UC SANTA BARBARA

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# Study Reveals an Oily Diet for Subsurface Life

Thousands of feet below the bottom of the sea, off the shores of Santa Barbara, single-celled organisms are busy feasting on oil.

Until now, nobody knew how many oily compounds were being devoured by the microscopic creatures, but new research led by David Valentine of UC Santa Barbara and Chris Reddy of Woods Hole Oceanographic Institution in Massachusetts has shed new light on just how extensive their diet can be.

In a report to be published in the Oct. 1 edition of the journal Environmental Science & Technology, Valentine, Reddy, lead author George Wardlaw of UCSB, and three other co-authors detail how the microbes are dining on thousands of compounds that make up the oil seeping from the sea floor.

"It takes a special organism to live half a mile deep in the Earth and eat oil for a living," said Valentine, an associate professor of earth science at UCSB. "There's this incredibly complex diet for organisms down there eating the oil. It's like a buffet."

And, the researchers found, there may be one other byproduct being produced by all of this munching on oil –– natural gas. "They're eating the oil, and probably making natural gas out of it," Valentine said. "It's actually a whole consortium of organisms –– some that are eating the oil and producing intermediate products, and then those intermediate products are converted by another group to natural gas."

Reddy, a marine chemist at Woods Hole, said the research provides important new clues in the study of petroleum. "The biggest surprise was that microbes living without oxygen could eat so many compounds that compose crude oil," Reddy said. "Prior to this study, only a handful of compounds were shown, mostly in laboratory studies, to be degraded anaerobically. This is a major leap forward in understanding petroleum geochemistry and microbiology."

The diet of the single-cell microbes is far more diverse than previously thought, Valentine said. "They ate around 1,000 of the 1,500 compounds we could trace, and presumably are eating many more," he said.

Research for this project began seven years ago and much of the testing was done at one of the planet's best natural labs. "We have the world's most prolific hydrocarbon seep field sitting right offshore of Santa Barbara, about two miles out," Valentine said. "We have something on the order of 100 barrels of oil a day coming up from the sea floor."

The source of this oil seepage is near Platform Holly, but it's not being caused by the drilling. "It's just oil that is naturally oozing out, probably has been for thousands of years," Valentine explained. "Holly just happens to be near some of these seepage areas, which is fortuitous because we were able to get samples from about a mile deep."

By studying samples from the subsurface, the ocean floor, the mid-water, and then from the surface, the researchers could determine how much of the oil was being degraded and digested by the microbes.

Using a new technique devised by Reddy, the scientists were able to pick apart the differences in the makeup of the oil, which is migrating to the surface through faults from deep below the sea floor. The microbes prefer the lighter compounds of oil, the gasoline part of the black goo. They tend to leave behind the heavily weathered residue, which is what makes its way to the surface and, sometimes, to the beaches in the form of tar.

"There always seems to be a residue," Valentine said. "They (bacteria) hit a wall. There seems to be stages in which they eat. There's the easy stuff ––the steak. And then they work their way to the vegetables, and then garnish, and then they stop eating after awhile. Just depends on how hungry they are and what's fed to them."

Reddy's new diagnostic technology is called a comprehensive two-dimensional gas chromatography (GCxGC). Typically, chromatography involves heating up a sample and putting it into a column around 60 meters long. Compounds are then separated based on their boiling points, which works well with light crude oil, Valentine said. But, with the two-dimensional test, the compounds are put into a cooled trap, for about 10 seconds, and a flash pulse of hot air releases them into the second column. This two-dimensional separation allows the researchers to pick out the many thousands of compounds.

"This new technology was actually too good at its job," Reddy said. "It was able to separate and help identify significantly more compounds in the oil samples than traditional analytical techniques. The end result was that we were handcuffed with too much data afforded by the GCxGC. However, we overcame this hurdle by using new algorithms to help us interpret the data, which in turn led us to these milestone discoveries."

The next steps in their research are already under way, according to Valentine. They are following the oil diet in controlled laboratory conditions, and tracking the fate of the oil once it forms a slick at the sea surface.

"When you fly out of the Santa Barbara Airport, you can look down and see these massive slicks," Valentine said. "You can follow them for about 20 miles. A lot of the oil comes up on the beaches, but then what happens to it after that? Certainly the microorganisms continue to act on it. Evaporation occurs, but most of it can't evaporate. Some of it breaks down from sunlight. So where does the rest of it end up? We want to know how far the organisms will go in eating the oil and what happens to the residual tar. It doesn't all stick to our feet and there must be a lot of it out there somewhere."

Wardlaw, the lead author of this paper, is a graduate student in the Marine Science program at UCSB. The other co-authors were J. Samuel Arey of the Swiss Federal Institute of Technology, and G. Todd Ventura and Robert K. Nelson, both of Woods Hole Oceanographic Institution.

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† Top photo: A video(.avi) shot by David Valentine shows a bubble of oil oozing from the ocean floor.

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