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Evaluating the Potential Use Clay's Capacity in the Injana Formation as a Geological Barrier for Protecting Against Oil Pollution

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Abstract

Oil spills are among the most dangerous pollutants for soil and water. These pollutants have the potential to penetrate into the groundwater aquifer and contaminate soil, harming agriculture. It is crucial to reduce these dangers, particularly in arid and semi-arid regions where groundwater is the primary source of life. The purpose of this study was to assess the effectiveness of attapulgite clay as a geological barrier to prevent oil pollutants from penetrating the soil and entering aquifers. Attapulgite deposits from Injana Formation were utilized to do this, in which several laboratory experiments were performed to create soil mixtures from the study site and identify the ideal mixture that offers the optimum environmental qualities as barrier for containment. Because it is situated above the Dibdibba Formation, i. e a significant groundwater aquifer, the Najaf Refinery area, north of Al-Najaf Al-Ashraf City, was chosen as the study site. Three primary experimental methods were used in this study: raw attapulgite with refinery soil, attapulgite after calcium carbonate removal, and a combination of attapulgite and crushed rice husks with refinery soil. Utilizing rice husks, which are abundant in the Najaf Governorate, is a sustainable way to recycle agricultural waste, reducing its environmental impact and encouraging their use in geotechnical applications. The mixture that performed best, as a geological barrier, was 60% attapulgite, 30% sand, and 10% rice husks, with superior isolation properties and reduced oil contaminant migration. These results indicate that this mixture could serve as an effective and sustainable hydrocarbon solution for protecting groundwater from oil pollution in Al-Najaf Refinery soil, with potential applications in oil refineries and other locations that are affected by oil spills.

Keywords: Injana clay; Geological barrier; Hydrocarbon containment; Rice husk; Groundwater protection; Al-Najaf; Iraq

1. Introduction

Crude oil is a complex mixture of hydrocarbons which been used to produce many petroleum products that can cause environmental pollution when spilled, especially for soil and water (Ali et al., 2019). Petroleum is extracted from beneath the ground and the seabed, which is composed of hydrocarbons, sulfur, nitrogen and oxygenated organic compounds (Valujeva et al., 2018). Maintenance of crude oil pipelines or tanks and oil exploration generates hydrocarbon petroleum waste (Yuniati, 2018). Soil physical features, such as soil texture and structure, aeration, saturated water absorption, and infiltration sensitivity, can be influenced by hydrocarbon contaminants (Banerjee et al., 2016). An

anti-seepage liner for heavy and light crude oils was tested using clay from Injana Formation in Iraq. By absorbing and stopping the migration of contaminants, the properties of fibrous clays, especially attapulgite and bentonite, can aid in reducing their transit (Al-Bidry and Hamied, 2022).

Palygorskite is a rare clay composed of very fine, needle-like fibers, which provides it with an enormous surface area and remarkable absorption capacity. Palygorskite and attapulgite are two names for the same mineral with the chemical formula ($MgAl_2Si_4O_{10}(OH)_4(H_2O)$) (Grim, 1962). Attapulgite is a 2:1 layered phyllosilicate containing periodic inversions of the tetrahedral sheet after every two silicate chains to form bands. Thus, the octagonal sheet is discontinuous, and a channel-like structure is formed (Giustetto and Chiari, 2004; Genieva et al., 2008) as a result of octagonal cationic substitutions involving magnesium, aluminum and iron (Suárez et al., 2007). The mineral contains two types of water, one bound to octahedral ions and the other loosely bound in zeolite water channels (Al-Ani and Sarapää, 2008). Attapulgite plays important roles in many industries, ranging from agriculture and winemaking to medicinal and cosmetic uses even as an additive for drilling mud (Grim, 1962). The adsorption capacity of palygorskite (as a percentage) increases upon thermal activation, reaching 93% at 600°C as the zeolite water is driven out by heating, thereby increasing the surface area and consequently, the adsorption capacity. However, at 800°C, the adsorption capacity drops to a minimum due to the breakdown of the palygorskite structure (Towfik, 2013).

This study aims to use geological materials to reduce hydrocarbon pollution by conducting a comprehensive evaluation of the effectiveness of attapulgite clay as a geological barrier to limit oil leakage into the surrounding soil and groundwater at oil production sites, Al-Najaf refinery. The use of sustainable materials, such as rice husks (R.H.), can help to prevent oil leakage into the soil and their contribution for environmental conservation, as R.H. which are both represented as a waste product and a source of pollution. It also aims to re-evaluate its resistance for leakage using purified attapulgite to achieve maximum protection against crude oil spills.

2. The Location and Geology of the Study Area

With outcrops visible from north to south, Injana Formation is one of Iraq's most extensively exposed geological formations (Jassim and Goff, 2006). It has garnered significant attention from numerous researchers due to its substantial economic value as a primary source of raw materials (Awadh and Awwad, 2021). The chronological age of the formation is attributed to the Late Miocene, as determined by its stratigraphic position (Bellen et al., 1959). In Al-Najaf Region, Injana Formation is stratigraphically situated between the underlying Dibdibba and the overlying Fatha Formations (Al-Enezy et al., 2023) (Figs. 1 and 2).

Lithologically, the formation is characterized by cyclic successions of medium-to coarse-grained red- to gray sandstone, interleaved with red- to gray siltstone and claystone of similar color. Additionally, thin layers of limestone are also present within the lower portion of the sequence. The depositional environment of Injana Formation is predominantly interpreted as fluviatile (river-dominated) (Bellen et al., 1959). Injana sediments in Tar Al-Najaf are subjected to long transportation because the source rocks are far apart and at a long distance from each other. The features of grains, the petrographic and mineralogical constituents support these conditions (Al-Jaefer, 2014).

The research area is in the central-western region of Iraq, inside the administrative borders of Al-Najaf Governorate, in the Najaf Depression (Bahr Al-Najaf). A geomorphological depression that has received continental deposits during relatively recent geological periods characterises this location, which represents as an important sedimentary habitat. This area was chosen due to its aptitude for the buildup of sediments rich in clay.

Table 1 lists the exact coordinates and geographic locations of the nine sampling stations in the study area.

3. Materials and Methods

The base material used in this study, attapulgite clay, was obtained from Injana Formation (Upper Miocene), which outcrops in the Bahr Al-Najaf area. Nine typical clay samples namely (S1 to S9) were methodically gathered from various Injana Formation exposure sites. A handheld GPS receiver was used to determine each sampling station's exact geographic coordinates and altitudes, which were compiled in Table 1 above.

Fieldwork involved collecting pure, unaltered attapulgite samples that were representative of the geological characteristics of the area. The attapulgite mineral samples were dried while preserving their properties, including mineral composition and fibrous structure, without any influence. Drying was achieved naturally through direct exposure to air and sunlight, without resorting to a furnace or to high temperatures. This method avoids the breaking down of the internal porous structure and micro-morphological characterization which was carried out using Scanning Electron Microscopy (SEM) and an inspect S50 system to observe fiber connections.

To obtain a uniform particle size of 75 µm, the mineral was manually pulverized using a mortar and pestle after natural drying. An electric grinder was not be used to preserve the structure and chemical composition of the sample. A No. 200 (75 µm) sieve was then used to sift the ground clay in order to obtain a uniform size (75 µm), ensuring a large specific surface area for the adsorption process and well compacted when packed and compressed during the experiment to achieve very low permeability.

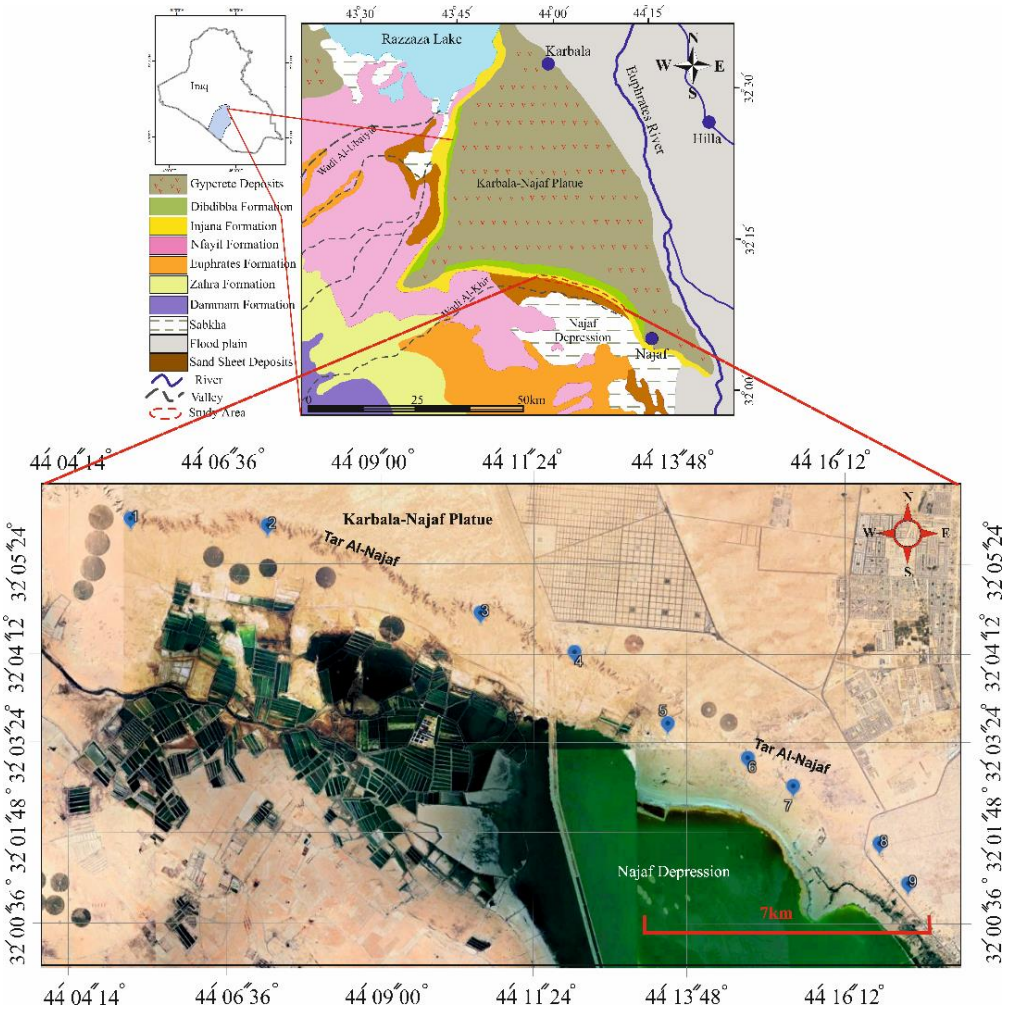

Fig. 1. The tectonic map of Najaf Governorate, showing the location of the study area for the clay (modified after Sissakian and Fouad, 2015)

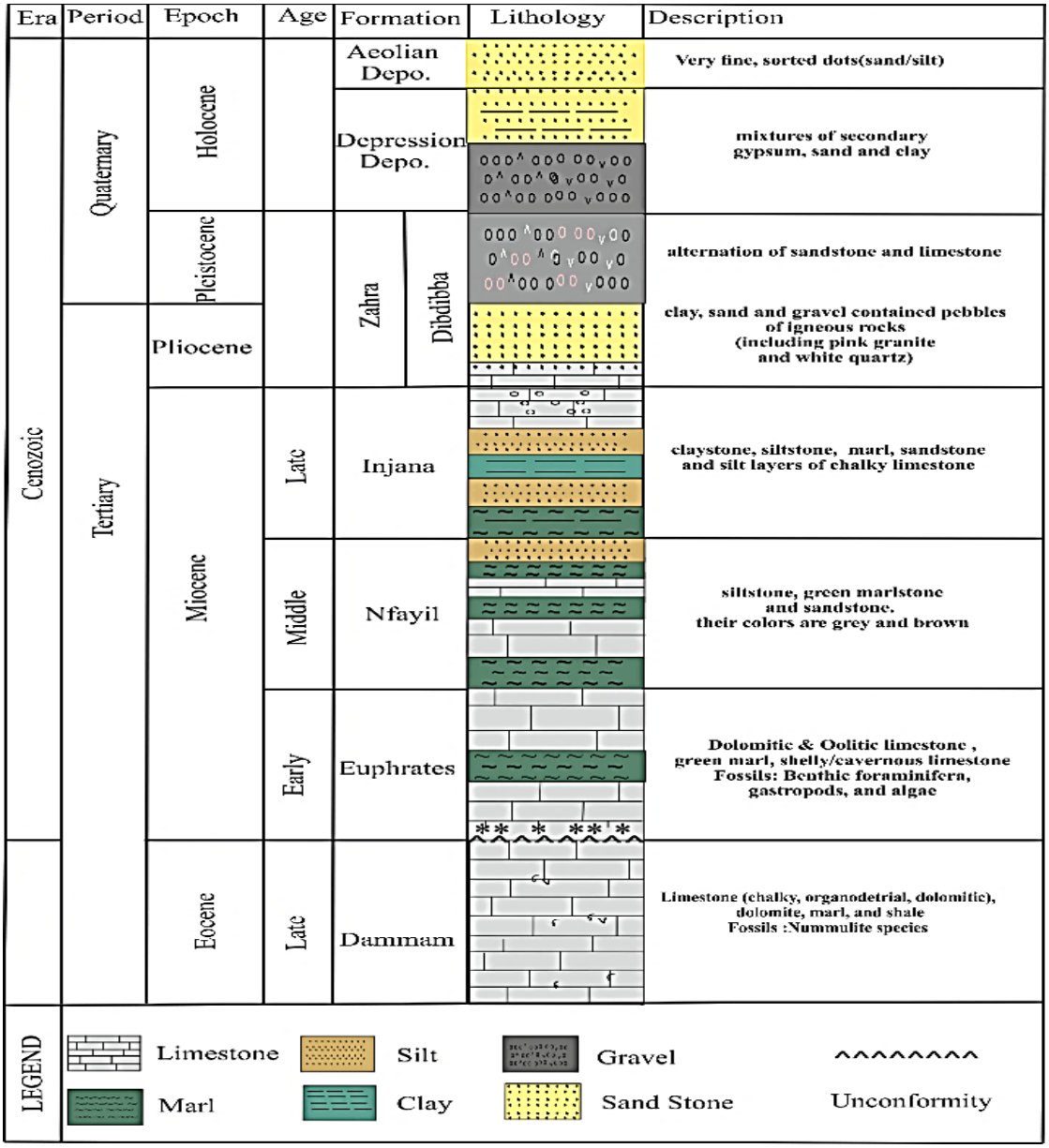

Fig. 2. The lithostratigraphic succession formations column at Tar Al-Najaf section (after Awadh et al., 2024)

Table 1. The exact geographic locations of the nine Injana Formation clay sample stations

Location	N	E
1	32°05'47.73"N	44°05'00.11"E
2	32°05'42.54"N	44°07'08.91"E
3	32°04'33.01"N	44°10'28.89"E
4	32°04'01.72"N	44°11'57.18"E
5	32°03'05.21"N	44°13'24.85"E
6	32°02'37.59"N	44°14'39.94"E
7	32°02'15.29"N	44°15'22.67"E
8	32°01'29.70"N	44°16'43.47"E
9	32°00'57.74"N	44°17'10.55"E

Natural sandy soil simulated field conditions and ensured highly accurate results that closely resembled field conditions; soil samples were collected from the original soil site of Al-Najaf Refinery.

This procedure was done to compare the original soil with the proposed composite barriers and measure its permeability, as it is the soil most exposed for contamination and represents the actual subsurface environment of the study area. The samples were taken from depths corresponding to the engineering foundation levels of the refinery facilities to ensure their realistic results.

After the sandy soil which taken from Al-Najaf refinery site was naturally dried by direct exposure to air and sunlight, it was sieved to obtain particles between 2.0 mm (sieve No. 10) and 0.85 mm (sieve No. 20), purified to remove impurities, for use in crude oil testing.

The physical properties of crude oil, listed in Table 2 were used to ensure more accurate results. The crude oil that used as the leakage fluid was obtained directly from Al-Najaf refinery, as using the actual site contaminant is crucial for calculating the quantity. Leakage from the proposed barriers for the same pollutants.

Table 2. Physical properties of crude oils (result fron Najaf Refinery Labritory)

Test	Crude Oil
API Gravity 60°F	28.4
Specific Gravity 60/60°F	0.8849
Density 15 C g/cm^3	0.8845
Header Salt Content mg/l	51
Input Salt Content mg/l	103
Output Salt Content mg/l	99
Water and Sediment Vol. %	0.2

The equipment needed for the tests was not readily available on the market, so it was modified manually to conduct the various laboratory experiments and to ensure accurate results. Transparent 250 mm cylinders were purchased and then perforated at the bottom to facilitate the vertical flow of oil outwards in order to measure the size of the leak. To keep the barrier layers tight and ensure precise filtration, a fine metal mesh was installed at the base of each cylinder, allowing only leaking crude oil to pass through. Transparent beakers were purchased and placed beneath the cylinders to collect the leaking crude oil. A specially designed and manufactured hardwood stand was built to guarantee this procedure to be executed precisely, offer a consistent testing environment, and preserve structural integrity. This procedure is aplied according to (AL-Bidry and Hamied, 2022). Throughout the experiment, this stand kept the cylinders in a stable vertical posture, preventing any mechanical disruptions that would have affected the natural leakage rate. To ensure accurate data collection, glass beakers were placed beneath each cylinder to collect any leaked crude oil. Furthermore, a highly accurate cylinder was used for volumetric measurements to ensure the highest possible accuracy in recording leakage flow over time.

Specimen preparation and manual compaction: before beginning the experiment, the samples must be prepared meticulously to ensure highly accurate and realistic results. To achieve different results, five geological barriers were tested to measure the crude oil seepage rates. The original refinery soil, attapulgite mineral, and R.H.were used in varying proportions in a 5 cm layer, topped with a 5 cm layer of crude oil. The barriers were arranged as follows:

- Specimen A: (70% clay + 30% Sand) (5 cm) + Crude Oil (5 cm)
- Specimen B: (30% clay + 70% Sand) (5 cm) +Crude Oil (5 cm)
- Specimen C: (20% clay + 70% Sand + 10% R.H) (5cm) + Crude Oil (5cm)
- Specimen D: (60% clay + 30% Sand + 10% R.H) (5cm) + Crude Oil (5cm).

Where these proportions were weighed by an electronic balance to accurately synthesize and mix the geological barrier layers, where the weight of the samples used was : crude oil (5 cm = 50 g, 58 ml),

sand 70% =87.5 g, Sand 30%=39.3g, attapulgite 20% = 16.7g, 30% = 23.1g, 60% = 54.2g, 70% = 66.7g, R.H.10%=4.2 g)

After weighing, the materials were manually mixed to achieve homogeneity being placed in test cylinders. The cylinders used were 250 ml, 4 cm in diameter, and 30 cm in height. To achieve homogeneity among the samples and completely eliminate air voids, the layer was added gradually and manually compacted with a special percussion tool to reduce voids and increase layer density.

Rice husks are a byproduct of rice milling that are commonly available locally due to the rice industry. Although R.H. are traditionally considered waste products, recent research has shown their potential for use in wastewater treatment (Bhatnagar et al., 2015). It highlights how well R.H. work as adsorbents to remove pigments, organic compounds, and heavy metals from wastewater. There is a lot of potential for both economic and environmental benefits when R.H. waste is used in water treatment. It can assist address the nation's persistent problems with water pollution and offers an affordable, sustainable substitute for conventional wastewater treatment techniques. Additionally, research has shown that swapping out some of the soil with rice husk ash on-site is an effective and beneficial method for improving its engineering (geotechnical) properties (Sujatha et al., 2021). In order to enhance the physical characteristics of a sandy soil composite containing attapulgite, natural R.H. was employed as a sustainable additive. To guarantee the material's appropriateness and purity, a number of manual processes were required in the preparation process. To ensure sample homogeneity, the raw husks were first cleaned of contaminants, crushed, then sieved to produce a consistent particle size. Subsequently, each particle was accurately weighed using a sensitive digital scale to achieve a required concentration of 10 by weight for samples C and D. This addition is intended to improve adsorption capacity and modify the barrier permeability for crude oil percolation.

Bulk XRD procedure: The procedure for preparing the bulk samples for X-ray diffraction analysis of soil samples is summarized in the following steps, according to (Folk, 1974) and (Carver, 1971):

- A 10 g of the sample was taken and dried in a dryer oven at 60 ℃ to remove moisture.
- The sample was disassembled using a wooden rod and moving on the sample to ensure that the sample was disassembled.
- The powder sample was inserted into the powder sample holder of the XRD Instrument.

4. Results and Discussion

The effectiveness of clay as a barrier material was tested against the site's natural soil (refinery soil), and the findings showed a progressive improvement that based on physical and chemical treatments: Sandy soil from Al-Najaf refinery was used to test the first barrier without any additions, i. e there was 5 cm of crude oil on top of the 5 cm thick layer. After 20 min, crude oil began to leak from the sand layer and within 4 h, the oil layer was obscured, with a final leakage volume of 27 ml as listed in Table 3. This indicates a high leakage rate, underscoring the significant environmental risks that posed by oil spills in the sandy terrain surrounding the refinery. This leakage is due to the highly permeable nature of the sandy soil, as shown in Fig. 3, or loose silt lacking clay minerals and possessing a fibrous structure, which makes the pores wide and unable to trap hydrocarbon molecules.

Effect of clay minerals: Table 4 shows a significant decrease in the leakage rate, which was observed upon the addition of clay from the Injana Formation. In samples a and b, as shown in Fig. 4, the presence of clay at concentrations of 70% and 30% significantly reduced their intergranular porosity and enhanced the physical and chemical retention of crude oil comparing with refinery soil as shown in Fig. 5.

Table 3. Seepage characteristics of the original sandy soil (control specimen) from Najaf Refinery with 5 cm layer thickness and 5 cm oil head

Time(hr)	Sand 100%(5cm) +Crude Oil(5cm)			Clay (5cm) +crude oil (5cm)		
	Saturated liner(cm)	Saturated rate (%)	Oil Leakage (ml)	Saturated liner(cm)	Saturated rate (%)	Oil Leakage (ml)
0	0	0	0	0	0	0
0.05	3.5	70	0	0	0	0
0.1	5	100	0	0	0	0
0.15	C.S*	100	0	0	0	0
0.2	C.S	100	0	0	0	0
0.25	C.S	100	I.S**	0	0	0
0.3	C.S	100	7	0	0	0
0.4	C.S	100	11	0	0	0
1	C.S	100	13	2	40	0
1.3	C.S	100	17	2	40	0
1.45	C.S	100	26	2	40	0
2	C.S	100	26	2.7	54	0
2.15	C.S	100	27	2.7	54	0
3	C.S	100	27	3	60	0
4	C.S	100	27	3	60	0
5	C.S	100	27	4	80	0
7	C.S	100	27	4.5	90	0
9	C.S	100	27	5	100	0
17	C.S	100	27	C.S*	100	0
24	C.S	100	27	C.S	100	0
32	C.S	100	27	C.S	100	0
38	C.S	100	27	C.S	100	0
46	C.S	100	27	C.S	100	0
51	C.S	100	27	C.S	100	0
57	C.S	100	27	C.S	100	0
64	C.S	100	27	C.S	100	I.S
72	C.S	100	27	C.S	100	0.5
81	C.S	100	27	C.S	100	0.5
93	C.S	100	27	C.S	100	0.5
105	C.S	100	27	C.S	100	0.5
129	C.S	100	27	C.S	100	1.5
176	C.S	100	27	C.S	100	1.5
214	C.S	100	27	C.S	100	1.5
225	C.S	100	27	C.S	100	1.5
273	C.S	100	27	C.S	100	1.5
331	C.S	100	27	C.S	100	1.5
344	C.S	100	27	C.S	100	1.5
392	C.S	100	27	C.S	100	1.5
477	C.S	100	27	C.S	100	1.5
523	C.S	100	27	C.S	100	1.5
594	C.S	100	27	C.S	100	1.5
786	C.S	100	27	C.S	100	1.5

*C.S. Completely saturated

**I.S. Initial seepage

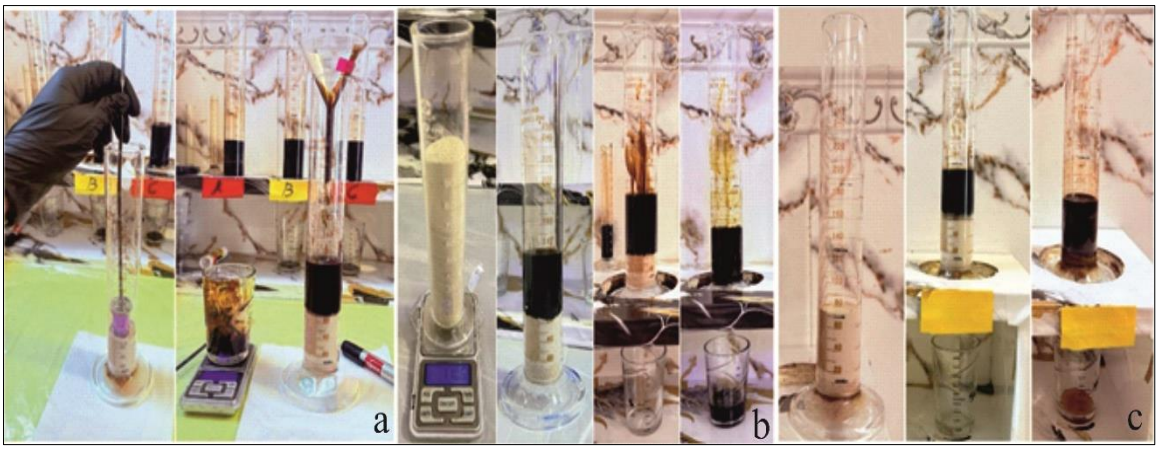

Fig. 3. Stages of conducting the experiment on a sample of sand and pure attapulgite: a) Sample preparation before initiation of the test, b) Sand barriers, c) clay barriers

Table 4. Performance of clay -sand barrier in oil seepage mitigation

Time (hr)	Specimen A: 70% Clay + 30% Sand			Specimen B: 30% Clay + 70% Sand		
	Saturated liner (cm)	Saturated rate (%)	Oil Leakage (ml)	Saturated liner (cm)	Saturated rate (%)	Oil Leakage (ml)
0	0	0	0	0	0	0
0:30	1.5	30	0	1.9	38	0
1	2.5	50	0	2.4	48	0
2	3.5	70	0	3.6	72	0
3	4.2	84	0	4.2	84	0
4	4.5	90	0	4.4	88	0
5	4.7	94	0	4.6	92	0
6	4.7	94	0	4.8	96	0
8	4.8	96	0	4.8	96	0
13	4.8	96	0	4.9	98	0
16	4.9	98	0	4.9	98	0
20	4.9	98	0	4.9	98	0
24	5	100	0	5	100	0
28	C.S*	100	0	C.S*	100	0
32	C.S	100	0	C.S	100	0
40	C.S	100	0	C.S	100	0
47	C.S	100	0	C.S	100	I.S**
52	C.S	100	0	C.S	100	1
57	C.S	100	0	C.S	100	1.5
64	C.S	100	I.S**	C.S	100	2
72	C.S	100	1	C.S	100	3
77	C.S	100	2	C.S	100	4
81	C.S	100	2	C.S	100	4
89	C.S	100	3	C.S	100	4.5
96	C.S	100	3.5	C.S	100	5.5
113	C.S	100	5	C.S	100	6.5
147	C.S	100	7.5	C.S	100	9
178	C.S	100	10	C.S	100	10.5
205	C.S	100	12	C.S	100	12
274	C.S	100	15.5	C.S	100	15
350	C.S	100	16.5	C.S	100	17
412	C.S	100	16.5	C.S	100	18.5

The role of R.H was investigated, and the results are tabulated in Table 5, indicated that samples C and D, containing 10% ground rice straw, achieved the highest barrier stability. As seen by the reduced ultimate leakage rate, the (R. H) microfibres served as filler during manual compaction, effectively sealing air spaces and boosting layer cohesiveness when compared to barriers without (R.H), it leaked

less. The relationship between weight and percentage showed that sample (d) as shown in (Fig. 5), contained the highest percentage of clay (60%) combined with (R.H) (10%), exhibited the best performance in reducing oil permeability. This indicates a direct relationship between the increased attapulgite content and the barrier retention capacity.



Fig. 4. (A, B, C, D) Prairies: a) Beginning of the test b) The barriers have reached the stage of crude oil saturation. c) Crude oil leaked through all barriers

Table 5. Performance of clay -sand barrier in oil seepage mitigation

Time (hr)	Specimen C: 20% Clay + 70% Sand + 10% R.H.			Specimen D: 60% Clay + 30% Sand+ 10% R.H.		
	Saturated liner(cm)	Saturated rate (%)	Oil Leakage (ml)	Saturated liner(cm)	Saturated rate (%)	Oil Leakage (ml)
0	0	0	0	0	0	0
0:30	1.9	38	0	1.8	36	0
1	2.3	46	0	2.2	44	0
2	3	60	0	3.2	64	0
3	3.7	74	0	3.8	76	0
4	4.3	86	0	4.3	86	0
5	4.5	90	0	4.6	92	0
6	4.6	92	0	4.7	94	0
8	4.8	96	0	4.8	96	0
13	4.8	96	0	4.9	98	0
16	4.9	98	0	4.9	98	0
20	4.9	98	0	4.9	98	0
24	5	100	0	5	100	0
28	C.S*	100	0	C.S*	100	0
32	C.S	100	0	C.S	100	0
40	C.S	100	0	C.S	100	0
47	C.S	100	0	C.S	100	0
52	C.S	100	0	C.S	100	0
57	C.S	100	0	C.S	100	0
64	C.S	100	0	C.S	100	0
72	C.S	100	0	C.S	100	0
77	C.S	100	0	C.S	100	I.S**
81	C.S	100	0	C.S	100	0.5
89	C.S	100	I.S**	C.S	100	1
96	C.S	100	1	C.S	100	2
113	C.S	100	2	C.S	100	3
147	C.S	100	4	C.S	100	4.5
178	C.S	100	5.5	C.S	100	6.5
205	C.S	100	6.5	C.S	100	8
274	C.S	100	8	C.S	100	9.5
350	C.S	100	10	C.S	100	9.5
412	C.S	100	10.5	C.S	100	9.5

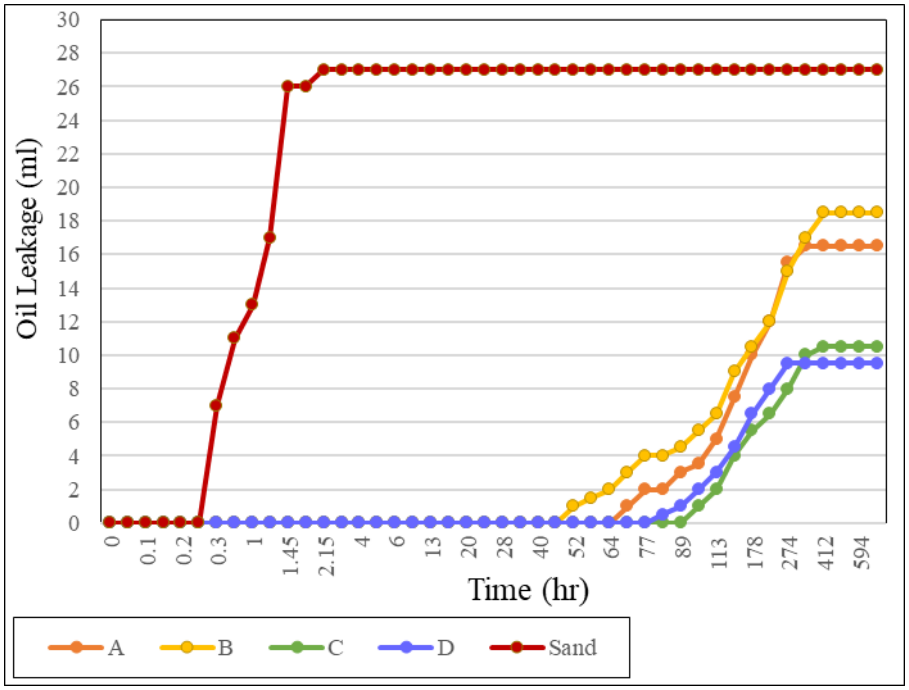

Fig. 5. The relationship between oil leakage (ml) and time (hr.) for sand and A, B, C, and D Prairie

The powdered attapulgite samples from Tar Al-Najaf region have a fibrous clay fraction and a sizable nonclay mineral component of silicate and carbonate, according to the XRD of bulk samples (Fig. 6). The major carbonate phase is quantitatively represented by calcite ($CaCO_3$), which makes up 49.6% of the bulk mineralogy. At 2θ angle values of 29.4º and 36º, its diagnostic reflection peaks are clearly defined. Quartz (SiO_2), the main nonclay mineral, made up 42.9% of the composition and may be identified by its peaks at (2θ) angle of 26.6º and 20.8º. Attapulgite, which has the formula $Mg_5(Si_4O_{10})_2(OH)_2(H_2O)_4$, 7.4% and 12.7% must be present. At a 2θ angle of 8.5º, it had a characteristic primary basal reflection peak. The high concentrations of nonclay minerals (calcite and quartz) that are closely related to palygorskite give strong geochemical evidence of a highly alkaline, evaporative lacustrine depositional environment.

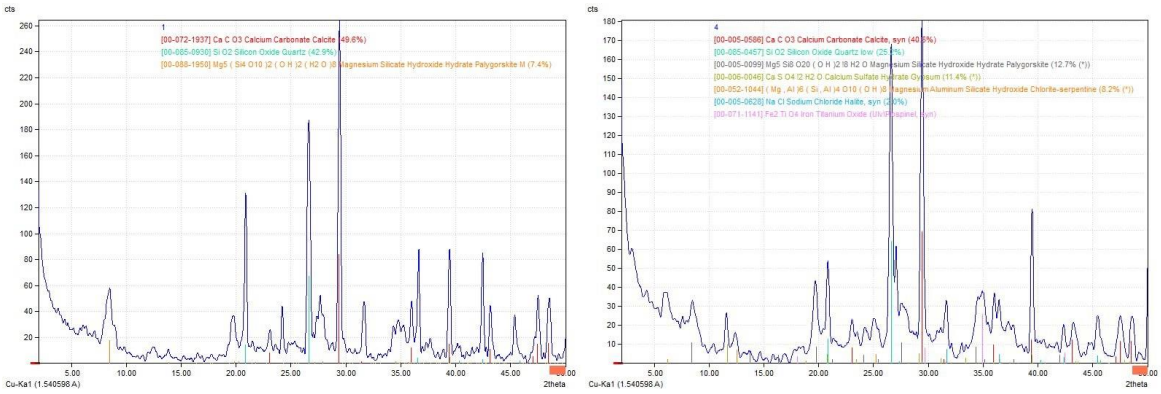

Fig. 6. X-ray analysis of raw attapulgite clay (1, and 2 samples)

The typical fibrous and needle-like crystal morphology of attapulgite is clearly visible in the Scanning Electron Microscopy (SEM) micrographs obtained at 500x and 1,000x magnifications as shown in Fig. 7. The minerals are distributed throughout the clay matrix as long, entwined fibrous/acicular needles. The pristine and well-preserved properties of these crystalline fibres provide unmistakable evidence of their authigenic origin, which was brought about by direct neoformation and

precipitation from magnesium-and-iron-rich (Mg-Fe) alkaline solutions within a confined lacustrine or playa environment rather than by a detrital influx.

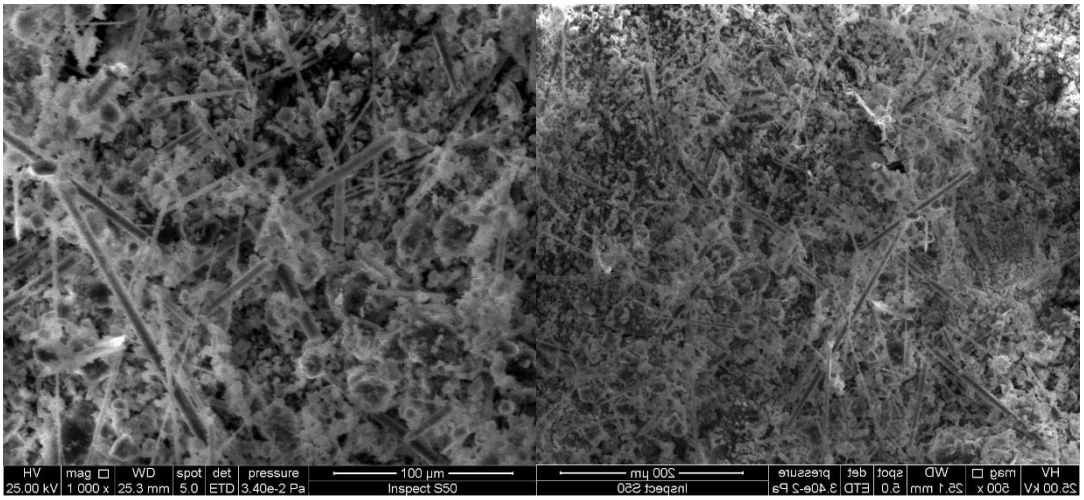

Fig. 7. Scanning Electron Microscopy (SEM) At 500x and 1,000x magnifications, micrographs of the examined attapulgite samples revealed interwoven fibrous and acicular needle-like structures

5. Conclusions

Based on multiple tests conducted on the various geological barriers, the soil at the refinery site is highly permeable and incoherent, making it susceptible to contamination from crude oil spills. This contamination affects not only the soil but also extends to groundwater, rendering it unusable and necessitating the use of engineered barriers. Attapulgite is a naturally occurring geological barrier that can be used in oil production locations because of its high porosity and extremely low permeability. Because (R. H.) is inexpensive and readily available locally, it can also be used to build artificial barriers. This is a big step in the direction of putting sustainable environmental engineering principles into practice. By strengthening soil characteristics, decreasing permeability and boosting cracking resistance, this plentiful agricultural resource increases the efficacy of barriers in stopping pollutants from seeping into groundwater and surrounding soil.

Recycling (R. H) also lessens the need for expensive industrial materials and carbon emissions like cement, as well as the burning of agricultural waste and the associated hazardous emissions. Therefore, using (R. H) in this field accomplishes two significant goals at the same time: lower engineering project costs and environmental conservation. These findings show that it is a cost-effective and ecologically benign choice for geological isolation projects. The purity of attapulgite and the rate of oil leakage have been shown to be inversely correlated in laboratory trials; the greater the purity and the smaller the particle size (75 µm), lower the leakage rates, decreased leakage volume, and delay time.

Engineering recommendation: Because purified attapulgite has a significant capacity to reduce permeability from free flow in refinery soil to almost nil leakage in the purified material, research suggests utilising it as a primary clay liner in regions vulnerable to oil spills.

Declaration of Competing Interest

The authors declare that they have no competing financial interests or personal relationships that could influence the work reported in this study.

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Data Availability

All data generated or analyzed during this study are included in this published article and/or its supplementary materials.

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