Using CO_2- induced magnesium carbonate as environmental friendly additives for petroleum decontamination sandy soils

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Abstract Chemical pollutants, including petroleum contaminations causes soil pollution due to improper transportation, leakage, or storage. In choosing the appropriate method and materials, paying attention to environmental issues, availability and cost-effectiveness of the used method is particularly important. In the current research, the ability of various environmentally friendly materials as absorbents of petroleum pollutants and their effect on sandy soil has been studied. Mineral additives including zeolite and perlite as well as magnesium carbonate produced by carbon dioxide released from industries have been selected as absorbents of petroleum pollutants. In the first stage of the research, the amount of absorption of oil pollutants (i.e., diesel and kerosene) has been investigated by different additives. The results showed the high absorption capacity of all three additives as well as magnesium carbonate absorbed more than 90% by weight of diesel pollutant, which is the highest absorption percentage among the additives, and compared to the absorption percentage of soil (26.5%). In addition to the significant amount of absorption of oil pollutants, magnesium carbonate can be considered by researchers and engineers as an environmentally friendly adsorbent due to the use of carbon dioxide released from industries in its production process.

Keywords: Soil petroleum contamination, CO_2 capture, Magnesium carbonate

1. Introduction

One of the most significant environmental contaminations is soil petroleum contamination results from storage and transportation, which has caused significant environmental impacts. These pollutions cause many problems in agriculture soil, groundwater industrial, and civil engineering structures (Essien & John, 2010; Qian et al., 2018; Karkush & Kareem, 2017). Some of the pollutants are classified as dangerous pollutants due to their resistance to decomposition as well as carcinogenic and mutagenic problems (Gao & Ling, 2006; Wilson& Jones,1993). There are many standard methods such as physical, chemical, biological, and thermal processes that have been applied to treat contaminated soils. Decontamination technologies involve using additives termed "sorbents" in the contaminated soil.

Sorbent materials are porous solids with developed specific surface areas that are commonly used to remove and immobilize petroleum from water and soil. As well as, it use as a barrier to prevent the further spread of contaminants (Silvani et al., 2017; Fokina & Miazin, 2019). Different types of sorbents are used to remove petroleum contaminants. Expanded mineral sorbents such as natural zeolites (Hoaghia et al., 2021), and perlite (Vogt & Płachta, 2017) are examples of applied sorbents. Zeolite consists of crystallized silicate with a porous structure and high specific surface area that has superior capability in adsorption and cation exchange (Chojnacki et al., 2004). Expanded perlite is a glassy volcanic rock of rhyolitic composition with high porosity and lower density than water that can expand as much as five to eight times its original volume (Bastani et al. 2006).

Carbon dioxide (CO_2) is an important heat-trapping gas that causes global warming. The governments around the world try to reduce CO_2 levels in the atmosphere to prevent climate change (Grimston et al., 2001). Mineral carbonation is one of the most encouraging techniques to reduce the industry's greenhouse gas (Lui et al., 2021). This technique has unique advantages because it allows the utilization of industrial wastes (greenhouse gases), and provide an appropriate method for recycling of CO_2. In this research, the effect of common hydrocarbon pollutants including diesel and kerosene on sandy soil behavior has been studied. In the following, mineral materials including perlite and zeolite as well as magnesium carbonate produced by absorbing carbon dioxide released from industries as absorbents of hydrocarbon pollutants have been investigated.

2. Materials and Methods

2.1. Sorbents materials

In this research, three different materials including magnesium carbonate prepared from carbon dioxide absorption, perlite and zeolite minerals have been studied as oil pollutant absorbers. Natural zeolite is the most common pozzolans, which is among volcanic materials or sedimentary volcanoes with a three-dimensional and crystalline structure. This material is classified as a hydrated aluminosilicate. Perlite is also a volcanic mineral, which is characterized by its hydrophilicity and the ability to absorb and retain fluids. Table 1 shows the physical and chemical characteristics of used materials. To produce magnesium carbonate, 0.25 kg of CO2 gas was injected into 3 liters of 1.5 M sodium hydroxide solution for 72 hours to produce sodium carbonate solution according to equations 1 -3. Next, sodium carbonate solution was combined with 1 M magnesium sulfate solution at a ratio of 1 to 1 to produce magnesium carbonate precipitation according to equation 4. This sediment was separated from the solution with filter paper and used as a powder after drying.

Table 1. Physical and chemical properties of additives

Properties	Perlite	Zeolite
Specific gravity	2.2	2.3
Particle size (mm)	1-1.2	0.6-1
Chemical composition (%)		
Sio_2	70	64
Al_2O_2	14	10.1
Fe_2O_3	1	1.8
CaO	1	1.8
MgO	1	0.8
Na_2O	7.5	4.9
K_2O	3.2	2.3
SO_3	0.08	1.2

$$CO_2 + NaOH + 2H_2O \rightarrow NaHCO_3(aq) \quad (1)$$

$$NaHCO_3\ (aq) + NaOH\ (aq) \rightarrow Na_2CO_3\ (aq) \quad (2)$$

$$Na_2CO_3 \rightarrow 2Na^+\ (aq) + CO_3^{2-}\ (aq) \quad (3)$$

$$MgSO_4\ (aq) + CO_3^{2-}\ (aq) \rightarrow MgCO_3 \downarrow \quad (4)$$

2.2. Petroleum pollutants

In this research, diesel and kerosene pollutants were used. These two are widely used oil derivatives in industrial areas such as refineries, fuel tanks, oil warehouses and transmission pipelines. There is a possibility of their leakage and penetration into the soil. The properties of the used pollutants are listed in Table 2.

Table 2. Properties of the studied pollutants

Pollutant	Parameter	Value
Gasoil	Density@15º	860 kg/m
	Kinematic viscosity@37.8º	2-5.5 c.st
Kerasone	Density@15º	820 kg/m
	Kinematic viscosity@37.8º	1 c.st

2.3. Determination of absorbance capacity

To evaluate the performance of the studied materials in absorbing petroleum pollutants, the absorption percentage of these materials was determined. The studied sand and additives including magnesium carbonate, zeolite and perlite were separately saturated with a specific weight of kerosene and diesel for 24 hours. Then these materials were placed on the filter paper for one hour to remove the extra pollutants. Finally, by determining the weight of each material and comparing it with the initial weight, the amount of absorption and retention of pollutants has been determined for each material.

3. Result and discussion

3.1. Sorbents materials and absorbance capacity

Figure 1 shows an SEM photo of sorbent materials. Magnesium carbonate mineral ($MgCO_3$) was precipitated by a CO_2-induced process as powder. As can be seen from the figure, $MgCO_3$ has a blade shape with a tangled texture (Figure 1a). Figures 1(b &c) illustrate an SEM photo of zeolite and perlite. It can be seen that perlite and zeolite have a porous and scaly texture.

Figure 2 shows the absorption percentage of clean sand and studied adsorbents including perlite, zeolite and magnesium carbonate for both diesel and kerosene pollutants. According to the obtained results, the highest absorption percentage was related to magnesium carbonate, which can absorb 91.5% of its weight in diesel. The ability to absorb magnesium carbonate is 3.5 to 4 times that of sandy soil. After magnesium carbonate, zeolite also has a significant absorption capacity. But perlite shows less absorbency compared to these two materials.

According to the SEM images, pearlite, and zeolite particles are larger and their surfaces are relatively smooth, therefore, they have shown the lowest percentage of absorption in the studied materials. Magnesium carbonate crystals are mostly needle-shaped and less than 1 μm in diameter. Therefore, it is expected that its specific surface will be higher and as a result, it will have a higher absorption percentage.

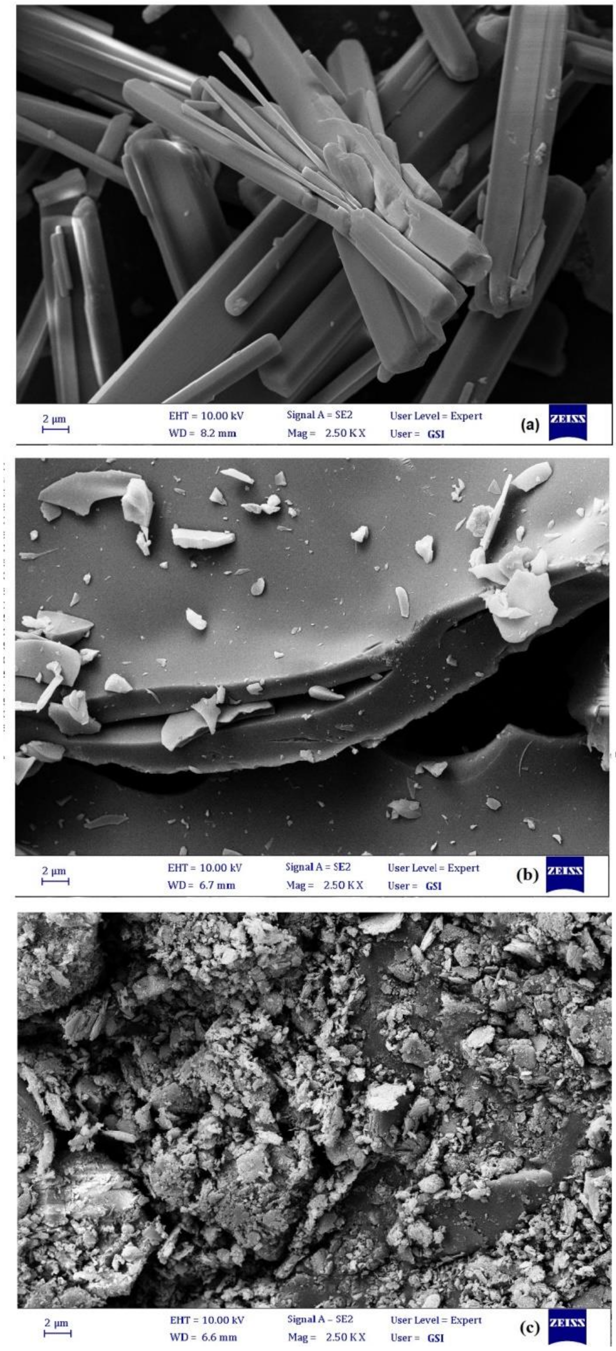

Figure 1. SEM photos of magnesium carbonate (a), perlite (b), and zeolite (c)

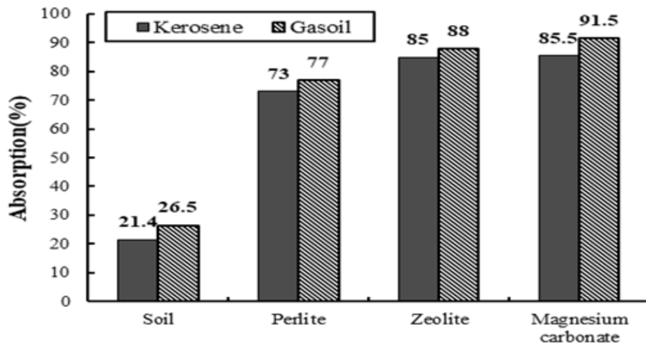

Figure 2. Absorption of pollutants by proposed additives

4. Conclusion

In this research, mineral materials including perlite, zeolite, and magnesium carbonate produced by carbon dioxide as absorbents of petroleum pollutants were investigated. The most important results obtained from this research are as follows:

- The ability to absorb petroleum pollutants by all three additives was significant and more than 3 times that of sand. Magnesium carbonate showed the highest absorption percentage and perlite showed the lowest absorption percentage due to its coarser particles.
- Taking into account the set of results of the absorption, as well as considering the production process of the studied absorbents, magnesium carbonate has a better performance as an absorbent of petroleum pollutants in the sand. On the one hand, this material has the highest percentage of absorption of petroleum pollutants. Also, magnesium carbonate produced by absorbing carbon dioxide released from industries not only does not cause damage to the environment, but by absorbing greenhouse gases, it can also help to deal with the global phenomenon of global warming.

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