PURIFYING OIL-CONTAMINATED WATER

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Project ID#

Q1: Research Question/Engineering Goal

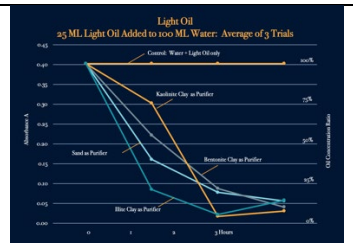
Can oil contaminated water be removed safely, with powdered Bentonite clay?

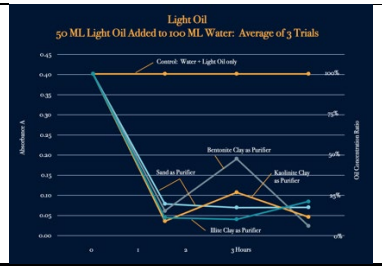
Least-Squares Fit Summary Tables

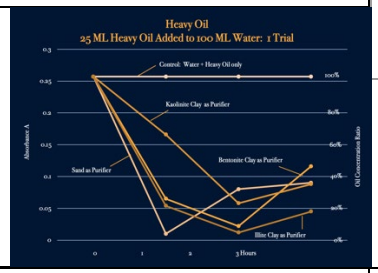
Oil Absorbent 25 ml Light Oil	Time Constant Tau (hours)	3 hours / Tau (Unitless)	$1 - e^{(-3/Tau)}$	Pearson Correlation Coefficient
Sand	1.22 hours	2.46	91.4%	99.51%
Bentonite	1.45 hours	2.07	87.4%	99.67%
Kaolinite	1.46 hours	2.05	87.2%	92.97%
Illite	0.71 hours	4.23	98.5%	98.79%

Oil Absorbent 50 ml Light Oil	Time Constant Tau (hours)	3 hours / Tau (Unitless)	$1 - e^{(-3/Tau)}$	Pearson Correlation Coefficient
Sand	0.81 hours	3.70	97.5%	97.38%
Bentonite	1.08 hours	2.78	93.8%	85.13%
Kaolinite	0.65 hours	4.62	99.0%	94.83%
Illite	0.49 hours	6.12	99.8%	97.94%

Oil Absorbent 25 ml Heavy Oil	Time Constant Tau (hours)	3 hours / Tau (Unitless)	$1 - e^{(-3/Tau)}$	Pearson Correlation Coefficient
Sand	0.49 hours	6.12	99.8%	89.32%
Bentonite	1.03 hours	2.91	94.6%	83.98%
Kaolinite	2.06 hours	1.5	77.7%	94.92%
Illite	0.69 hours	4.35	98.7%	98.26%







Q3: Data Analysis & Results

Time	25ML Light Oil Results	50 ML Light Oil Results	25 ML Heavy Oil Results
1 Hour	Illite Clay had best purification. Sand had second best purification. Bentonite Clay had third best purification. Kaolinite Clay had worst purification.	Sand and all 3 clays had nearly the same absorbance at 1 hour. Kaolinite had slightly the best absorbance, followed by Illite Clay and Bentonite Clay. Sand had slightly the worst absorbance.	Sand had best purification overall. Illite Clay had second best purification. Bentonite Clay had third best purification. Kaolinite Clay had worst purification.
2 Hours	Illite and Kaolinite Clays had best purification (nearly equal) and best overall purifications. Sand and Bentonite had second best purifications (nearly equal).	Large divergence in absorbance. Illite Clay showed slightly improved absorbance, as did Sand. Kaolinite Clay and Bentonite Clay showed dramatically worse absorbance.	Illite Clay had best purification. Bentonite Clay had second best purification. Kaolinite Clay had third best purification. Sand had worst purification.
3 Hours	Third hour has mixed results: Illite and Kaolinite Clays had slightly less purification than at 2 hours. Sand and Bentonite had slightly better purification than at 2 hours.	Absorbance more converged. Bentonite had the best absorbance, followed by Kaolinite, then Sand. Illite Clay had the worse absorbance.	Third hour saw loss of purification from second hour for all purifiers. Illite Clay had best purification. Kaolinite Clay and Sand had second best purifications (nearly equal). Bentonite Clay had worst purification.

Q2: Methodology/Project Design

1. Mix crude oil samples into distilled water. Use a surfactant, if necessary, to help oil and water mix together. A phosphate might be a good choice for a surfactant, followed by a sulfate
2. Measure the initial concentration of oil in the distilled water. Use either the Unico S2150 UV/Vis Spectrophotometer to measure absorbance "A" versus wavelength from 190nm to 1100nm, or use Paper Chromatography or Thin-Film Chromatography to measure the retardation factor, Rf
3. Add laboratory-grade powdered Bentonite clay to the contaminated water. Stir frequently.
4. After 1 hour, filter a sample of contaminated water to remove the Bentonite clay particles and the attached oil.
5. Measure the concentration of oil in this treated sample. Use either the Unico S2150 UV/Vis Spectrophotometer to measure absorbance "A" versus wavelength or use Paper Chromatography or Thin-Film Chromatography to measure the retardation factor.
6. Repeat steps D and E hourly, to be able to graph the purification of water versus time.
7. If the Unico S2150 Spectrophotometer is used, apply the Beer-Lambert law A = εLC
8. to derive the ratio of the concentrations "C/C_initial" versus time. L is the dimension of the cuvette, which is 1 cm and a constant for all measurements. For a specific wavelength, ε is a constant. Thus, C/C_initial = A/A_initial, namely the ratio of the concentrations is the ratio of the absorbances A, for a given wavelength.

Q4: Interpretation & Conclusions

Description of Absorbance Data Experiment: Application of Beer-Lambert Law and Plank's Law

My absorbance "A" data was taken at a specific wavelength, λ = 546nm, using a Unico S2150 UV/VIS Spectrophotometer.
I applied the Beer-Lambert Law A = εLC. The length L was the optical transmission length through the Unico cuvettes, 1 cm, a constant for all measurements. Since the wavelength was constant at 546nm for all measurements, the molar attenuation coefficient ε was also constant for all measurements. Thus, I could form a ratio of absorbances to obtain a ratio of oil concentrations:
A(time)/A(time-zero) = Oil_Concentration(time)/Oil_Concentration(time-zero)
Thus, the following three plots show the drop in Absorbance A (left) and Oil Concentration Ratio (right) versus time (horizontal axis). These plots showed that the oil concentration ratio (in percent) dropped from 100%, due to the drop in absorbance A. Thus, sand as well as Illite, Kaolinite, and Bentonite Clays all proved successful in the removal of oil from water.
I then applied Plank's Law E = hc/λ, where h (Plank's constant) is 6.626E-34 Joule-seconds, c (speed of light in a vacuum) is 2.998E8 meters/second, and 1 eV (electron volt) is 1.602E-19 Joules. Thus, at λ = 546nm, I excited all oil-water mixtures at an energy of 2.27eV in my studies. An electron volt (eV) is a tiny amount of energy suitable for molecular analyses such as mine. A common Joule is simply too large a unit of energy for molecular studies.

Discussion of Least-Squares Fit Summary Tables

Column 1 shows the oil type (light or heavy) and volume (ml), as well as the absorbent.
Column 2 shows the time constant Tau (in hours) for the least-squares fit of
Absorbance A = A(0)*e(-Time/Tau), where A(0) is the absorbance at time zero.
Column 3 divides the duration of the experiment (3 hours) by the time constant Tau, to create a non-dimensional ratio of (3 hours) divided by Tau (hours).
Column 4 calculates 1-e(-3/Tau), which is the "completeness" of the experiment for each oil and each absorbent, based on the number of time constants Tau in the 3-hour test duration. My three-hour testing duration was between 1.5 and 6.12 time constants long. Some standard values used in statistics are: 1-e(-1) = 63.2% (one time constant) and 1-e(-2) = 86.5% (two time constants).
Column 5 gives the Pearson Correlation Coefficient, which is a statistical measure of the agreement between the empirical absorbance data and the theoretical equation A(0)* e(-Time/Tau). 100% denotes a perfect fit and 0% denotes no correlation. All of my correlations showed excellent agreement between my data and my theoretical equation. My highest correlation was 99.67%. I used the PEARSON function in Excel to calculate all correlations.

Conclusions

My project showed that clay was very successful in separating oil from water. However, Bentonite was not a universal solution, but part of an overall solution. Kaolin and Illite were the star winning clays that effectively removed oil from the contaminated water, making clean water. There were advantages to all the clays and even advantages to sand which mimics bodies of water. Thus, my hypothesis was accepted. For Light Oil Recommendations I recommend purifying water with Illite Clay for 2 hours, then change purifier to Bentonite Clay. For Heavy Oil Recommendations, I recommend purifying water with sand for 1 hour, then change to Illite Clay as the purifier.