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Mysterious beach closures may be linked to contaminated groundwater, study finds

Scholars say higher pollution levels coincide with spring tides

BY MARK SHWARTZ

Photo: L.A. Cicero

Alexandria Boehm takes a water sample from Capitola Beach in 2002 as part of her ongoing research on bacterial pollution. Lately, Boehm has turned her sights on a Los Angeles-area beach closed many times due to contamination.

Every summer, coastal communities from Maine to California are forced to temporarily close some of their most popular beaches because of unsafe levels of bacteria in the water. Typically, these sudden bacterial blooms disappear, only to return without warning later in the season. In many cases, health officials are unable to pinpoint the cause of the contamination, leading frustrated beachgoers to blame everything from offshore sewage pipes to passing cruise ships.

But according to a new study by Stanford University scientists, the source of some of these unexplained pollution events may lie just a few feet below the sand, in contaminated groundwater that discharges into the surf zone, particularly during periods of extreme tides. The findings were published May 20 on the *Environmental Science & Technology (ES&T)* website.

"Our study is the first to show that beach groundwater is a potential source of pollution," said Alexandria B. Boehm, the Clare Boothe Luce Assistant Professor of Civil and Environmental Engineering at Stanford and co-author of the *ES&T* paper. She pointed out that most beach pollution studies have focused on major

infrastructure failures, such as inadequate sewage treatment plants or overwhelmed storm drain systems, while ignoring the possibility of groundwater contamination in the beach aquifer itself.


Adina Paytan

"Most people think that, once groundwater passes through sand and rock, the bacteria are filtered out," added co-author Adina Paytan, an assistant professor of geological and environmental sciences at Stanford. "What we've found is that sand is really not a filter or a barrier."

The discovery that contaminated groundwater can discharge into the ocean and mix with coastal seawater may help explain some of the mysterious bacterial infestations that plague American beaches every year. According to a National Resources Defense Council survey, of the more than 12,000 beach closings and advisories in the United States in 2002, 62 percent were attributed to "unknown sources."

Huntington Beach

The Stanford study was conducted at Huntington Beach near Los Angeles -- one of the most popular recreational sites in Southern California. More than a million swimmers, surfers and sunbathers visit Huntington Beach in a typical summer. But in July 1999, during the peak season, health authorities closed several miles of beachfront after lab tests found unacceptably high concentrations of bacteria associated with fecal contamination. The shutdown, which lasted about two months, angered many residents and business owners, who were particularly upset by the failure of county officials to identify the source of the pollution.

But the controversy has not gone away. In fact, portions of Huntington Beach have been closed dozens of times since 1999 because of elevated bacteria counts, yet officials there have been unable to explain why most of these incidents occurred.

Some residents blame a sewage outfall that has been dumping treated waste into the Pacific Ocean since 1971. A recent study suggested that it was theoretically possible for underwater currents to carry treated sewage from the outfall, which extends 4.5 miles offshore, all the way back to shore.

But Boehm and Paytan suspected a more immediate source of fecal bacteria -- namely, the aquifer directly below the beach. Boehm had co-authored a study at Huntington Beach in 2002 that showed bacteria levels were higher during spring tides, when the difference between high and low tides is greatest. That finding led her to wonder if spring tides could exert enough force to pump polluted groundwater to the surface.

Testing the waters

To find out, Boehm and Paytan decided to conduct a chemical analysis of the water at Huntington Beach using a technique known as isotope tracing. Isotopes are atoms of the same element with different masses. For scientists who study groundwater, two radium isotopes are of particular interest: 223-radium and its slightly heavier cousin, 224-radium. Both are common in salty coastal groundwater, and both are produced from the decay of uranium and thorium, which occur naturally in the bedrock.

To measure radium isotope levels, the Stanford team collected water samples at Huntington Beach from Aug. 2 to Sept. 12, 2003. Researchers scooped up large amounts of seawater while standing ankle-, knee- and waist-deep in the surf. Other samples were obtained 1,500 to 4,500 feet offshore. "We must have collected about 15 tons of seawater from the surf zone," Boehm recalled.

The researchers also pumped groundwater from a coastal aquifer that lies just a few feet below the sand. Lab analysis revealed that radium isotope levels in the aquifer were about 20 times higher than in the seawater samples collected 4,500 feet offshore. But tests also showed that seawater collected in the surf had isotope levels that were, on average, twice as high as in the offshore samples -- a strong indication that that high-radium groundwater from the aquifer was coming to the surface and mixing with low-radium seawater.

Bacteria and radium

The scientists also tested for microbial and nutrient contaminants. The aquifer turned out to have unusually high levels of nitrate -- a nutrient typically associated with sewage. Lab tests also found low levels of fecal bacteria in several groundwater samples. However, one sample, pumped from a shallow test hole on the beach, contained bacteria concentrations well in excess of California health standards. That test hole was located about 300 yards from a restroom sewer line -- a potential source of bacteria and nitrates.

The researchers also found that, of 62 seawater samples collected in the surf zone, more than half contained fecal bacteria concentrations that exceeded state standards. The majority of those contaminated samples were collected during spring tides and also contained high radium-isotope levels.

"These results suggest that radium-rich groundwater containing nitrate and bacteria could be pumped from the aquifer during spring tides," Boehm noted.

"Geochemists have used radium isotopes to study groundwater discharge into the coastal oceans for years," Paytan added, "but this is the first time that radium has been coupled with bacteria contamination."

To determine if bacteria can actually pass through sand unfiltered, the researchers set up a laboratory experiment in which contaminated seawater was pumped for 20 hours through a sand-filled tube. Virtually all of the bacteria survived the ordeal, providing more evidence that groundwater bacteria can reach the surf zone.

"Although we didn't find a large plume of bacteria in the aquifer, we did find a mechanism for transporting contaminated groundwater to the surf zone," Boehm said. "What we've shown,

therefore, is that groundwater could be the direct source of bacteria or of nutrients that nourish bacteria already in the surf zone."

Sewer irregularities

A 2001 study commissioned by the Orange County Sanitation District revealed "irregularities" in the sewer lines below two Huntington Beach restrooms. Although repairs were made, Boehm and Paytan plan follow-up experiments to determine if bacteria and nitrates in the groundwater are coming from the restrooms or another source.

"If there's a broken or leaky sewage pipe, we can flush dye down the toilets and see if it ends up in the groundwater," Paytan explained.

The research team has begun similar groundwater-bacteria coupling studies at beaches in Singapore and Israel, and plans to expand its work to other beaches in Northern California.

The *ES&T* study was also co-authored by former Stanford graduate student Gregory G. Shellenbarger, now at the U.S. Geological Survey office in Sacramento. Research was supported by the Clare Boothe Luce Program at the Henry Luce Foundation, the Stanford School of Engineering and the UPS Urbanization Research Fund.