A Hands-on Soil Remediation Learning Activity for High School Students

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As population of the earth rising, the need for energy is increasing day to day. Fossil fuels are the most used energy source for cars and widely used for power plants. Crude oil is one raw form of fossil fuels, which is found in some parts of the earth but use in other parts. Therefore, transportation of crude oil from where it is found to the refineries and where it is used needs special attention. There exist the possibility of accidental spoils of the crude oil producing soil contaminated with oil. The cleaning of spoiled oil from soil is essential to save the soil from degradation. An interactive oil extraction from oily pool sands activity has been developed to give opportunity for K-12 students to learn some of the soil remediation basic techniques. This activity has been developed as a part of a collaboration with the National Science Foundation's outreach program at the University of Mississippi. Many of State mandated educational standards are followed to develop this hands-on activity and it can be used in any chemistry or environmental science class as a supplement.

The extraction of oil from oil contaminated pool sands is a convenient, cheap, and effective method to teach students applied science, engineering principles and what engineers do. The vehicle for this teaching involves soil remediation and solvent extraction processes. The procedure is easy to perform and can be done using basic tools which are easy to purchase. This procedure has a number of advantages. It is fast and easy to perform and there are opportunities to focus on engineering, engineering problem solving, and engineering economics.

The activity begins by discussing basics of the soil contaminations with oil and solvent extraction. Then, students will start experiment. The students are responsible for the keeping track of the extraction process and collecting data. The activity will finish with a series of calculations to determine the extracted amount of oil and extraction percentage.

Audience:

The procedure for the extraction of oil from oil contaminated pool sands was prepared for the high school students.

Chemistry concepts:

Soil remediation, solvent extraction, surfactants, evaporation

Engineering concepts:

Community acceptance, economic of the various choices, optimization, process engineering

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1. Introduction

Fossil fuels are made from crude oil which can be found in places such as the Gulf of Mexico off the coast of Mississippi. In 2016, 96 million barrels of oil and liquid fuels were used daily as a source of energy. Oil contains a large number of hydrocarbons. The produced oil needs transportation to the refineries and petrochemical companies in order to convert it to useful products such as gas and diesel. However, there is a possibility for the accidental leak or spill during transportation leadings to soil pollution. Spilled oil on soil threatens wildlife, human health, water sources, and etc. Soil contamination can happen even in the households by leaking of heating oils. Figure 1 shows an example of the spilled oil on soil.

Figure 1. Spoiled soil with oil

Cleaning spilled oil from soil is known as soil remediation, which involves cleaning hydrocarbons such as petroleum, oil, etc. from soil. Soil remediation is required to keep soil in accordance with health and environmental quality standards. The standards are based on the human health and ecological requirements.

There are many ways of removing or extraction contamination from soils; such as solvent extraction, leaching, evaporation, or “soil washing.”

Solvent extraction is technique which can be used to separate materials. This method involves in separation of a substance, which known as solute, from a solid by using a liquid as a solvent. Different types of solvents such as water or organic solvents can be used. in a typical solvent extraction from solids, the solid mixture contains particle in which they are different in size. The separation of solute starts with addition of the solvent to the solid mixture. The filtration of solids from solvent leads to an enriched solvent with solute. The whole solute is dissolved in the solvent in an ideal extraction process. However, in the most practical extraction processes, it is impossible to reach ideal extraction. Figure 3 shows a schematic diagram of a solvent extraction process.

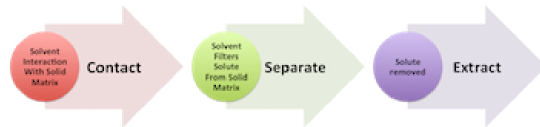

Figure 1. A schematic diagram of solvent extraction from a solid process

Solvent extraction process can be improved by using surfactants by lowering surface tension or interfacial tension between two liquids or one liquid and a solid. Surfactants are surface active agents and usually are organic compounds. Surfactants mostly have water-soluble and water-insoluble compounds. Surfactants are used in the usual life as detergents, shampoos, and etc. Surfactants help removing chemical species which mostly are proteins or oils from body, dishes or clothes by increasing the solubility of these species in water. Figure 4 shows chemical structure sodium dodecyl sulfate which widely used to make soaps and detergents.

Figure 2. Sodium dodecyl sulfate chemical structure

For this activity, detergents are used to increase the oil extraction from oily pool sands. Pool sands, canola oil, and detergent are required to complete this activity and all these materials can be found easily in the shopping centers such as Walmart and Walgreen's.

2. Activity

Tell students that they are going to be an environmental engineer for the day and they clean oil from pool sands. Show them the materials that they will work with. Explain the activity and solvent extraction method for separation. Discuss that sometimes it is difficult to find proper solvents for special extraction purposes. Break the students into groups and give them materials with hand-outs. After explaining the hand-out and procedure, let them to start the experiment.

3. Hand-outs

In this hands-on activity, the extraction of oil from oily pool sands are presented to simulate soil remediation processes. After completion of the extraction and washing procedure, the water will be evaporated to determine extraction efficiency. Table 1 shows the required materials for each group. In addition, Figure 5 shows the step by step procedure diagram.

Table 1. Required materials for each group

Material	**Quantity**	**Comments**
Pool sand	100 g	
Beaker (500 mL)	2	
Weighing scale	1	
Heater	1	
Spoon	1	
Graduated cylinder (100 mL)	1	Should be plastic or non-reactive
Sieve	1	
Canola oil	50 g	
Detergent	10 g	
Aluminum foil		
Metallic plate	1	

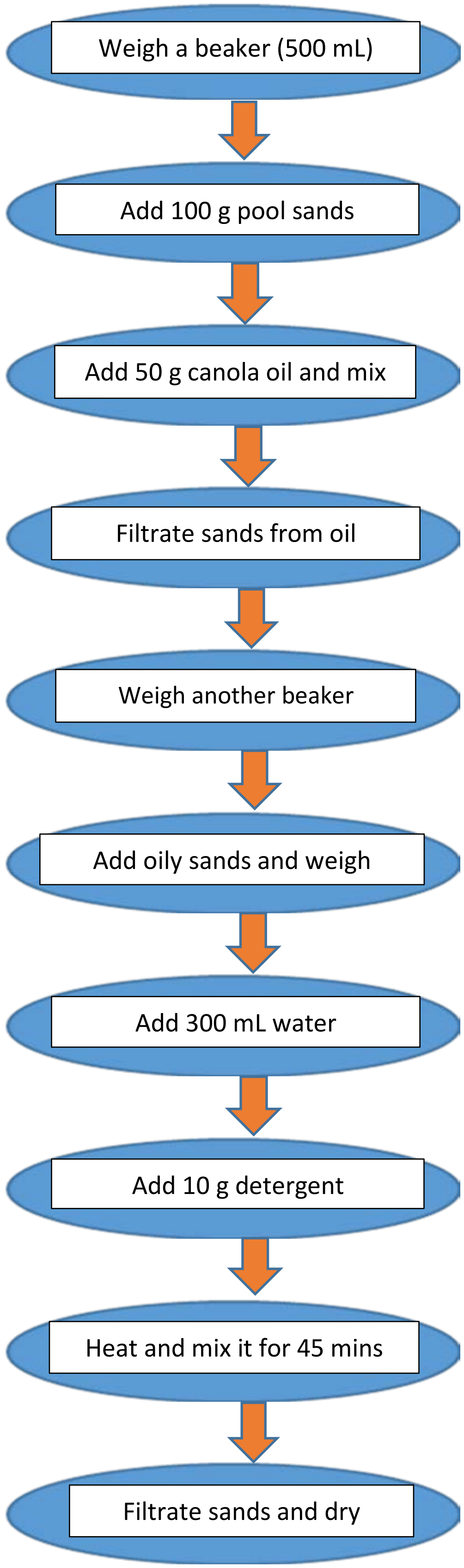

Figure 3. Step by step procedure

Detailed procedure for oil extraction from sand particles:

1. Weigh the empty beaker
2. Add 100 grams of pool sands to the beaker
3. Add 50 grams of canola oil
4. Mix the sands and oil using spoon
5. Use sieve to filtrate sands from oil
6. Weigh the other beaker
7. Add sands into the beaker
8. Weigh beaker and sands
9. Add 300 mL water using graduated cylinder
10. Add 10 grams of detergent
11. Mix the solution
12. Heat the solution using a heater. Temperature should be around 50^{o}C.
13. Mix the solution every 5 minutes for 45 minutes
14. Cool down the solution to the room temperature
15. Use sieve to filtrate sands from the solution
16. Select a piece of aluminum foil which is enough for covering the metallic plate
17. Cover the metallic plate with aluminum foil
18. Weigh metallic plate and aluminum foil
19. Put sands on the foil
20. Heat the metallic plate until all of the water evaporates
21. Be careful to turn off the heater right after the whole water evaporates.
22. Leave the metallic plate on the heater until it cools down to room temperature
23. BE CAREFUL ABOUT HOT SURFACES SUCH AS HEATER SURFACE
24. Weigh the metallic plate again to determine how much oil you have extracted

4. Questions

1. Complete the following conversions (1000 mg = 1 g):
   2.14 g = mg
   0.27 g = mg
   6.45 g = mg
   7.23 mg = g
   9.14 mg = g
   1.56 mg = g
2. The oil and surfactant chemical structures are shown in the introduction (Figures 1 and 4). However, to avoid confusion and simplify the structure, some of the carbon atoms are not shown. This is common in the chemistry. Redraw the caffeine structure and show all of the atoms including carbon and hydrogen atoms.
3. Determine the chemical formula for the oil. For example, C_4H_{10} is a chemical formula.
4. Use the chemical formula from previous question and determine oil molecular weight. Here are atomic molecular weights: C=12 g/mol, H=1 g/mol, N=14 g/mol, O=16 g/mol, S=32 g/mol.
5. How much oil did you use for the extraction?
6. How much oil did you extract?
7. How much is the extraction efficiency?

5. Notes for instructors

This activity is both fun and instructive for students and they will enjoy conducting science with hands-on activities. Table 2 shows the experimental data for 10 runs.

Table 2. Experimental data for ten groups doing the experiment

Run	Pool sands (g)	Oily pool sands (g)	Extracted oil (g)	Extraction efficiency (%)
1	128.73	135.4	5.06	76
2	88.36	92.93	3.92	86
3	140.2	147.18	5.46	78
4	105.5	111.78	5.43	86
5	104.51	109.65	4.06	79
6	101.06	106.12	4.78	94
7	104.55	112.35	7.1	91
8	101.3	108.93	7.03	92
9	122.86	129.03	5.21	84
10	100.07	103.37	3.05	92

6. Safety concerns

The most import safety concern for this activity is working with hot surfaces such as heater. Students should be very careful at the time they are using heater. In addition, safety goggles and gloves should be worn throughout this activity.

7. Helpful notes

- Tap water can be used for the experiment.
- Almost 90% of the students should obtain some caffeine.