TAMING TOXIC TIDES

Can we slay poisonous algal blooms with clay?

BY JANET RALOFF

Marine scientists have been documenting a disquieting trend in the past few decades—increasing blooms of poisonous algae. Outbreaks in Chinese coastal waters, for example, increased 10-fold between 1975 and 1995. Many species tint the water a deep hue, from red or blue-green to dirty brown. Others proliferate more stealthily. Recognition of their intoxicating presence generally dawns only when wildlife or people sicken.

Scientists have logged some 50 different species of toxic algae. The microbes' targets and modi operandi can vary dramatically. At least one *Pfiesteria* species appears to kill by swarming all over a fish and secreting factors that eat away the unwitting host's skin (*SN: 8/10/02, p. 84*). Several secrete poisons that cause acute, gut-wrenching disease in people, while toxins of others paralyze, induce permanent amnesia, or trigger respiratory problems that are sometimes severe.

Harmless concentrations of these microscopic poison factories can be isolated from coastal waters at any time. However, those diffuse populations periodically—and unpredictably—mushroom almost overnight into vast blooms that can blanket hundreds of square miles of open water (*SN: 9/27/97, p. 202*).

Known as algal tides, these profusions of algae can float atop the water or reside throughout it, creating a toxic soup that extends to the seafloor. There's been no stopping a red tide or any other algal bloom as it's buffeted by winds and shuttled by currents. So, at the first signs of one's emergence, fishing fleets, recreational boaters, and beach bathers disappear—temporarily devastating the economy of coastal communities.

BLOOM FIGHTER — In Puget Sound, algal blooms periodically devastate fish farms. Don Anderson sprays a phosphatic-clay solution into an enclosed salmon pen there. The test probed impacts on water quality, plankton, and seafloor animals.

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But help may be on the way. A growing international cadre of scientists has begun exploring a remarkably simple control strategy. The researchers fling dirt into the water to sweep away harmful algae.

Not just any dirt. The particles must be mined from fine, silty clay. And not just any clay. Depending on its mineral composition, one clay might wipe out a bloom, while another just irritates the algae.

So far, only Asian researchers have wrangled permission to test this clay therapy in open waters—and then almost exclusively to protect pens of high-value farmed fish. But if some of their U.S. counterparts get their way, experimental sprays of wet clay could be coming to an algally challenged bay in as few as 3 years.

AN ASIAN RECIPE Japanese scientists originated the clay therapy. The idea behind it: Find something heavy that sticks to the algae and weighs them down like microanchors.

In 1989, several Japanese publications described shipboard dispersal of wet clays onto blooms of algae threatening pens of fish. "Though the reports were all favorable," says Mario R. Sengco of the Woods Hole (Mass.) Oceanographic Institution, the Asian researchers shelved the concept, citing prohibitive costs.

Then, in 1995, a major bloom of *Cochlodinium polydrikoides* algae devastated Korea's marine aquaculture industry. It killed fish worth some $100 million. Overnight, interest in the clay defense system soared.

Korean scientists immediately ramped up a research program to field-test techniques for spraying clay onto affected waters. Those nationwide trials during the next year cost an estimated $1 million but held Korea's aquaculture losses to just $5 million. "The Koreans have been using clay ever since," says Sengco.

This year alone, Korean researchers have dispersed roughly 140,000 tons of yellow clay in treatments that typically remove 90 percent of the algae, according to Sam-geun Lee of Korea's Harmful Algal Blooms Research Department in Pusan. Although environmental assessments of this technique are still under way, Lee told *Science News* that his group has not yet found any negative impact.

Buoyed by such reports, U.S. scientists launched their own investigations in the 1990s. The bottom line, Sengco now reports, is that though clay indeed can sequester toxic algae into the sediment, "one size doesn't fit all." Users have to select a clay to target a specific microbe and, in some cases, employ chemical boosters, he notes.

FLUFFY IS BEST Clay is dirt made from especially small mineral particles. Anticipating that not all minerals would exhibit equal affinity for sticking to algal cells, Sengco and his colleagues tested 25 U.S. clays and Korea's yellow clay against the Florida red-tide organism, now called *Karenia brevis*, and a New York brown-tide alga, *Aureococcus anophagefferens*.

In mineral composition, six of the U.S. clays were bentonites, two were montmorillonites, and one was a phosphatic clay—a scrap residue of Florida's phosphate-mining industry. In test-tube experiments, these nine clays each trapped about 80 percent of the red-tide algal cells when applied at a dose of at least 0.25 gram per liter of treated water. That's equivalent to adding a few pinches of powder to a gallon of liquid.

In contrast, clays with mineral characteristics like those of the Korean yellow clay achieved the best removal of the brown-tide cells. But the concentrations required were at least 16 times as high as those needed for the best red-tide control agents to be effective.

Sengco's team reported its findings in the Jan. 26, 2001 *Marine Ecology Progress Series*.

Since the phosphatic clay performed so well against the red tide alga and was literally free for anyone willing to cart it away, Sengco and his Woods Hole colleagues are working out the best ways to use it in trials in Florida and the Pacific Northwest.

Clay clears algae from water by two means. First, organic materials on the surface of algae are sticky, so the microbes bond to clay particles and sink. Second, some clays swell in seawater and coagulate into fluff, or what Sengco describes as "marine snow." As these flakes sink, they rake down additional algal cells.

Whether a particular clay forms marine snow depends on its crystalline structure. Bentonites, for instance, consist of sandwiched layers of tetrahedral silicon-based units and an octahedral aluminum-based compound, Sengco says. Water molecules can slide between the layers, swelling a particle to perhaps double its dry size. A similar swelling occurs with moistened montmorillonite but not with some other clays, Sengco explains.

To further enhance the fluffiness of wet clays, his group has added a chemical booster called polyaluminum chloride, or PAC. Water treatment plants often rely on this commercial coagulant to gather small pollutant particles into big flocs that settle out for collection. The Woods Hole scientists find that with PAC, clay forms stickier, more voluminous sieves for filtering algal cells out of the water.

Toxic cells dragged to the seafloor by clay can survive for at least a couple hours, Sengco's studies show. He observes that if not firmly pinned down—by more clay, for instance—the algae can wriggle out "and swim to the surface to reestablish their vegetative growth."

ALL CHOKED UP? The Woods Hole research team is coordinating efforts by several U.S. research groups to determine just how much extra clay an environment's residents can tolerate. In Puget Sound, consulting biologist Jack Rensel of Arlington, Wash., has been dumping clay onto pens of juvenile Atlantic and Chinook salmon. His initial 5-hour trial in open-bottom cages simulated what might happen if fish farmers were to treat algae that infiltrated aquaculture pens at sea.

The 10-pound salmon clearly found the clay irritating, Rensel observes, and "did what fish do in response to a lot of things that interfere with their gills: They coughed." Later examination of their gills turned up no permanent damage, however.

Anticipating environmental restrictions, the Woods Hole scientists and their collaborators typically have applied clays at about one-fortieth the dose that Korean investigators used on open waters. However, Sandra Shumway of the University of Connecticut in Groton has tailored her studies to match Asian application rates.

She administered clay to water over filter-feeding bivalves—scallops, limpets, hard clams, and other crustaceans that sieve their meals of tiny organisms from water pumped through their body cavities. In October at the International Conference on Harmful Algae in St. Pete Beach, Fla., Shumway reported "significant negative impacts of clay on filtration" in all species.

These animals extract oxygen from the water, so any drop in their filtration rate can be serious, she says. For bay scallops, adding just 10 milligrams of clay per liter of water halved the filtration rate. In two species of oysters, 100 mg/l clay applications cut filtration by 50 percent, and at 1,000 mg/l, the animals' filtration "almost shut down," Shumway says.

The filtration effects may explain other findings reported at the same conference by Monica Bricelj of Canada's National Research Council in Halifax. She and her colleagues simulated an algae-control program by applying phosphatic clay to water flowing over juvenile hard clams. When flow rates were slow enough for the clay to settle out rapidly, the clams fared fine. But when there was enough turbidity for clay to remain suspended for 2 weeks—a worst-case scenario—the clams' growth rate dropped by 90 percent.

SACRIFICIAL CLAMS Florida scientists have applied low concentrations of clay—with and without PAC—to laboratory tanks containing a bottom-dwelling estuarine fish and tiny burrowing crustaceans known as amphipods.

By itself, algae-free clay floc that settled on the tank bottoms didn't harm the critters, says ecotoxicologist Michael A. Lewis of the Environmental Protection Agency's laboratory in Gulf Breeze, Fla. However, the red-tide algae wiped them out—even when a clay floc with PAC had been used. In fact, he says, flocculation may largely transfer the algae's poisons from the water to sediment.

To Shumway, these preliminary findings suggest that clay treatment "has to be approached with great caution because, while it may appear to be a quick fix for the aquaculture people with fish pens, over the long term, it may actually do more harm than we currently appreciate." Indeed, she concludes, "scientists and managers have to consider the possibility that no intervention is the best policy."

However, Richard H. Pierce, director of ecotoxicology at the Mote Marine Laboratory in Sarasota, Fla., counters with another view. He argues that a clay treatment might be considered beneficial if it limits losses to just the sediment communities.

A toxic tide can leave in its wake a dead zone that includes seafloor communities. In an estuary, for example, an algal bloom "pretty well wipes out everything," Pierce explains. Not only does Florida's red tide produce at least nine neurotoxins, he says, but the bloom's high nighttime respiration can also suck much of the oxygen from the water.

NO SHOW STOPPERS Currently, clay has great promise for taming a host of toxic algae, says Donald M. Anderson, who heads Woods Hole's clay investigations. However, in North America, unlike Korea, getting a go-ahead to use clay will take a long time, he adds, "because we're going to have to do a lot more to prove to everybody that it's safe."

Toward that end, Anderson's team has just secured a 3-year federal grant to coordinate a new round of clay investigations at several laboratories. Many of the experiments will be conducted in large, closed pens in open bodies of water.

Yet even if the tests establish that clay is largely benign, economic hurdles may still limit its deployment. Although some clays are virtually free for the taking, there would be major costs for transporting them to bloom-threatened areas and financing crews to spray slurries. Fish farmers may be willing to spend a few thousand dollars to safeguard their pens, but would cities spend millions to head off blooms threatening their beaches?

Future tests may further define the economics of clay therapy, but the tests are, in part, at the mercy of nature, Anderson notes.

Indeed, Rensel relates, "we had been experiencing blooms at [Puget Sound] fish-farm sites every single year from 1989 to 1999." Then he received a grant to study the fish-killing *Heterosigma* algae around aquaculture pens, and suddenly, the red tides were nowhere to be found.

"The fish farmers think it's because I'm studying [the blooms]," he jokes. "So, I've been offered a retainer to study them for the rest of my life." ■

TOXIC SOUP — Fish carcasses float in water rust-colored by a brown algal bloom.

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