from low levels to levels approaching those of uncontaminated soils. It also enhances the availability of essential nutrients such as nitrogen, phosphorus, and potassium, which supports plant growth and strengthens the biotic interaction between roots and soil microorganisms[23].

Therefore, this study aims to

Therefore, this study aims to evaluate the effects of different levels of used engine oil and fermented sheep manure on gypsiferous soil properties under an incubation period of four weeks.

Materials and methods

Preparation of Soil, Organic Matter and Spent Engine Oil

Soil samples were obtained from a 0-30cm depth at a site within the University of Anbar, classified within the Lithic Haplogyps great group [28]. These samples were air-dried, ground, and sieved using a 2 mm sieve. Some physical and chemical properties were determined according to the methods described in [13; 18; and 27], as shown in Table (1).

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Spend engine oil was obtained by collecting these oils from various car mechanics workshops in the city of Ramadi, and they were mixed to obtain a composite sample, the characteristics of which are shown in Table (2).

Preparation of sheep manure

After bringing sheep manure from the Al-Jazira area in Ramadi, it was placed in a polyethylene-lined basin with dimensions of 0.5 x 1.5 x 0.5 m and moistened with an appropriate amount of water throughout the fermentation process, with the addition of 1% urea fertilizer (fertilizer/organic matter) to increase the effectiveness of microorganisms [3], with the process of mixing and stirring every seven days. At the end of the fermentation period of 45 days, the organic matter was mixed well to ensure homogeneity, and a sample was obtained for chemical analysis, as shown in Table (3).

Table 1. Some physical and chemical properties of the soil used in the study.

Parameter		The value	Unit of measurement
Soil particle size distribution	Sand	441	gkg^{-1}
	Silt	320	
	Clay	239	
Soil texture		Sandy loam	
Soil bulk density		1.26	$Megm^{-3}$
Soil available water content		16	%
Electrical conductivity of a 1:1 extract (soil: water)		3.46	dSm^{-1}
pH for a 1:1 extract (soil: water)		7.58	
Soil organic matter content		7.4	gkg^{-1}
Soil carbonate equivalent content		85	gkg^{-1}
Soil gypsum content		166	gkg^{-1}
Soil dissolved Cat ions content	Ca^{++}	27.0	$mmoll^{-1}$
	Mg^{++}	15.0	
	Na^{+}	12.3	
	K^{+}	1.2	
Soil dissolved an ions content	$SO_4^{=}$	39.2	
	Cl^{-}	12.8	
	$CO_3^{=}$	Nil	
	HCO_3^{-}	1.5	
ESP		3.79	%
CEC		11.23	Cmol kg^{-1} soil
Soil content of	Available Nitrogen	22.3	$mgkg^{-1}$
	Available Phosphorus	6.3	
	Available Potassium	132	
	Available Iron	3.3	
	Available Lead	20.1	
	Available Zinc	4.2	

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Table 2. Specifications of the SEO used in the study*

Parameter	The value	Unit of measurement
Acid Number	3.16	mg KOH g^{-1}
Base number	5.22	mg KOH g^{-1}
Specific gravity at 15.6 ^{o}C	0.9	Meg m^{-3}
Viscosity at 40°C	61.35	kg $m^{-1}s^{-1}$
Viscosity at 100°C	6.06	kg $m^{-1}s^{-1}$
Toluene insoluble	2.87	%
Flash point	218	$^{\circ}$C
Ca	114.30	mg kg^{-1}
K	10.82	
Mg	32.71	
Na	51.22	
pb	23.18	
Ar	0.75	
Cr	4.06	
Cd	0.94	
Fe	18.43	
Cu	7.29	
Zn	23.23	
Mn	34.02	
Co	13.3	

***The representative sample of spend oil used in the study was analyzed in the laboratories of the Chemical and Petrochemical Research Center/Ministry of Industry and Minerals.**

Table 3. Some chemical properties of fermented sheep manure used in the study.

Unit	**Value**	**The characteristic**
dSm^{-1}	9.45	Electrical conductivity of a 5:1(Organic matter: Water) extract
	6.53	pH
%	2.11	Total Nitrogen
%	0.97	Total Phosphor
%	1.11	Total Potassium
%	27.25	Organic Carbon
	12.9	N/C ratio

Experimental design of the study

A factorial experiment was conducted according to a completely randomized block design under laboratory conditions using 500g plastic containers. The first study

factor included four levels of added used engine oil:

O0 Soil not treated with used motor oil
O2 Soil treated with 2% used motor oil
O4 Soil treated with 4% used motor oil
O6 Soil treated with 6% used motor oil

The second factor in the study included three levels of adding fermented sheep manure, as follows:

M0: No sheep manure added

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M1: Added sheep manure at a level of 10 Megha^{-1}

M2: Added sheep manure at a level of 20 Megha^{-1}

Laboratory Procedures

The saturated water conductivity was determined using the constant head method [20] . The electrical conductivity (EC) and soil reactivity were determined in a 1:1 soil: water solution according to the method described by Richards [27] .

Available Nitrogen was extracted from the soil using potassium chloride (2M) solution. Using magnesium oxide, the nitrate ion was reduced to ammonium using a Devardian alloy. After volatilization, the solution was distilled using a micro-Kjeldal apparatus and titrated with sulfuric acid (H_2SO_4 0.005 N) according to the method described by Nelson and Keeney in [26].

Available phosphorus was extracted using sodium bicarbonate ($NaCO_3$ 0.5M) at pH 8.5 according to the Olsen method described in [26]. The color was developed with ammonium molybdate and ascorbic acid, and then determined using a spectrophotometer at a wavelength of 882 nm, following the procedures described by [31].

Available potassium from the soil was extracted using ammonium acetate (NH_4OAC) at pH 7 and measured using a flame photometer according to the method described in [26]. To determine the soil's heavy metal content (Pb, Fe, Zn), 2 g of soil was weighed, passed through a 100-µm sieve, and placed in a digestion tube. 10 ml of aqua regia ($HCl:HNO_3$ 1:3 (v: v)) and 1 ml of concentrated per chloric acid were added, and the mixture was left at room temperature for one hour. The digestion tubes were then placed in a water bath for three hours to complete digestion. Afterward, the samples were allowed to cool at room temperature, and the volume was brought up to 50 ml with distilled water [12].

e soil's heavy metal concentrations were then determined using an Atomic Absorption Spectrophotometer (AAS).

Results and discussion

It is noted from the results of Table 4 that there is a significant effect of adding spent engine oil on the saturated hydraulic conductivity of the soil, which decreased from 6.54 cmhr^{-1} in the soil not treated with spent engine oil to 4.6 cmhr^{-1} in the soil treated with 6%used engine oil, as a result of a group of physical and chemical changes that occur in the soil structure, as the oil, which is a viscous and hydrophobic substance, coats the soil particles and fills the gaps and micro pores through which water passes and blocks the soil pores (pore clogging).

This blockage directly reduces the hydraulic conductivity of the soil and prevents the movement of water [24].

This result is agreed with the observations of [10], where increasing the level of oil added reduced the saturated hydraulic conductivity, as shown by the following regression equation:

$Y = 6.54 – 0.373X \quad r = -0.657^*$

Where: Y=Saturated hydrolic conductivity of the soil (cmhr^{-1}) X=Percentage of used engine oil added to the soil.

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Table 4. The effect of the level of added spend engine oil and the fermented sheep manure on the saturated hydroulic conductivity of the soil (cmhr^{-1})

Spend engine oil levels (%)	Fermented sheep manure levels (Megha^{-1})			Mean of spend engine oil levels
	Mo	M1	M2	
O0	5.83	6.52	7.28	6.54a
O2	4.44	5.02	5.64	5.03b
O4	4.25	4.85	5.48	4.86c
O6	3.98	4.58	5.25	4.60d
Mean of the fermented sheep manure	4.63c	5.24b	5.91a	
$LSD_{0.05}$ for SEO	0.053			
$LSD_{0.05}$ for M	0.038			
$LSD_{0.05}$ for interaction between SEO*M	0.086			

Regarding the effect of adding fermented sheep manure, the results show a significant positive impact on this characteristic. The soil's saturated hydraulic conductivity increased from 4.63 to 5.24 and 5.91 cmhr^{-1}, representing increases of 13.2% and 27.6% for the two treatments M1 and M2, respectively, which included the addition of fermented sheep manure, compared to the control treatment. This is attributed to the role of organic matter as a binding agent between fine soil particles (clay and silt), leading to the formation of stable aggregates. This process transforms the soil from a compacted to an aggregated state, reducing the dispersion of fine particles that clog interstitial spaces. Furthermore, the increased aggregate size and free cross-sectional area within the soil, resulting from the increased aggregates and decomposition of organic matter, provides easier pathways for water movement [15].

As for the interaction of both factors (adding spent engine oil and fermented sheep manure, the results showed significant differences, as treatment O0M2 recorded highest saturated hydraulic conductivity 7.28 cmhr^{-1} compared to treatment O6M0, which recorded the lowest value of this physical property of 3.98 cmhr^{-1}, indicating the role of both factors and their interaction in the saturated hydraulic conductivity. The differences between the interaction coefficients are statistically significant according to the $LSD_{0.05}$ test.

The results in Table 5 show a significant effect of adding used engine oil on soil electrical conductivity. It decreased by 11.3%, 23.4%, and 37.0% for treatments 2%, 4%, and 6%, respectively, compared to the control treatment. This is attributed to the fact that used oil generally reduces soil electrical conductivity, making it less able to conduct electricity. Oil is a non-polar organic material and an electrical insulator. When mixed with soil, it coats soil particles and fills pores, hindering the movement of ions and dissolved salts that conduct electricity, thus reducing the electrical Conductivity [7].

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Table 5. The effect of the level of added spend engine oil and the fermented sheep manure on soil electrical conductivity (dSm^{-1})

Spend engine oil levels (%)	Fermented sheep manure levels ($Megha^{-1}$)			Mean of spend engine oil levels
	Mo	M1	M2	
O0	3.46	3.23	3.01	3.23a
O2	3.07	2.77	2.56	2.80b
O4	2.65	2.31	2.11	2.36c
O6	2.18	2.08	2.02	2.09d
Mean of the fermented sheep manure	2.84a	2.60b	2.43c	
$LSD_{0.05}$ for SEO	0.083			
$LSD_{0.05}$ for M	0.051			
$LSD_{0.05}$ for interaction between SEO*M	0.102			

As for the effect of adding fermented sheep manure, also was showed similar results in terms of the effect of adding used engine oil, as it decreased by 8.5% and 14.4% for M1 and M2 treatments compared to the control treatment(M0). The reason for this is attributed to the improvement of the physical properties of the soil, and then the improvement of soil structure, increased stability of its aggregates and permeability, and increased soil porosity, which helps in high water movement through the soil and reduces the upward movement of salts, and increases the rate of salt leaching, which leads to reducing the harmful effect of salts [5]. The interaction of both study factors also had a significant effect on reducing the electrical conductivity of the soil. The highest electrical conductivity was recorded with the O0M0 interaction treatment, reaching $3.46dSm^{-1}$, while the lowest value for this chemical property was $2.02dSm^{-1}$. This indicates the possibility of using both study factors in the sustainability of saline soils after determining the appropriate levels of addition.

The results shown in Table 6 demonstrate a significant effect of adding spend engine oil in reducing soil pH. The values of this characteristic decreased by 1.5%, 1.9%, and 2.3% for treatments O2, O4, and O6, respectively, compared to the control treatment(O0). This is attributed to nitrification, a biological oxidation of ammonia compounds resulting from the decomposition of organic matter in used engine oil to form nitrites and nitrates by Nitrosomonas and Nitrobacter bacteria. This leads to an abundance of hydrogen ions in the medium, and consequently, a decrease in soil acidity [34] .Regarding the effect of adding fermented sheep manure on soil pH, the results in (Table,6) indicate a significant effect in reducing the values of this characteristic. The average pH decreased from 7.48 to 7.40 and 7.32 for the two sheep manure addition treatments, M1 and M2, respectively. This is attributed to the role of organic acids resulting from the decomposition of organic matter in sheep manure, such as humic and fulvic acids, in reducing soil pH.

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Table 6. The effect of the level of added spend engine oil and the fermented sheep manure on soil pH

Spend engine oil levels (%)	Fermented sheep manure levels (Megha^{-1})			Mean of spend engine oil levels
	Mo	M1	M2	
O0	7.58	7.52	7.41	7.50a
O2	7.46	7.39	7.32	7.39cb
O4	7.44	7.36	7.29	7.36b
O6	7.42	7.33	7.25	7.33c
Mean of the fermented sheep manure	7.48a	7.40b	7.32c	
$LSD_{0.05}$ for SEO	0.053			
$LSD_{0.05}$ for M	0. 031			
$LSD_{0.05}$ for interaction between SEO*M	0.0841			

This is consistent with what [9] observed when they studied the effect of organic manure on the pH of gypsiferious soil, which is often highly alkaline, exceeding 7.5. With a significant effect of the interaction of both study factors on this chemical property, the lowest soil pH value was recorded in treatment O6M2, reaching 7.25, compared to the control treatment O0M0, which recorded a value of 7.58.

As the concentration of spend engine oil increased, the soil nitrogen content initially decreased(Fig. 1), the control treatment recording the highest available nitrogen content of 22.3 mg kg^{-1}. This was higher than other soil samples treated with varying amounts of spend engine oil. This is attributed to the fact that adding oil to the soil, a very carbon-rich substance (high Carbon/Nitrogen C:N ratio), causes microorganisms (bacteria and fungi) to increase their activity in breaking down these carbon compounds. In order to break down the carbon, these microorganisms consume available nitrogen (nitrates and ammonia) present in the soil, thus "fixing" it within their bodies and making it unavailable for plant uptake [4].

This is agreed with [29], who observed reduced nitrogen levels in soils treated with spend engine oil. Reduced nitrogen levels affect plant growth and ecosystem functions, as nitrogen is an essential element for plant growth and often a limiting factor for soil fertility. The results in Figure 1 show that fermented sheep manure provides a sustainable source of nitrogen. The treatments incorporating sheep manure significantly outperformed the control treatment in terms of soil nitrogen content, reaching 32.5% and 47.7% for treatments M1 and M2, respectively. The study demonstrated that the higher rate of fermented sheep manure addition, the greater the percentage of available nitrogen in the soil. This is attributed to the nitrogen content of the manure, and its addition increases the soil's nitrogen content. This aligns with [11].

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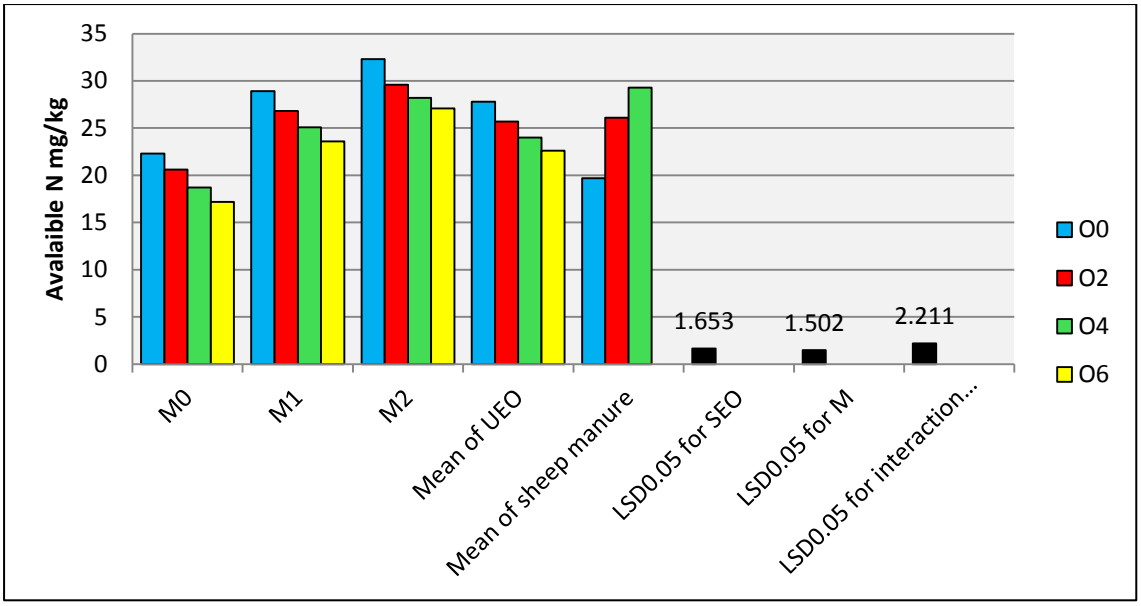


Figure 1. The effect of the level of added spend engine oil and fermented sheep manure on the soil content of available Nitrogen (mg kg⁻ ¹).

The interaction of both study factors also recorded a significant effect on the soil content of available nitrogen. The highest soil nitrogen content was recorded at 32.3 mg kg^{-1} in O0M2treatment, while the lowest

content was recorded in O6M0 treatment at 17.2 mg kg^{-1}, which indicates the importance of studying the interaction between both factors and determining the appropriate level of addition to obtain sustainable agriculture.

Figure 2 shows that adding spend engine oil significantly reduced soil phosphorus content. This indicator decreased by 7.4%, 11.7%, and 19.1% for treatments O2, O4, and O6, respectively, compared to the control treatment. This is attributed to the fact that adding spend engine oil leads to substantial negative effects on soil chemical and physical properties, specifically on phosphorus content, thus reducing soil fertility and negatively impacting plant growth [19].

While the addition of sheep manure had a positive effect on the soil's available phosphorus content, its addition caused a significant increase in the content of this nutrient by 59.2% and 112.9% for treatments M1 and M2 respectively, compared to treatment M0. This is attributed to the high content of organic acids in sheep manure, which reduces the soil's acidity and dissolves some insoluble phosphorus-containing compounds in the soil, thus increasing the availability of phosphorus in the soil [16].

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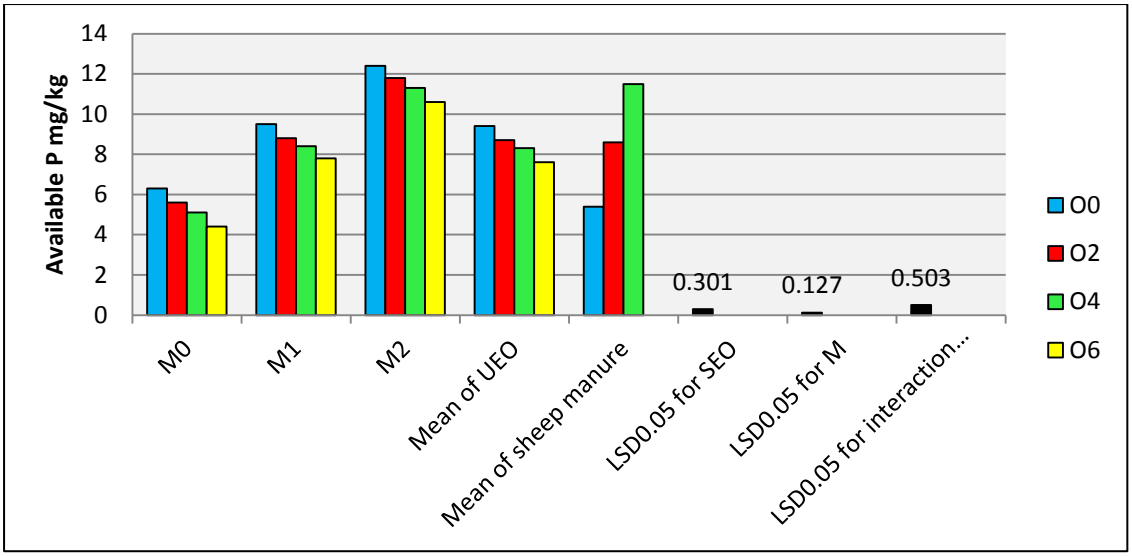


Figure 2. The effect of the level of added spend engine oil and fermented sheep manure on the soil content of available Phosphor (mg kg^{-1}).

This was reflected in the significant interaction between the two factors, as treatment O0M2 recorded the highest phosphorus availability at 12.4 mg kg^{-1}, compared to the lowest recorded content of 4.4 mg kg^{-1} for treatment O6M0. This indicates the positive role of organic matter in mitigating the negative impact of adding spend engine oil and maintaining an appropriate phosphorus level in the oil-treated soil. Therefore, adding organic matter to oil-treated soil is one of the possible treatments for restoring soil nutrient balance.

The results in Figure 3 show a significant decrease in the soil content of available potassium by adding spend engine oil, with a decrease of 8%, 9%, and 14.4% for O2, O4, and O6 levels respectively, compared to the O0 treatment. This is attributed to the oil acting as a barrier layer that adheres to soil particles, preventing potassium from being released and converting it into forms unavailable for plant uptake. [30] also indicated that treating soil with used engine oil altered its physical The results in Figure 3 indicate a significant decrease in soil potassium content with and chemical properties, and they observed significant changes in the proportions of plant nutrients, including available potassium.

While adding sheep manure significantly increased soil potassium content, with increases of 17.0% and 37.4% for treatments M1 and M2, respectively, compared to treatment M0. The organic matter resulting from the decomposition of sheep manure increases soil potassium availability, making it more readily available for plant uptake [16]. This aligns with the findings of [1]. The interaction of these two factors also significantly impacted soil potassium content, with the highest content (183 mg K kg^{-1}) recorded in treatment M2 O0 and the lowest (113 mg K kg^{-1}) in treatment M0 O6.

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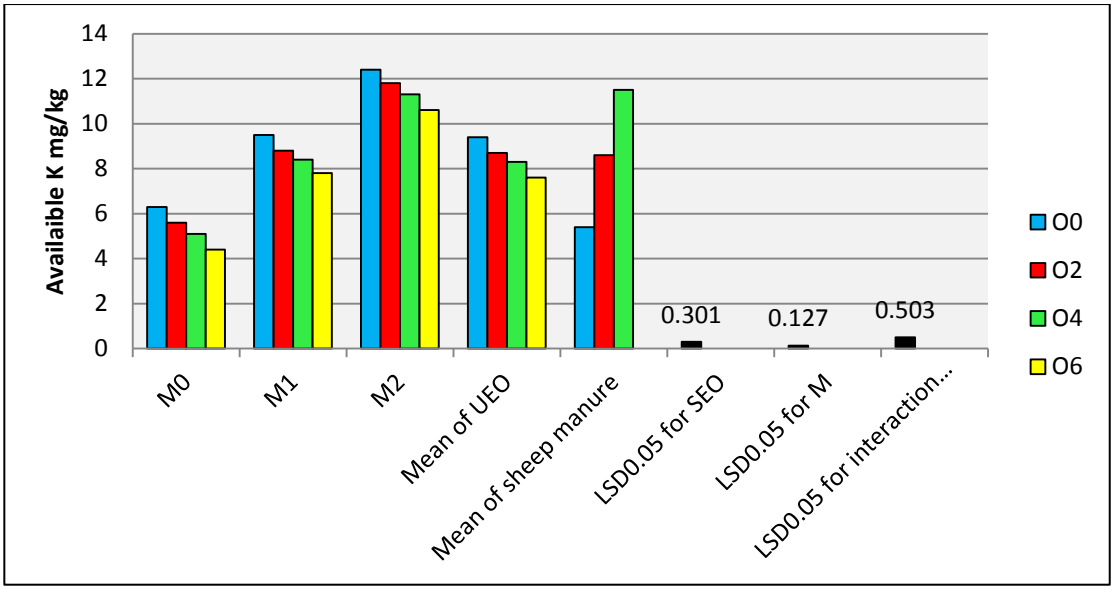


Figure 3. The effect of the level of added used engine oil and fermented sheep manure on the soil content of available Potassium (mg kg^{-1}).

The results in Table 7 show a significant effect of adding spend engine oil in reducing the soil's zinc content. It recorded a decrease of 5.4%, 8.9%, and 14.3% for treatments O2, O4, and O6 respectively, compared to treatment O0. This is attributed to the mixing of the oil with the soil components, which leads to the "stabilization" of the elements. This is agreed with [4].

As for the effect of adding sheep manure, the results show a significant increase in the available form of this element with increasing levels of sheep manure addition. The increase reached 28.9% and 84.2% for treatments M1 and M2 respectively, compared to treatment M0. This is attributed to the fact that the decomposed organic matter from sheep manure forms complex compounds (chelates) with zinc, which prevents its fixation in the soil and makes it more available for plant uptake [33]. The interaction of both study factors was also significant in the soil content of available zinc, as the highest concentration was recorded in treatment O0M2, reaching 7.3 mg kg^{-1}, while the lowest concentration was in treatment O6M0, reaching 3.8 mg kg^{-1}.

The results in Table 8 show that there is a significant effect of adding spend engine oil on the soil's available iron content. Increasing the level of its addition caused an increase in the available concentration of this nutrient in the soil, as it increased by 7.2%, 17.4%, and 23.2% for treatments O2, O4, and O6 compared to treatment O0. This is attributed to the fact that spend engine oil contains a high percentage of minerals that have accumulated as a result of the friction of engine parts, including iron, lead, zinc, and copper [4] .

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Table 7. The effect of the level of added spend engine oil and the fermented sheep manure on available Zn (mgkg^{-1})

Spend engine oil levels (%)	Fermented sheep manure levels (Megha^{-1})			Mean of spend engine oil levels
	Mo	M1	M2	
O0	4.2	5.3	7.3	5.6a
O2	3.9	5.0	7.1	5.3b
O4	3.6	4.7	6.9	5.1c
O6	3.4	4.4	6.7	4.8d
Mean of the fermented sheep manure	3.8a	4.9b	7.0c	
$LSD_{0.05}$ for SEO	0.095			
$LSD_{0.05}$ for M	0.058			
$LSD_{0.05}$ for interaction between SEO*M	0.321			

Table 8. The effect of the level of added spend engine oil and the fermented sheep manure on available Fe (mgkg^{-1})

Spend engine oil levels (%)	Fermented sheep manure levels (Megha^{-1})			Mean of spend engine oil levels
	Mo	M1	M2	
O0	3.3	6.0	11.3	6.9a
O2	3.9	6.6	11.8	7.4b
O4	4.5	7.3	12.4	8.1c
O6	5.1	7.8	12.7	8.5c
Mean of the fermented sheep manure	4.2a	6.9b	12.1c	
$LSD_{0.05}$ for SEO	0.434			
$LSD_{0.05}$ for M	0.348			
$LSD_{0.05}$ for interaction between SEO*M	0.721			

Regarding the effect of adding sheep manure, the results in the Table 8 show a significant increase in soil iron content, reaching 64.3% and 188.1% for the two sheep manure addition treatments, M1 and M2, respectively, compared to treatment M0. [21] indicated that adding organic fertilizer significantly improved iron availability in the soil, increased its absorption and accumulation in the plant, alleviated iron deficiency symptoms, and stimulated photosynthesis and plant growth.

The results of Table 9 show that adding spend engine oil caused an increase in the soil content of available lead by a percentage of 9.8%, 17.6% and 25.5% for treatments O2, O4 and O6 respectively compared to treatment O0. This is attributed to the fact that used engine oil contains high concentrations of heavy metals as a result of friction inside the engine (wear of engine parts) and fuel combustion, and lead is considered one of the most prominent of these metals [7].

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Table 9. The effect of the level of added spend engine oil and the fermented sheep manure on available Pb (mgkg^{-1})

Spend engine oil levels (%)	Fermented sheep manure levels (Megha^{-1})			Mean of spend engine oil levels
	Mo	M1	M2	
O0	20.1	15.4	10.4	15.3a
O2	22.1	16.6	11.6	16.8b
O4	22.8	17.5	13.8	18.0c
O6	26.2	19.8	11.5	19.2c
Mean of the fermented sheep manure	22.8a	17.3b	11.8c	
$LSD_{0.05}$ for SEO	1.104			
$LSD_{0.05}$ for M	1.268			
$LSD_{0.05}$ for interaction between SEO*M	2.151			

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acceptable limits, despite increasing after the addition of varying amounts of spend engine oil.

Recommendations

• It is essential to utilize these industrial byproducts by studying their potential to improve the properties of gypsiferious soils. Studies involving higher application rates should be conducted to determine the optimal level without adverse effects on soil, plant, and environmental properties.

• The effect of gypsum content in the soil should be investigated in subsequent studies to determine optimal application levels under different soil gypsum conditions.

• Future studies should examine the effect of different soil conditions on plant growth in gypsum soils.

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The effect of adding sheep manure was inverse and significant, showing a significant decrease in soil lead content with increasing application levels. The reduction was 24.1% and 48.3% for treatments M1 and M2, respectively, compared to treatment M0. In general, adding sheep manure reduces the available lead content in the soil, making it an effective amendment for stabilizing this heavy metal. Sheep manure provides functional groups (such as carboxyl and hydroxyl groups) that bind to lead ions through chelation and adsorption. This creates alkaline conditions that promote the precipitation of lead in insoluble forms, such as lead carbonate or lead phosphate[17].

The interaction between the two study factors in available formula for lead was also significant, as the highest concentration was recorded in the O6M0 treatment, reaching 26.2 mg kg^{-1}, while the lowest concentration was in the interaction treatment O0M2, reaching 10.4 mg kg^{-1}, which indicates the possibility of using the method of adding organic matter to improve the level of heavy elements in soils contaminated with used engine oil.

Conclusions

A significant decrease was observed in saturated water conductivity, electrical conductivity, and soil reactivity, as well as in the available soil content of nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn). Conversely, the available soil content of iron and lead increased in soils treated with spend engine oil, influenced by the concentration of added oil. The addition of sheep manure significantly improved the soil content of the studied parameters, suggesting the potential use of organic matter addition to mitigate the negative effects of used motor oil pollution. Heavy metal concentrations (iron, lead, and zinc) remained within

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