A dusty wind heralds human impacts in the ocean

By Genevieve Perkins

Dust storms around the world swirl tiny bits of clay, silt, and pollutants off the ground and up into the clouds. These clouds, and their brews of particles, mushroom out and follow the blowing wind. When the tiny travelers eventually fall, some land in the balmy waters of the Red Sea. There, near the white beaches of Israel, they make their watery dive and encounter an equally tiny, and rather mysterious consumer: phytoplankton.

Adina Paytan, a biogeochemist at UC Santa Cruz, studies the poorly understood relationship between phytoplankton and dust. Paytan examines different kinds of dust particles, their nutrients, and whether they might ultimately help or harm ocean life. Her startling new findings reveal that dust can just as easily kill as it can nourish the small, abundant marine plants.

Phytoplankton, photosynthetic plants and bacteria, form the most elemental unit of life in the ocean. They drift, aimless and abundant in the waves, until tiny floating animals or small fish turn their translucent cells into a meal. Indirectly, they feed most ocean life. A diminished number of phytoplankton would reverberate through marine—and global—food webs.

"The big picture interests me, the ecological and environmental impacts" says Paytan. Behind her desk at UCSC, a table hosts a beautiful arrangement of fossilized marine life. Shells, coral, sand dollars and sea stars resemble a museum display, or an altar to the sea. "Even though I study little things, dust or plankton, I’m always looking at the bigger ideas, the implications."

The atmospheric dust she studies comes from hot spots like the Saharan desert, dustier parts of Europe, large swaths of dried-out river basins, overly tilled soils, and more industrial sources like smokestacks. Wind sweeps one to three billion tons of dust into the sky each year from deserts alone. Known as aerosols, they are tiny particles of solid or liquid suspended in a gas, small enough to drift in the atmosphere for weeks. Their length is about half the diameter of a human hair. Within that tiny size, a single speck can contain material from the earth’s crust and from human-made pollutants.

The same aerosols can have wide and varying impacts. They are equally likely to create haze over Florida, polluting the air, as they are to fertilize the rainforest with plant food such as nitrogen and phosphorus. Dust even contributes to cloud cover: Water droplets latch onto dust particles and hang together to form new clouds. They bring iron and other nutrients to the open ocean, where phytoplankton often starve for food. Because oceans cover two-thirds of the earth, aerosols provide vital nutrients to vast areas where plants otherwise would not grow.

Paytan studies one of these low-nutrient environments in the Gulf of Aqaba, an inlet of the Red Sea. Lying between two deserts, the gulf unites the shores of Egypt, Israel, Jordan and Saudi Arabia. This distant saltwater crescent interests Paytan because of its distinct physical properties. “It’s very deep, it has low nutrients. It’s an analog to the big open ocean, but it is close enough to the shore so you can get there within a few kilometers,” Paytan says. “The Red Sea is also unique because there is a lot of dust there, and many different kinds of dust with different composition blow in the region.”

Paytan’s lab first described aerosol fluxes into the Gulf of Aqaba in 2008. Iron, lead and copper are elevated in the surface water. Virtually no rivers lead to the gulf; the only water source is through the straits of Tiran, bringing negligible amounts of metals. The study suggests that the heavy metals must have come from atmospheric dust falling earthward, into the water.

Even the smallest trace elements in the ocean can influence seawater chemistry. Many chemical elements in dust come from the earth’s crust, but about half of all aerosols come from human-made sources. Copper, nickel, zinc, mercury, and lead are among these pollutants. Research in the last ten years suggests that the effect of this dust in the oceans is overwhelmingly positive. One storm bringing trace elements to the gulf, for instance, could make marine algae grow three times faster.

In Paytan’s groundbreaking new study, she compared the impact of different dusts on three species of phytoplankton. The findings, published March 2009 in the *Proceedings of the National Academy of Sciences,* surprised even Paytan. For the first time, her group showed that some aerosols can harmed phytoplankton.

Most dust in the Red Sea blows in from Europe and the Mediterranean. About one-third of the time, the wind blows from Africa. The Saharan dust examined proved toxic to the marine organisms, killing some phytoplankton in just 24 hours.

“I wanted to do a comparison to see how the different dust types have an effect. And that’s where I kind of stumbled on the toxic dust. It’s weird; we were expecting the phytoplankton to grow, not to die!” Paytan says with astonishment.

Paytan’s team incubated samples of sea water containing the photosynthetic bacteria *Prochlorococcus* and *Synechococcus*, and other tiny algal plants with European and Saharan dust. They added about 6 milligrams of dust to each sample, roughly the amount that would settle on a small volume of water over two weeks.

Paytan hypothesized that a trace metal made the Saharan dust toxic. Scientists already knew that copper could be poisonous, and the trace metal can be released from dust. When Paytan retested the phytoplankton with a similar amount of isolated copper, the samples showed the toxic effect. Other trace metals didn't kill the plankton at these concentrations; copper was the culprit.

"Oceanographers have always thought of dust deposition as good for phytoplankton, because it provides nutrients such as nitrogen, phosphorus, and iron," Paytan says. "But we know air pollution has negative effects on the terrestrial side. We need to think about such effects of pollutants that may be deposited in the oceans."

The decline of some phytoplankton but not others raises questions about whether some phytoplankton can evolve ways to cope with toxins, Paytan says. She notes that her findings have complex ecological implications: "Any change in the community structure at the base of the food chain will have a role in affecting other organisms. Whether or not this will affect, you know, the dolphins down the line, I can't say," she says with a wink. "We just don't know what's going to happen in the future."

Dust storms in Israel can last from days to weeks. Paytan collects the aerosols during each storm. She uses an instrument that catches particles 0.2 microns and larger by pumping air through a fine filter (a micron is a millionth of a meter). Researchers trace the aerosols as they travel by watching weather reports on websites like the National Oceanic and Atmospheric Administration. "Because of good meteorology sites like NOAA, you can tell where the air is coming from," Paytan says. "We calculated how the air traveled over the past 5 days. We can actually track it."

About 30% of copper aerosols globally come from human sources, most of it from combustion and industrial process. Copper concentration in dust is now on average 200 times more than it was in preindustrial times. It seems to be increasing, particularly through emissions from coal burning across Asia. The brown cloud of pollution hovering above South Asia, for instance, continues to grow slowly at an estimated 4% each year. Coal burning spews more dust into the air than any other fuel: It releases mercury, copper, lead, and other metals, even radioactive materials.

Paytan received a National Science Foundation grant in 2009 to study the marine impact of this ubiquitous dust in Bermuda, China and in Monterey Bay over the next several years.

Dust travels thousands of miles in only days. But nature's messenger now carries a more disturbing notice. With the blowing wind comes all the materials cast off by human activities across the world. These traveling leftovers can harm life, both in the ocean and on land.

"There are no boundaries," Paytan says. "It can be distributed everywhere and anywhere." As our understanding of the earth improves, dust stands out as material that links everything together. The tiniest pieces, shed by a sloughing earth and by modern human societies, carry profound effects that span this sensitive green globe.

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Genevieve Perkins, a senior majoring in ecology and evolutionary biology, wrote this article in spring 2009 for SCIC 160: Introduction to Science Writing.