Interaction between oil and suspended sediments in class 1-2 rivers

Sergio Perez, Ph.D. (perezs@usmma.edu), Ping Furlan, Ph.D. (furlanp@usmma.edu), Nagy Hussein, Ph.D. (husseinn@usmma.edu), David Shinn, Ph.D. (shinnd@usmma.edu), and Richard Crook, B.S., Lab Director (crookr@usmma.edu).

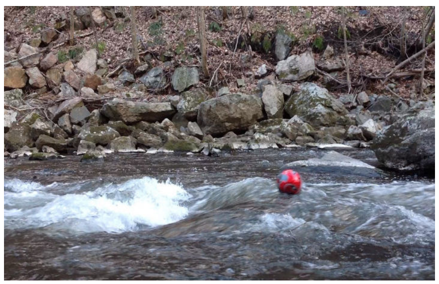
Abstract

We report on laboratory experiments dealing with the interaction of clay-sized sediments with oil slicks on Class 1-2 rivers. We find that given enough time, clay-sized sediments can sink nearly all surface oil.

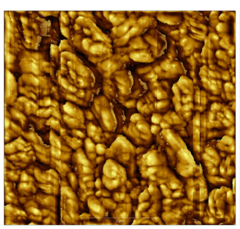
We present plots for estimating the rate at which sediments attach to and bring down oil slicks – at the maximum rate observed, about 15% of a slick of intermediate fuel oil (IFO) could be sunk in 1 km of rapids with 0.5 m waves; half of a slick could be sunk in about 4500 m of river length.

Background

Class 1 rivers are considered easy to navigate, smooth or with small ripples, while Class 2 rivers have a moderate level of difficulty. Class 2 rivers may have frequent waves as high as about 0.5 meter. The figure below shows a soccer ball in class 2 rapids with a wave height of about 0.5 m (measured from trough to crest).



At left is the experimental set-up. An automatic shaker mixes water, oil and kaolinite sediments. A spectrophotometer was used to measure the oil entrained by the sediments. Intermediate (IFO or #2) and Heavy (HFO or #6) fuel oils were tested.



Kaolinite clusters of small particles. The image is six by six microns.

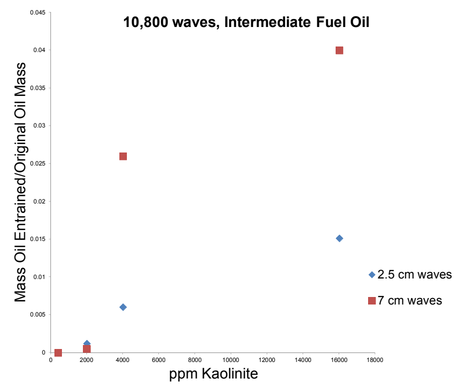


Figure 1. Results for IFO fuel

Effect of sediment load and wave height

Figure 1 shows the effect of sediment load on the amount of fuel oil captured by the sediments, as well as the effect of wave height. The x- axis shows the kaolinite load in parts per million (ppm) by mass, and the y-axis the mass ratio of oil captured to original oil in the slick (before shaking).

The test was conducted at wave heights of approximately 2.5 and 7 cm, trough to peak. IFO was used, and subject to ~10,800 waves in 30 minutes of agitation.

Figure 1 shows that the entrained oil amount increases at about the same rate as the increase in wave height: an increase in the wave height by a factor of about 3 increases the captured oil by about the same factor. This indicates that the experimental data from the laboratory may be scalable to real-sized waves.

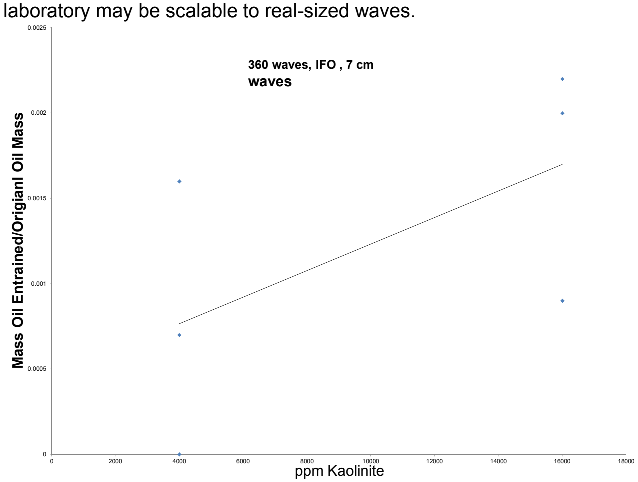


Figure 2. IFO results over one minute of shaking. These results are used to calculate oil entrainment rates. There is scatter in the data due to difficulties measuring low ppm values.

Effect of oil type

We found a significant difference between HFO and IFO fuel. HFO is more viscous than IFO (3900 vs. 1350 centipoise), and demonstrates a dramatic difference in the amount of oil interacting with sediments - IFO is entrained at about 20 times greater rate than HFO.

Sample Calculation

A 1 km long and 10 m wide stretch of river rapids with 0.5 m waves has clay-sized sediments with a sediment load of 16000 ppm. 1,000 kg of #2 fuel oil are spilled, and the spill spreads from bank-to-bank. The river surface has 1 wave every 2 square meters. Calculate the amount of oil which may be entrained by the sediments.

We see from Figure 2 that for 360 waves and 16000 ppm, we can expect about 0.0016 kg of oil per kg of slick entrained by the sediments with 7 cm waves. The mass of oil is decreasing as the slick moves along the rapids, so the rate at which sediments are entrained also decreases. We assume that initially, before the rapids, the 1,000 kg of oil are evenly dispersed across the 10 m river cross-section and an unspecified length of river. The rate of change of the slick mass per unit length of river rapid is then:

□□ = −□ □ □□□ □ = □□ □ $\frac{h}{h}$

Where m is the surface slick mass, l is length in the direction of river flow, □ is the rate at which the sediments are entrained, per wave per kg of surface slick (0.0016/360 from Figure 2), □ is the average number of waves per square meter of river surface (0.5), w is the river width (10 m), h is the average height of the waves (0.5 m), and *h* is the height of the waves in the test tank (0.07 m).

The solution to this differential equation is:

□ = □ [1]

Where □ is the original slick mass, m is the mass of the slick and L is the river length.

Applying the equation we find that about 15% of the slick is entrained over the 1 km length.

Further Work

We are currently performing CFD (Computational Fluid Dynamics) simulations to determine the accuracy of scaling the laboratory results, as well as the effect of the container walls.

References

- James McCourt and Larry Shier (*1999*) Interaction Between Oil and Suspended Particulate Matter In The Yukon River. International Oil Spill Conference Proceedings: March 1999, Vol. 1999, No. 1, pp. 1249-1252.
- Bragg, J.R. and E.H. Owens (1995), “Shoreline Cleansing by Interactions Between Oil and Fine Mineral Particles”, in *Proceedings of the 1995 Oil Spill Conference,* American Petroleum Institute, Washington, D.C., pp. 219-227, 1995.Bragg and Owens