



CHESAPEAKE BAY FOUNDATION
Saving a National Treasure

REPORTS



**Bad Water 2009: The Impact on Human Health
in the Chesapeake Bay Region**

POTENTIAL THREAT	WHAT IT IS.....	SEE PAGE
VIBRIO	<i>Vibrio</i> is a salt water bacteria, some varieties of which can cause life-threatening skin and blood infections and intestinal illnesses.	3
CYANOBACTERIA	Also known as blue-green algae, cyanobacteria grows in mostly fresh to low-salinity water and produces toxins that can cause liver disease, skin rashes, nausea, and vomiting.	8
CRYPTOSPORIDIUM	A protozoan pathogen found in human and animal waste, <i>Cryptosporidium</i> can cause diarrhea, and in people with compromised immune systems, more serious illnesses.	10
MERCURY	Mercury is an element that accumulates in fish and can cause neurological damage and increased risk of heart disease. Coal-fired power plants are the largest single source of mercury emissions in the U.S.	13
NITRATES	A compound in polluted runoff from farms, lawns, and streets, nitrates seep into surface and ground water. Drinking water with excessive nitrates can potentially raise the risk of cancer, nervous system deformities in infants, hemorrhaging of the spleen, and other problems.	15

ABOUT THE COVER:

Upper Left: *Vibrio* infection survivor Joe Stover, photo by Tom Pelton (See page 6.)

Upper Right: Child drinking water, iStockphoto

Lower Left: Cyanobacteria bloom, photo courtesy of Dr. Peter Tango (See page 8.)

Lower Right: Skin infection on leg of swimmer Bernie Voith, photo courtesy of Bernie Voith (See page 11.)

Bad Water 2009: The Impact on Human Health in the Chesapeake Bay Region

EXECUTIVE SUMMARY

The Chesapeake Bay and its tributaries are stunningly beautiful and central to the culture and economy of the whole Mid-Atlantic region. But beneath the surface, pollution and bacteria are spawning human health threats that some scientists see as a warning. Citizens and governments should take notice.

- **VIBRIO** The combination of warmer waters, nutrient pollution, and other factors in the Chesapeake Bay are contributing to the growth of bacteria called *Vibrio* that can cause life-threatening skin and blood infections and intestinal illnesses, according to Dr. Rita Colwell, former director of the National Science Foundation and current Distinguished University Professor at the Johns Hopkins Bloomberg School of Public Health and University of Maryland, College Park. Although infrequent, the number of annual *Vibrio* infection cases reported in both Virginia and Maryland has increased in recent years. In Virginia, the number has more than doubled over the last decade, from 12 in 1999 to 30 in 2008. Reports of infections have also risen in Maryland, but a change in reporting requirements in that state in 2003 complicates the picture there. In both states, it is unknown how many of these cases come from eating or handling shellfish from other regions. Nutrient pollution is nitrogen and phosphorus from many sources, including stormwater runoff from streets, farm fields, barnyards and lawns; discharges from sewage plants, septic tanks and industries; and air pollution from power plants, factories and vehicles that settles into the water.
- **CYANOBACTERIA** Nutrient pollution and warmer weather also stimulate the growth of harmful algal blooms. Blue green algae, also known as cyanobacteria, can cause liver disease, skin rashes, nausea, and vomiting. Dr. Peter Tango, Chesapeake Watershed Monitoring Coordinator for the U.S. Geological Survey, recently co-authored a report that called harmful algal blooms a “significant and expanding threat to aquatic life, human health, and regional economies.” Between 2000 and 2006, Dr. Tango tested waters with cyanobacteria blooms and found that 31 percent had enough toxins to make the waters unsafe for children to swim in.
- **CRYPTOSPORIDIUM** During the summer, polluted runoff, animal waste, and sewage often create high bacteria levels at swimming beaches. In the Chesapeake Bay watershed, Pennsylvania had 22 closures at 17 swimming areas last summer; Maryland had 44 no-swimming advisories or closures at 31 beaches during the same period; and Virginia had 10 advisories at 6 beaches. But even these numbers might not reflect the true prevalence of pathogens at beaches, according to a Johns Hopkins Bloomberg School of Public Health researcher. Dr. Thaddeus Graczyk has concluded that local health departments don’t test swimming areas often enough, thoroughly enough, or quickly enough to protect the public. A study by Dr. Graczyk found the dangerous protozoan pathogen *Cryptosporidium* (which local health departments do not test for) at levels that could infect people in 70 percent of weekend samples at a Baltimore County beach.

- **MERCURY** This heavy metal, often released by the burning of coal, pollutes waterways, taints fish, and can potentially damage human intelligence. In the Chesapeake region, governments have issued statewide fish-consumption advisories for mercury for all lakes and rivers in Pennsylvania and Maryland, and for many rivers in Virginia. This advisory includes consumption of rockfish from the Maryland portion of the Chesapeake Bay. Despite the possible risks, a study by Virginia Commonwealth University found that roughly half of state anglers were unaware of the mercury advisories. The study found that about 38 percent of survey participants were eating fish with mercury at doses that exceeded the warning level set by the federal government.
- **NITRATES** Polluted runoff causes not only low oxygen “dead zones” in the Chesapeake Bay, it also can hurt the health of rural families that drink from private wells. Recent studies found that between 21 percent and 60 percent of wells tested in Pennsylvania’s lower Susquehanna River Basin had nitrate levels exceeding public drinking water standards. Drinking water with too much nitrates can raise the risk of cancer, nervous system deformities in infants, hemorrhaging of the spleen, and other problems.

These are examples of how our waters have become unhealthy not only for fish, but also for people who fish, swim, boat, and drink contaminated water. The U.S. Environmental Protection Agency (EPA) and Chesapeake Bay states have a long way to go before they achieve the standards of “fishable, swimmable” waters promised by the 1972 federal Clean Water Act. More than a quarter century after a 1983 deadline for bringing the Bay and other waterways up to these “fishable, swimmable” standards, the numbers do not look good. In the Bay watershed last year, Pennsylvania, Maryland and Virginia issued 76 no-swimming advisories and closures because of unhealthy bacteria levels; warned people to avoid or limit consumption of fish because of mercury or PCB contamination in the Bay and 195 other bodies of water; and restricted or closed 224,369 acres of shellfish harvesting waters because of bacteria threats.¹

About 90 percent of the shellfish waters in the Bay remained open last year, and most swimming beaches were judged safe. Eating fish remains healthy, as long as people follow government consumption guidelines. But the fact that many health departments warn people to avoid swimming in the water for two days after any significant rain shows that EPA and the Bay states are far from meeting their goals. More research is needed into the connection between infections in people and pathogens in the Bay. And strong federal leadership is required to force EPA and state governments to meet the clean-up commitments they made nearly a decade ago in the *Chesapeake 2000* agreement. On May 12, 2009, President Barack Obama issued an Executive Order that directed the EPA Administrator to chair a committee of federal agency representatives that must “define the next generation of tools and actions to restore water quality in the Chesapeake Bay” and issue a draft report within six months. As EPA weighs its options, the Chesapeake Bay Foundation strongly urges the federal agency to create a strong and enforceable cap—or limit—on the total amount of nutrient and sediment pollution allowed into the Bay and its rivers. While doing so, EPA should impose strict numeric limits on nitrogen, phosphorus, and sediment pollution in all stormwater runoff control permits. And the federal agency should deny permits for sewage plants, factories, construction projects, and power plants that propose to add more nutrient or mercury pollution.

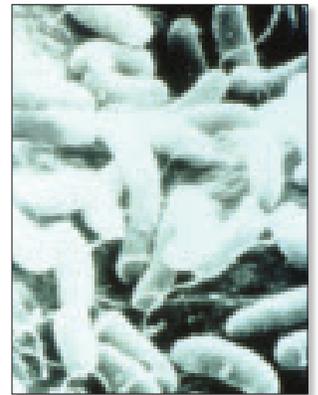
The need for decisive action can no longer be ignored, because it not just the Chesapeake's oysters and fish that are threatened by the effects of pollution and bacteria, but our people as well.

VIBRIO

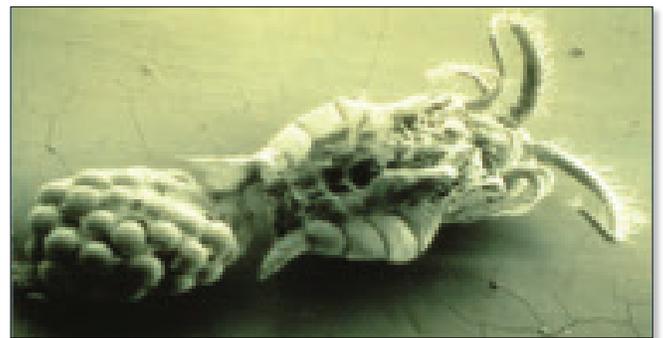
The Chesapeake Bay in summer is like a warm pond with a broth of nutrients at the right temperature to breed algae and bacteria. As the Earth's climate has warmed, average water temperatures in the nation's largest estuary have risen by about a half degree Fahrenheit per decade.² And scientists expect the Bay to keep heating up, with average temperatures rising another four to 11 degrees Fahrenheit this century.³ Meanwhile, every time it rains, excess fertilizer and other sources of nutrient pollution wash from lawns, farm fields, streets, and sewage plants, into the Bay. Last year, an estimated 291 million pounds of nitrogen and 13.8 million pounds of phosphorus flooded into the Chesapeake.⁴ Those nutrients feed plant growth in the water, just as fertilizers feed plant growth on land. But in the water, the plant life—algae—sometimes blooms out of control. And that growth can trigger chain reactions that can harm the health of aquatic life and humans.

One of the indirect effects of nutrient pollution and warmer waters is the multiplication of a potentially dangerous bacterium. *Vibrio* are in a family of bacteria with a curved rod shape and flagella. They are native to oceans and waterways around the world with warmer temperatures and moderate to low salinity levels, including the Chesapeake Bay. One of several species is *Vibrio vulnificus*, which can cause severe skin ulcers, gangrene, and deadly blood infections in people who expose cuts to warm saltwater containing the bacteria, as well as gastrointestinal illnesses in people who eat tainted shellfish.⁵ Another species, *Vibrio parahaemolyticus*, causes diarrhea, vomiting, and skin infections, but is seldom deadly.⁶ The best known variety, *Vibrio cholerae*, causes cholera, a diarrheal disease now virtually eliminated from the United States, but still endemic to developing nations where people drink untreated water and eat contaminated food.⁷ Most of the vibrio infections in this region are *V. parahaemolyticus* and *V. vulnificus*, with only a handful of cholera cases in Maryland, and none since 1994 in Virginia.⁸

More than a quarter century ago, doctors believed that *Vibrio* (and especially *V. cholerae*) came from sewage. But Dr. Rita Colwell and her colleagues demonstrated that the comma-shaped bacteria are natural inhabitants of most of the world's warm bays and oceans.⁹ Colwell and her fellow researchers discovered that *Vibrio* are carried by microscopic, crab-like animals called copepods. These floating crustaceans—a form of zooplankton common in the Chesapeake Bay and elsewhere—have a cooperative relationship with *Vibrio* similar to the one that people have with bacteria that live in their intestines to help digest food. *Vibrio* live inside the gut of copepods and also attach themselves to their outer shells, which the bacteria feed on.¹⁰



Source: Dr. Rita Colwell *Vibrio*

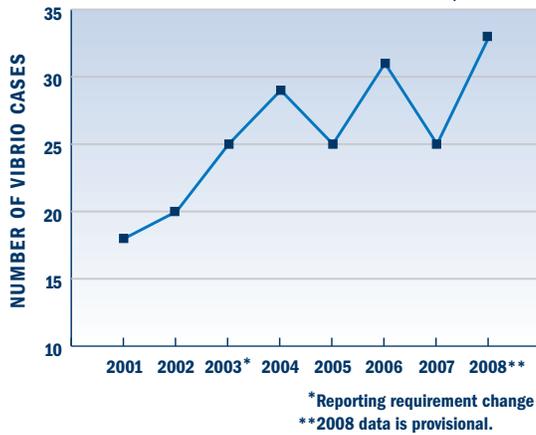


Source: Dr. Rita Colwell

Copepod

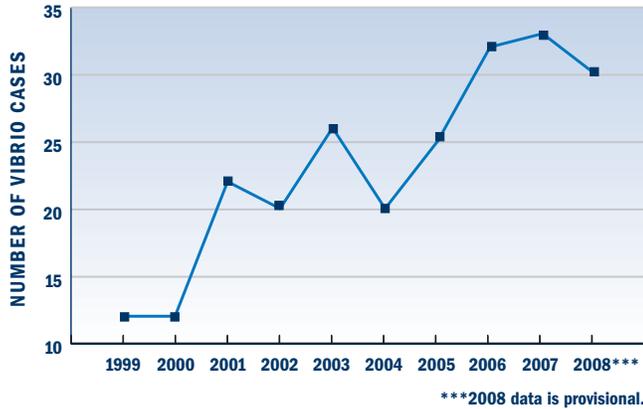
The copepods are like the cows of the Bay, spending their days grazing on plants—in their case, gobbling up algae. Nutrient pollution stimulates the growth of algae, especially during warm-weather conditions. And algal blooms fuel the multiplication of copepods. Research has suggested that intense algal blooms have the potential to support “explosive growth” of *Vibrio*.¹¹ When copepods die, *Vibrio* are shed into the water.¹² And if the bacteria are in very dense concentrations, people can get sick if they drink the water or expose an open cut.¹³

REPORTED VIBRIO CASES, MARYLAND



Source: Maryland Department of Health and Mental Hygiene

REPORTED VIBRIO CASES, VIRGINIA



Source: Virginia Department of Health

The number of *Vibrio* infections reported in Virginia annually has risen steadily over the last decade, from 12 in 1999, to 20 in 2004, to 30 in 2008.¹⁴ In Maryland, the number of reported *Vibrio* infections has also grown, from 18 in 2001, to 33 in 2008.¹⁵ But in 2003, Maryland made a change in reporting requirements which may have contributed to the increase there. Over the last decade 22 deaths in Maryland and 9 in Virginia have been linked to *Vibrio* infections.¹⁶ State health department data do not indicate whether *Vibrio* infections come from the Bay or other sources. And it is unknown how many of these cases came from people eating shellfish imported from other regions.¹³

While the reason for the increase is unknown, a 2008 study by a U.S. EPA Chesapeake Bay Program scientific committee noted that *Vibrio* outbreaks in the Chesapeake Bay were more common in an especially hot recent summer (2005) than in cooler summers.¹⁸ “Increasing temperatures in the Bay would favor these [*Vibrio*] bacteria, increasing the threat of the disease in the basin,” said the report by the Science and Technical Advisory Committee.

Other researchers have concluded that rising water temperatures around the world are causing *Vibrio* outbreaks—normally associated with balmy waters like those in the Gulf Coast—in once cold areas, such as off the coast of Alaska.¹⁹ Scientists believe these bacteria are spreading and causing illnesses in cooler parts of America and Europe where they have never been reported before.²⁰

Dr. Colwell, who has been studying *Vibrio* in the Chesapeake Bay for almost four decades, believes *Vibrio* infections are rising in the Bay region because of a combination of warming waters, nutrient pollution, and ideal salinity levels. Although the numbers of illnesses in the Chesapeake Bay area remain small, she said they are “an early warning system” that our natural environment is being thrown out of balance by climate change and nutrient pollution.²¹



Dr. Rita Colwell

Distinguished University Professor
University of Maryland,
College Park, and Johns Hopkins
Bloomberg School of Public
Health

*“It’s a dramatic effect, when people become ill and a few people die (from *Vibrio*). That’s a pretty dramatic indication that something is going wrong. Unfortunately they are the human canaries that tell us there are environmental factors creating problems. It tells us we ought to be paying attention to these changes.”*

TINY CUT ON BOATER'S THUMB LEADS TO BATTLE WITH INFECTION



Joe Stover at dock in Newport News, Virginia.
Photo by Tom Pelton/CBF staff

Joe Stover is lifelong boater who fell in love with the water in his youth, while guiding a canoe down cascading rapids on the Shenandoah River.

Now a 67-year-old real estate broker and motorboat enthusiast in Newport News, Virginia, Stover always connected water with good health. That was until June 2008, when he spent 10 days in a hospital and underwent surgery because of a terrifying infection from waterborne bacteria called *Vibrio*.

The illness struck when he was with his grandson at the Denbigh Park Boat Ramp on the Warwick River, a Chesapeake Bay tributary. Stover slipped while trying to nudge his boat onto its trailer and suffered a slight cut on his right thumb.

That was at 4:00 p.m. on Friday, June 20, 2008. By Sunday morning, his hand had “swollen up to the size of a catcher’s mitt. It had me quite worried...because the hand had swollen so grotesquely,” he recalled while visiting the boat ramp again on a recent afternoon.

His wife drove him to the emergency room at Riverside Regional Medical Center, where the doctors at first did not believe that Stover had a *Vibrio* infection, perhaps because he wasn’t a waterman. But then a culture came back from the lab proving that the bacteria was, in fact, *Vibrio*, according to his medical records.

Vibrio, a bacteria more often associated with warmer waters and the Gulf Coast, can cause life-threatening infections in people who eat contaminated shellfish or expose open cuts to salt water with the germs.

Over the last decade, the number of *Vibrio* infection cases reported in Virginia has more than doubled, from 12 in 1999 to 30 in 2008, and Maryland authorities have also recorded an increase, although it is not clear why. Dr. Rita Colwell of the University of Maryland College Park, and Johns Hopkins Bloomberg School of Public Health believes these normally warm-water bacteria are multiplying in the Bay because of a chain reaction of climate change and increased nutrient pollution. This combination spawns algal blooms and algae-eating crustaceans called copepods that harbor *Vibrio*.

“In the case of *Vibrio*, it’s kind of an early warning system,” Colwell said of illnesses and deaths caused by the bacteria. “It’s a signal that we might want to interpret as telling us something very dramatic is occurring in the environment that we had better pay attention to.”

Vibrio are naturally occurring bacteria found all over the world, she noted. But with excess pollution and global warming, *Vibrio* can grow so numerous they create a risk to human health.

Ken Smith, president of the Virginia State Waterman’s Association, said he knows at least three watermen who have had *Vibrio* infections, including himself. He fought off a *Vibrio* infection in his arm last spring that hospitalized him for three days. “There are a lot of infections that are going around right now,” Smith said. “You used to never hear of any infections here in the Bay, but it’s something you hear more about all the time now.”

Mark Allen, a fourth-generation waterman from Hague, Virginia, nearly lost his left leg after he contracted what his doctor concluded was a *Vibrio* infection. "My leg got so hot, it started to blister and turn black," Allen, 44, recalled on the couch in his home, pulling up his jeans to show a scar from a skin graft. "The fever was bad enough that my lips peeled."

Joe Stover has similarly harrowing memories. He said that after four days of intense antibiotic therapy, his hand was still swollen up like a balloon. "The hand looked kind of red and black, a lot of different colors," Stover said

Streaks of unhealthy colors were coursing through the veins on his arm. "I thought, 'Oh boy, this could be blood poisoning,'" he said. "It scared the dickens out of me."

A surgeon was called in to slice a three-inch cut into his hand and release the puss, relieving the pressure.

After a week and a half of treatment in the hospital, and several months of post-operative care, his hand recovered. But the illness changed him, and now when he returns to the waterfront, he no longer has the carefree mindset he enjoyed while canoeing in his youth.

"It really brought to my attention how important it is that we pay attention to our water, and how dirty our water is," Stover said, as seagulls whirled and cried behind him over the Warwick River.

He pointed at a sign nailed to a post on the pier. "WARNING," the sign proclaims in red letters. "Health advisory on eating fish...PCB and Kepone."

"The water...you can't even get your body into it, it's so dirty," Stover said. "For somebody who has been playing in the water since he was a young man, I was shocked to learn of this bacterium."

He said he learned a lesson with a connection his industry: real estate. He believes there is a link between the illness he suffered, and excessive development that is creating polluted runoff.

"All of the rivers that flow into the Chesapeake Bay are constantly being polluted from the development—and there is more and more development going in all the time," Stover said. "We need to do everything in our power to make sure the Bay stays clean."

HOW TO PROTECT YOURSELF

Here are some web sites about swimming beach safety:

- For Maryland residents, www.MarylandHealthyBeaches.com
- For Virginia residents, <http://www.vdh.state.va.us/epidemiology/DEE/BeachMonitoring/>
- For Pennsylvania residents, <http://www.dcnr.state.pa.us/stateparks/recreation/swimming.aspx>
- For all area residents: <http://www.epa.gov/beaches/>

Here are a few tips that public health websites suggest to protect yourself against infection:

- Avoid swimming 48 hours after any heavy rainfall.
- Do not swim with an open cut or wound.
- If you get cut while in the water, wash it thoroughly and cover with a waterproof bandage.
- Try not to swallow water while swimming.

HARMFUL ALGAL BLOOMS AND CYANOBACTERIA



Dr. Peter J. Tango
Chesapeake Watershed
Monitoring Coordinator
U.S. Geological Survey

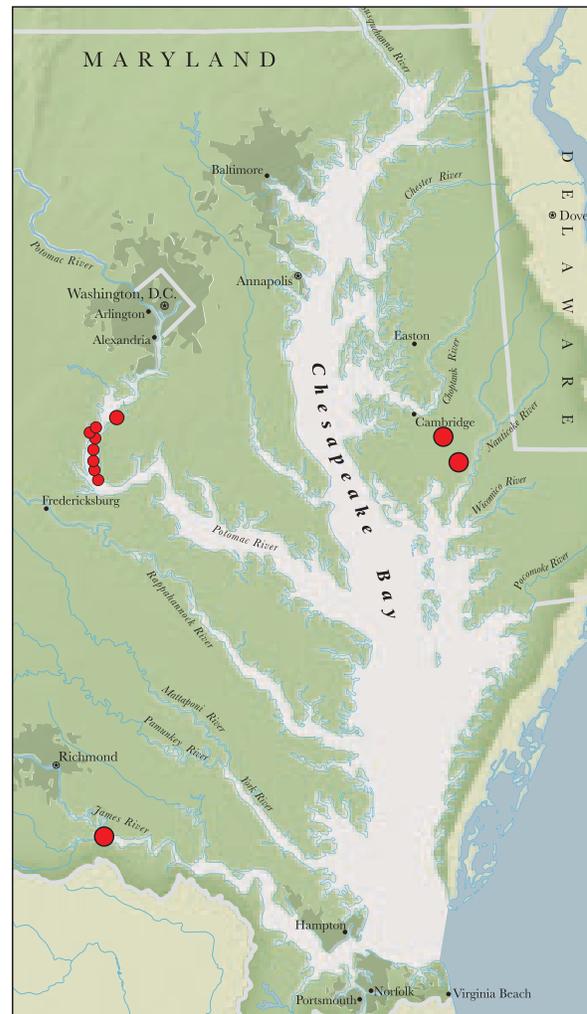
"There are potentially toxic cyanobacteria, and we should be concerned, because in other parts of the world, there have been cattle deaths, dog kills, and illnesses in people from ingesting water contaminated with these blooms."

Nutrient pollution and warm conditions promote the growth of algae, including harmful species that release toxins.²² One toxin-producing form, called blue-green algae, is not really algae at all, but rather a class of bacteria, called cyanobacteria. It is a primitive organism that has been found among the oldest fossils on Earth.²³ These cyanobacteria are like algae in that they grow in water and use photosynthesis to transform sunlight into food. After excess fertilizer and other sources of nutrient pollution flow into waters with low salinity, cyanobacteria can multiply into chunky mats of vibrant-colored slime. One type of cyanobacteria found in Chesapeake Bay tributaries is *Microcystis*, which can produce toxins that have been associated with fish kills, bird and livestock deaths, and, in people, liver and kidney disease, vomiting, fevers, and skin rashes.²⁴

Cyanobacteria blooms have been causing problems in the Potomac River and other waterways at least since the 1930s. Massive blooms on the Potomac in the 1960s were believed to be worse than today.²⁵ But researchers began studying toxic algae—of all kinds—more intensively after a 1997 bloom of a dinoflagellate called *Pfiesteria* was blamed for temporary memory loss in watermen on the Pocomoke River on Maryland's Eastern Shore. Since then, state health officials have set up surveillance systems and tried to be more vigilant about warning the public about blooms through websites and swimming beach notices.²⁶

The first confirmed presence of toxins from cyanobacteria in the Chesapeake Bay's tidal waters came in 2000 in the Sassafras River on Maryland's Eastern Shore.²⁷ Since then, state officials have issued no-swimming advisories or beach closures because of cyanobacteria blooms on the Sassafras, Potomac, and Transquaking rivers.²⁸ Researchers have investigated reports of nausea, vomiting, fevers, and skin rashes among people who have come into contact with

MICROCYSTIS ALGAL BLOOMS 2008



Source: Maryland Department of Natural Resources, Virginia Department of Environmental Quality

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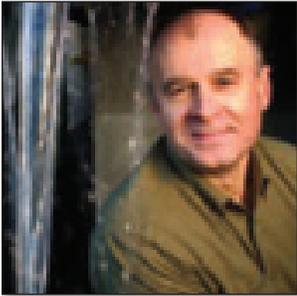
Source: Dr. Peter Tango

Cyanobacteria bloom

blooms.²⁹ Among other incidents, researchers documented a kill of about 1,800 fish on the Bush River in 2003 that they linked to blue-green algae.³⁰ Blue-green (*Microcystis*) algal blooms were reported on 26 occasions in Maryland in 2008, including on Mat-tawoman Creek and the Potomac and Transquaking rivers.³¹ (See map on page 8.) In Virginia last summer (July 2008), blue-green algae bloomed on the James River near Hopewell.³² Scientists have found it difficult to discern any trends either in the number of blooms or numbers of illnesses caused by them.³³

A 2008 study co-authored by Dr. Peter J. Tango, Chesapeake Watershed Monitoring Coordinator for the U.S. Geological Survey, reported that between 2000 and 2006, 31 percent of the waters tested with blue-green algal (cyanobacteria) blooms had enough toxins to make them unsafe for children to swim in, based on recommended guidelines in scientific literature.³⁴ The report concluded: “Harmful algal blooms in general represent a significant and expanding threat to aquatic life, human health, and regional economies. As long as eutrophic symptoms (high nutrient levels, low oxygen) continue in the Chesapeake Bay, the persistence of cyanobacteria blooms will remain a signature indicator of impaired Bay health.”

In addition to *Microcystis*, several other potentially toxic varieties of algae have been identified in recent years in the Chesapeake Bay. The list of toxic varieties of algae living in the estuary stood at 12 in 1996, and grew to 34 by 2005.³⁵ Dr. Tango said this increase was mostly due to more searching.³⁶ However, climate change might be expanding the range of a few new toxic species of algae into the estuary, and causing others to bloom earlier, according to a 2008 report by a scientific advisory committee of the U.S. EPA Chesapeake Bay Program.³⁷ For example, a toxic alga normally associated with Florida and the Gulf Coast, *Alexandrium monilatum*, in 2007 was believed to have been responsible for killing whelks (a species of sea snail) in the York River in Virginia. It was the first known bloom in this area, and it represented a potential shift northward, according to the EPA committee report. A large bloom of a toxic alga normally found in the Caribbean Sea, *Cochlodinium polykrikoides*, killed young fish and oysters in the lower Chesapeake Bay in August 2007. If blooms of these organisms continue to expand their range into the Bay, the impact on the Chesapeake’s chain of life “could be profound,” the EPA committee report says.³⁸



Dr. Thaddeus K. Graczyk
Associate Professor
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"You have this delay in getting answers about water quality, and by the time you get your answer, the conditions in the water have totally changed. We need to find better indicators of pollution."

BEACH CLOSURES AND *CRYPTOSPORIDIUM*

During summer months, beach closures and no-swimming advisories are relatively common, with most triggered by high fecal bacteria levels in the water. In the Chesapeake Bay watershed, Pennsylvania had 22 closures at 17 beaches or swimming areas in the summer of 2008; Maryland had 44 no-swimming advisories or closures at 31 beaches and waterfront areas; and Virginia had 10 no swimming advisories at 6 beaches and parks.³⁹ Many local and state health departments warn people not to swim in the water for 48 hours after every heavy rainfall. How often people become ill with diarrhea from accidentally gulping fecal pathogens while swimming at the beach is unclear, because the disease is often not reported.⁴⁰

Local health departments routinely test public beaches for *E. coli* and *Enterococci* bacteria, as potential indicators of whether disease-causing organisms might be present.⁴¹ But a scientist at the Johns Hopkins Bloomberg School of Public Health questions the adequacy of these beach-monitoring programs. Dr. Thaddeus K. Graczyk, Associate Professor at the school's Center for Water and Health, believes current water testing procedures miss the true prevalence of pathogens like *Cryptosporidium* because local health departments do not test for *Cryptosporidium* or other protozoans. Illnesses caused by *Cryptosporidium* are not typically fatal, but can be for people with weakened immune systems because of cancer, AIDS, or other diseases.⁴² Moreover, water-quality tests at public beaches are typically performed during the week, when fewer people are likely to be at the beach or in the water, and sediments laden with pathogens are not being stirred up.⁴³ The protozoan pathogens often come from sewage, or pet, farm animal, or wildlife feces that are washed by rain or are directly deposited into waterways. Sampling that Dr. Graczyk performed in 2006 at a beach at the Gunpowder Falls State Park on the Gunpowder River (a Bay tributary) found *Cryptosporidium* at levels that could cause infection, in 32 percent of 60 total samples, including 70 percent of weekend samples and none of the weekday samples.⁴⁴ He tested both during the week and on weekends and found the beaches were open on days when the levels *Cryptosporidium* were high enough to make people sick because the health department did not test for the pathogen. Another problem, Dr. Graczyk has concluded, is that the bacterial sampling of swimming areas now performed by local health departments uses tests that take two days or longer to show results. So by the time health officials know there is a problem and want people out of the water, it is too late.

Officials at the Maryland Department of the Environment disagree with Dr. Graczyk's study and conclusions, and say current testing procedures for beaches are effective in protecting the public.⁴⁵

Kathy Brohawn, chief of the beaches and shellfish program at the Maryland Department of the Environment, said that testing for *Cryptosporidium* would be impractical and expensive, because it is only one of several pathogens that can be present in fecal matter. She said a more efficient method of checking for fecal contaminations in general is to perform a simple test for *E. coli* or *Enterococci* bacteria. These tests, performed by local health departments, follow guidelines set up by the U.S. Environmental Protection Agency, and use a conservative estimate of risk. In addition to sampling for bacteria, all local health departments in Maryland are required at least once per season to conduct shoreline surveys around beaches to look for potential sources of contamination, such as pet waste or leaky septic tanks.

SWIMMING IN BACTERIA



Bernie Voith



Bernie Voith's wound

Photo courtesy of Bernie Voith

It was the Fourth of July weekend four years ago, and Bernie Voith was swimming and splashing with his grandson behind Voith's home on a tributary to the Severn River in Anne Arundel County, Maryland.

Voith, a retired printer, had a tiny cut on his right calf that he got from scraping against a plastic deck chair earlier. He didn't think much about it. "We were just fooling around, you know?"

When he climbed out of the water, he looked again at the scrape—and, to be safe, decided to apply disinfectant and a band aid. Then he went to bed, relaxed and happy after a weekend of fun with his family.

He woke at about 5:00 a.m., with a searing pain in his calf like somebody was sticking needles into the wound. "Then my finger tips all started to turn numb and I started hyperventilating," he recalled. "I was scared, so I called 911."

An ambulance drove him up to the hospital, where doctors discovered he had a temperature of 105 and a life-threatening bacterial blood infection.

One of his physicians, Dr. Sarah Jamieson, concluded that a variety of bacteria commonly found in human and animal feces had entered his cut—most likely from the water—and quickly raced through his body.

The dime-sized nick on his calf blossomed into a festering wound as wide as a tomato and filled with what looked like raw hamburger meat tinted yellow, red, and green.

"It was a very large and significant wound on his leg that he got while swimming in his creek," Dr. Jamieson said. "He was basically almost on the verge of death by the time he was admitted to the hospital.... All system failure was where he was headed."

Voith eventually recovered, but he spent the next two weeks in the hospital, and four months in and out of medical treatment. "I felt very fortunate I didn't lose my leg or my life," Voith said.

Water quality monitoring on the Severn River not far from Voith's beach the day he got sick showed fecal bacteria at 10 times the level that the EPA would consider safe for swimming, according to Dr. Sally G. Hornor, a biology professor at Anne Arundel Community College who has been monitoring the river for nearly two decades. It rained that day, and bacteria levels in rivers often jump after rainfalls, because they flush bacteria from dog waste, leaky septic tanks, and other sources into waterways.

Another point downstream on the Severn that day had bacteria at nearly 30 times the EPA's recommended safe levels for swimming, Dr. Hornor's data show. Overall, Dr. Hornor's testing on the Severn River in recent years has found levels of bacteria above recommended EPA levels for swimming about 25 percent of the time.

"It's a travesty," said Dr. Hornor. "People used to swim here all the time and spend all the summer in the water as children. And now they can't let their kids in the water anymore."

It's not clear how often people get infections from swimming in Chesapeake Bay tributaries with open cuts, because patients and doctors often don't report these illnesses.

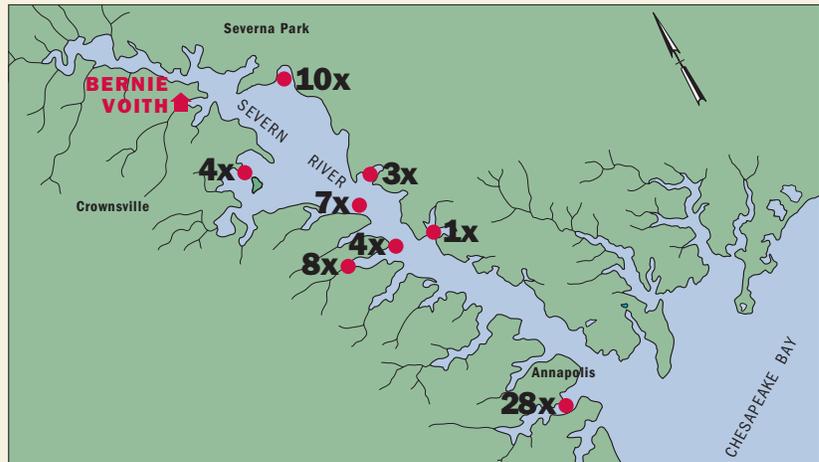
Skin infections from the fecal bacteria that hospitalized Voith are not tracked by the local health department. But a different species of bacteria more commonly associated with waterborne infections, *Mycobacterium marinum*, is tracked. Reported infections of *Mycobacterium marinum* have more than doubled in Anne Arundel County over the last decade, with the county recording nine

cases of what's commonly called "fish handler's disease" in 1998, and 25 in 2008, according to data from the Anne Arundel County Health Department.

"A lot of people say they've had infections," said Kurt Riegel, President of the Severn River Association, who had a *Mycobacterium* infection on his hand. "I had this infection for two solid years. My doctor told me, 'I had the same thing myself, on my leg.'"

Barbara D. Samorajczyk, a former member of the Anne Arundel County Council, said she suffered a *Mycobacterium* infection on her leg after slipping on the rocks along the Severn River. "I do not go in the water anymore in July and August," she said. "Once the water gets warm and I know there are high bacteria counts, I don't go in, anymore."

**BACTERIA LEVELS IN THE SEVERN RIVER ON THE DAY
BERNIE VOITH GOT HIS INFECTION, JULY 6, 2005. *
(compared to level considered safe for swimming by EPA)**



*On July 6, 2005, approximately 1 inch of rain fell within the 24 hours prior to sampling
Source: Dr. Sally Horner

The Severn and nearby rivers on Maryland's western shore are in such poor health that the University of Maryland Center for Environmental Health gave them the worst grades in the Chesapeake region—an F—in a report card issued in April 2009.

Since 1996, the U.S. Environmental Protection Agency and the Maryland Department of the Environment have had the Severn River on a federal list of waters impaired for shellfish harvesting because of high fecal bacteria levels. The Severn is by no means alone. Parts of hundreds of waterways in the region are listed as impaired by bacteria, from the Susquehanna River in Pennsylvania to the York River in Virginia.

Where do the bacteria come from? There are about 180 failing septic tanks in the Severn River's suburbanized watershed, according to the Maryland Department of the Environment (MDE). But a far more significant source of bacteria in the river is pet waste, which produces an estimated 69 percent of the *E. coli* bacteria in Voith's section of the Severn River, with wildlife contributing 24 percent, livestock three percent, and humans three percent, according to an April 2008 MDE analysis of pollution in the Severn River. About 41 percent of dog owners in the area admit they do not pick up after their animals most of the time, the report says. "Some people may not realize how much pet waste contributes to these problems," said Kathy Brohawn, Chief of the Bacteriological Assessments Division at the Maryland Department of the Environment.

Brohawn added that bacteria levels in the Severn River actually have improved over the last five years, in part because a leaky sewage plant for a trailer park closed. "We walk the shoreline and look for pipes or anything that would contribute pollution into the river," she noted,

Anne Arundel County, like many jurisdictions, has a web site that warns people not to have any contact with water for 48 hours after rain. "Anytime after a significant rainfall... we know the water will be overloaded with bacteria," said Kerry D. Topovski, director of environmental health for the Anne Arundel County Health Department.

Voith said it didn't cross his mind to stay out of the water that day. Today, he feels fortunate just to be alive. But he also feels a sense of loss. Every day after work, he used to wade into the cool waters of Plum Creek from the sandy beach behind his home and refresh himself before dinner.

"I used to be a very avid swimmer. The water was very pleasant back then," he recalled, fingering the scar on his leg. "Now I haven't been swimming in the creek since I had my problem. I'm afraid to, actually."

As part of a national effort to make sure swimming beaches are safe, the U.S. Environmental Protection Agency (EPA) this summer plans to conduct health studies that will examine fecal contaminants in the water at beaches in South Carolina and Puerto Rico. EPA will use these data as it develops new water-quality criteria and faster testing methods for beaches from the Chesapeake Bay to California.⁴⁶

MERCURY CONTAMINATION

Mercury is a highly toxic chemical, especially to developing nervous systems, and can cause IQ deficits in children. For this reason, fetuses, infants, children, and women of childbearing age are at greatest risk. A 2004 study by the U.S. Centers for Disease Control found that one in 15 U.S. women of childbearing age has blood mercury levels at or in excess of what is considered safe by EPA for developing babies, and some researchers have suggested that this number is even higher.⁴⁷ Adults may also suffer from neurological damage from mercury poisoning and an increased risk of cardiovascular disease.⁴⁸

Mercury increases in concentration as it moves up the food chain and wildlife, fish, and people consume contaminated food. As an example, concentrations in fish tissue can be more than a million times higher than in surrounding water. Though mercury is a naturally occurring element, two-thirds of the mercury cycling in the environment is a product of human activities.⁴⁹ In the Chesapeake region, mercury is responsible for government fish consumption limits in more waters than any other pollutant.⁵⁰ In many cases, these waters are in areas considered “pristine” with very little human activity or industry. If so, then where is the mercury coming from?

The air is one answer. Mercury floats out of the smokestacks of power plants and factories and is washed by rain into the Chesapeake Bay and other waterways. Another source of mercury is contaminated industrial sites.

According to EPA, coal-fired electricity generators are the largest single source of mercury air emissions in the U.S., accounting for more than 40 percent of the pollution.⁵¹ Metal processors and incinerators also produce mercury emissions. Thousands of pounds of mercury are emitted from power plants in Pennsylvania, Virginia, and Maryland each year, and added to this is airborne mercury from other regions that blows into, and is deposited in, the Bay watershed. Pennsylvania receives among the highest rates of mercury pollution of any location in the northeastern U.S.⁵² A recent study indicated that eight to 13 micrograms (one microgram is less than one ten-millionth of an ounce) of mercury per square meter were deposited in Pennsylvania in 2006 from rain and snowfall.⁵³ Although it might not seem like much, this amount of mercury deposited annually onto a 25-acre lake is enough to make fish unsafe to eat.

Fish advisories are issued by the states to warn residents that concentrations of mercury are being found at levels in fish that may present a human health risk and to recommend safe consumption amounts. According to EPA, the number of advisories across the country for mercury increased from 2,436 in 2004 to 3,080 in 2006.⁵⁴ Most states have issued mercury advisories and 35 of them apply statewide.

In the Chesapeake region, governments have issued statewide fish consumption advisories for mercury for all lakes and rivers in Pennsylvania and Maryland, and for many rivers in Virginia. This advisory includes consumption of rockfish from the Bay. In Virginia, there are 1,351 miles of rivers and streams; 38,493 acres of lakes; and eight square miles of Virginia's portion of the Chesapeake Bay that are impaired for mercury.

Unfortunately, despite warnings from the government, strong evidence exists that the majority of the more than two million anglers in the region are not fully aware of public health risks. A survey conducted by Virginia Tech researchers on anglers fishing in Baltimore, Washington, D.C., and the Hampton Roads/Norfolk area found that between 30 and 40 percent of them were not aware of existing consumption advisories.⁵⁵ This result was confirmed in a more recent study by Virginia Commonwealth University (VCU) that focused on Virginia anglers. This report found roughly half of anglers were unaware of advisories.⁵⁶ The VCU study also indicated that roughly 38 percent of the survey participants were consuming mercury from caught and purchased fish at doses that exceed EPA's warning level.

Surveys conducted in Pennsylvania highlight the fact that some ethnic groups may be at even greater risk of exposure to contaminated fish.⁵⁷ Two-thirds of the Vietnamese and Cambodian shore anglers from the greater Philadelphia region were found to have consumed wild fish from the Delaware River above the Pennsylvania recommended limit. Both ethnic groups were also least aware of the fish consumption advisory, with only about 15 percent of these anglers knowing about the warning.

HUMAN-CAUSED SOURCES OF MERCURY

Coal-fired power plants produce about 40% of the human-caused mercury emissions in the United States. Other sources are coal-fired boilers (10%), burning hazardous waste (5%), and chlorine production (5%). Burning municipal waste and medical waste was once a larger source of emissions, but EPA and state regulation have cut this source by 85-90%. Old "legacy" pollution from industrial spills, mining, and landfills also continue to release mercury to the environment. The relative contribution of these sources can vary by the part of the country under consideration. For example, mining is a major source of mercury in the Western U.S. Coal-fired power plants and industrial spills are likely the largest sources in the Chesapeake Bay Watershed.

The main human-caused sources include:

- Coal-fired power plants
- Coal-fired boilers
- Hazardous waste incinerators
- Chlorine (chlor-alkali) production plants
- Gold mining
- Cement, steel, iron, and other manufacturing
- Use and disposal of consumer products through wastewater treatment and landfills (dental amalgam, lotions, tooth-pastes, soaps and detergents, thermostats, fluorescent light bulbs, batteries, switches and relays, medical instruments)

Source: U.S. Environmental Protection Agency. 2003. "1999 National Emissions Inventory." www.epa.gov/ttn/chief/net/1999inventory.html#final3haps

NITRATES IN DRINKING WATER

The same fertilizers and nutrients—notably nitrogen—that cause algal blooms and “dead zones” in the Chesapeake Bay also contaminate the drinking water wells of many rural and farming families.⁵⁸ Years of farming and applying fertilizers, along with the use of excess manure or chemical fertilizer, can result in the pollution of groundwater that eventually flows into streams and the Chesapeake Bay. Rainfall over fields can also flush fertilizer directly into surface streams, which also empty into the estuary.⁵⁹

Dr. Conrad “Dan” Volz, director of the Center for Healthy Environments and Communities at the University of Pittsburgh’s Graduate School of Public Health, is among the scientists who maintain that there is clearly a connection between the quality of drinking water and of water in streams, rivers, and the Chesapeake Bay.⁶⁰ This link is especially clear in Pennsylvania’s lower Susquehanna River basin.

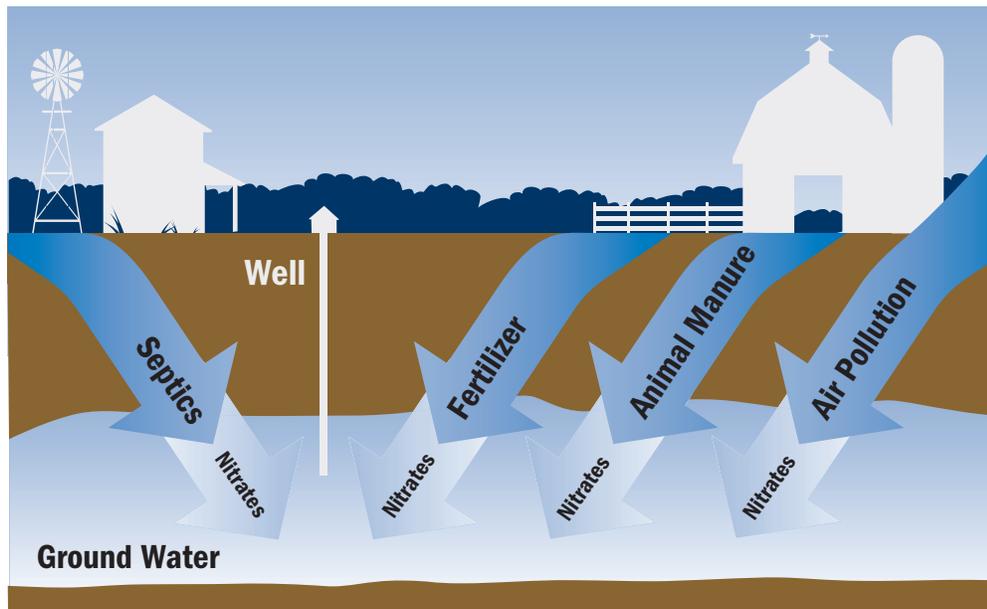
Nationally, about 43 million people, or 15 percent of the American population, drink water from private wells, including many in rural areas of Maryland, Pennsylvania, and Virginia.⁶¹ Private wells are not tested by the government, nor protected (as public drinking water systems are), by health standards set in the Federal Safe Drinking Water Act.⁶² About four percent of private drinking wells sampled across the country by U.S. Geological Survey (USGS) in a recent study had levels of nitrates higher than the public drinking water standards.⁶³ Those failing the standard nationally are most commonly found in farming areas, where about 25 percent of home wells sampled in areas of “relatively intense agricultural land use” have nitrate levels above the federal public drinking water standard of 10 mg/liter of nitrates.⁶⁴ Elevated concentrations of nitrates in drinking water “usually originate from man-made sources, including fertilizers, livestock, and septic



Dr. Conrad "Dan" Volz
Director
Center for Healthy Environments
and Communities at the
University of Pittsburgh's
Graduate School of Public Health

“People need to understand that surface water and ground water are connected, particularly in that part of Pennsylvania....All the nitrates are eventually going to go downstream into the Chesapeake Bay.”

NITRATE CONTAMINATION OF PRIVATE WELLS



FAMILY ANGRY ABOUT DRINKING WATER CONTAMINATION



Mark and Diane Thomas with daughter Mullaney and son Mark Jr. outside their barn in Delta, Pennsylvania. Photo by Tom Pelton

Mark Thomas, a major in the Maryland Air National Guard, is an Iraq war veteran, and he expects to be deployed overseas again soon to fight for his country. But where he also wants to fight is right at home: against his own government for failing to protect his family's water supply and health.

"I'm extremely disappointed that neither our state nor our federal governments are looking out for the citizens of this country," said Thomas, as he stood in his kitchen in Delta, Pennsylvania, and shook his head in disgust at a glass of tap water contaminated with nitrates and bacteria.

The Thomas family has a lot of company in having drinking water from private wells that fails public health standards.

Recent studies found that between 21 and 60 percent of wells tested in Pennsylvania's Lower Susquehanna River basin had levels of nitrates exceeding public drinking water standards.

Almost half of the wells sampled in rural Pennsylvania, mostly in the region surrounding the southern Susquehanna, also tested positive for coliform bacteria, an indicator of possible contamination from a variety of sources, and 12 percent tested positive for *E. coli*, a fecal bacteria, according to a 2002 USGS study.

Some bacterial contamination can cause diarrhea and digestive illnesses. And according to some studies, elevated levels of nitrates (a compound found in fertilizer and animal waste) have been linked to higher cancer rates and spine deformities in infants, among other health problems.

Thomas, 46, his wife Diane, 44, and their daughter Mullaney, 12, and son Mark, Jr., 7, moved almost four years ago from Maryland into their quaint 19th century farmhouse on 19 acres of land in York County not far from the Susquehanna River.

When they first moved in, they had their well tested and found the water had slightly more nitrates than would meet the EPA's public drinking water maximum contaminant level of 10 mg/liter. Their well had 11 mg/liter nitrates. Then they had the water tested again in March 2007, and the nitrates had jumped to 22 mg/liter, according to an analysis by Master Water Conditioning Corp.

Coliform bacteria, which can come from feces, soil, or other sources, also began showing up in their water. A report from a private lab, Analytical Laboratory Services Inc., in September 2008 advised the family not to drink the tap water, saying it violates EPA drinking water standards and "is considered bacteriologically nonpotable." However, *E. Coli*, a fecal bacteria considered one of the more significant coliform threats to human health, was not detected.

Because of the nitrate and coliform bacteria contamination, the family has switched to bottled water and is looking into buying an expensive filtration system for their home—a common expense for rural families in this area.

Mark Thomas worries about his family's health, because they drank the water for two years. And he blamed the water quality problems on manure that a neighboring hog farmer sprayed on his fields as fertilizer.

The Chesapeake Bay Foundation can not independently verify the source of the pollution in the family's well water. But the family lives in a heavily agricultural area.

Thomas said he called the U.S. Environmental Protection Agency (EPA) to complain about the runoff pollution, and ask why the agency isn't taking action by stop it, or pushing the state of Pennsylvania to act. "Apparently, they aren't willing to do anything about it," he said of the EPA, his voice rising in frustration.

State and federal laws today provide few protections for the drinking water quality of people who own private wells, unlike people on public water systems. However, the EPA, under the federal Clean Water Act, has the authority to regulate the manure management of hog farms and livestock operations.

David Sternberg, a spokesman for EPA, said the agency does not have a record of Thomas' call, but will now try to contact him. "I'm not questioning Mr. Thomas' credibility, but if he did call, it did not get to the right place," Sternberg said. "We will do our best to address the situation."

Soon after the Chesapeake Bay Foundation contacted the EPA on April 20 to ask about the family's complaint, the agency called the family and said they would meet with the Pennsylvania Department of Environmental Protection to discuss the matter.

Lauri Lebo, a spokesman for state Department of Environmental Protection (DEP), confirmed that her agency received a complaint about hog waste near the Thomas home. "Runoff and groundwater contamination are very important issues to the DEP," Lebo said. But she added: "Finding the point source for elevated nitrates is a very difficult issue, because of the history of agricultural use in the area."

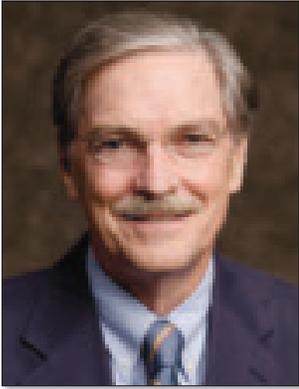
For over 15 years, Pennsylvania has required all farms to have manure-management plans designed to reduce contaminated runoff. In 2005, the state expanded the requirements to include not only farms that generate manure but also receive fertilizer from other farms. The Commonwealth also in 2007 enacted the Resource Enhancement and Protection Act of Pennsylvania (REAP) which gives state income tax credits to farmers who adopt conservation measures, like planting crops without fertilizer in the offseason to absorb extra nutrients, and creating protective strips of forested land along streams.

These and other agricultural conservation practices appear to be helping, as nitrogen concentrations in the Susquehanna River as it flows out of Pennsylvania into the Chesapeake Bay declined in the period 1985 to 2007, according to the U.S. Geological Survey.

Although these improvements have been made, much more reduction of nitrogen pollution is needed before Pennsylvania meets its own goals to clean up the Chesapeake Bay.

Mark Thomas believes his state must do still more to reduce excessive spreading of fertilizer, because the health of rural families like his is tied to the health of the estuary.

"Pennsylvania needs to get a heck of a lot more serious about the runoff, and the condition of drinking water and the streams," Mark Thomas said. "Because all that feeds into the Chesapeake Bay."



Dr. Robert Lawrence
Director
Center for a Livable Future
Johns Hopkins Bloomberg
School of Public Health

"We need to end this practice of hyper concentration of animal waste in delicate ecosystems," Dr. Lawrence said. "From both a public health perspective and an ecological perspective, the current system is unsustainable."

systems," the USGS study states.

A study of 29 wells in the Delmarva peninsula showed that about one third had nitrate levels above the public drinking water standards.⁶⁵ And a 2006 USGS report found that the highest nitrate levels in the entire region from New Jersey to Alabama were in Pennsylvania's Lower Susquehanna River Basin, where 60 percent of wells tested exceeded the public drinking water standard.⁶⁶ This section of Pennsylvania is vulnerable to drinking water contamination because it has intensive agriculture, and the limestone bedrock is perforated, so pollutants can sink down into underground drinking water supplies.⁶⁷

A study released in January 2009 by a public policy agency of the Pennsylvania General Assembly called the Center for Rural Pennsylvania, found that 2 percent of 701 wells tested statewide had nitrate levels in excess of the public drinking water standard, but the "concentrations were significantly higher in the southeast and south central regions."⁶⁸ On the western side of the lower Susquehanna River, in York County, 30 percent (3 of 10 wells tested) failed the nitrate standard. On the eastern side of the river, in Lancaster County, 21 percent (4 of 19 wells) failed. In an earlier sampling effort funded by the U.S. Department of Agriculture, 78 percent of 125 Lancaster County wells tested failed the public health standard for nitrates in 1991 to 1992, as did 10 percent of 80 York County wells.⁶⁹ A scientist who helped with both reports, Bryan Swistock, a hydrologist at Penn State University College of Agricultural Sciences, said he believes better management of fertilizer by farmers could be leading to lower levels of nitrates in drinking water. But he added that it is difficult to determine a clear trend, or compare past studies to his most recent study, because different wells were analyzed, and in the cases of York and Lancaster Counties, the number of wells sampled was too small to reach a meaningful conclusion.⁷⁰

Some studies have shown a positive association between nitrate levels in drinking water and higher risks of cancer, as well as deformities of the nervous systems and brains of infants, while others have not shown such an association.⁷¹ EPA warns that long-term exposure to nitrates above the maximum contaminant level of 10 mg/liter can cause hemorrhaging of the spleen and improper functioning of the kidneys.⁷² The Pennsylvania Department of Environmental Protection is not aware of any studies that have examined the possible health impacts of nitrogen in drinking water on residents in the Lower Susquehanna River area.⁷³

Pennsylvania is one of only two states, along with Alaska, that lacks any regulations governing the construction and protection of private drinking wells, although some counties and townships have adopted local ordinances.⁷⁴ Meanwhile, over three million rural and suburban Pennsylvania residents get their drinking water from private wells, and another 20,000 new wells are drilled each year in the state. One approach to addressing this issue is a volunteer-based education and testing program for well owners, established by the Center for Rural Pennsylvania, called the Master Well Owner Network. From 2004 to 2008, this network of volunteers engaged over 20,000 Pennsylvania homeowners, providing information on the proper construction, protection, and testing of private wells.⁷⁵ Between 50 and 80 percent of all participants surveyed were able to avoid unsafe water through voluntary actions, such as treating their water, installing new well caps, and keeping fertilizers and pet waste at a safe distance from wells. Despite the obvious value of this kind of education, however, up to 78 percent of the well owners who took part in the program said they supported the creation of new regulations to govern the

construction and location of wells, as well as the certification of well drillers.

Dr. Robert Lawrence, director of the Center for a Livable Future at the Johns Hopkins Bloomberg School of Public Health, said more research needs to be done to determine the extent of illnesses caused in the Chesapeake region by nitrates and other contaminants in rural drinking water, because today there is very little surveillance of the issue or good data.⁷⁶ He believes that better management of manure and fertilizer would likely help the health of both farm families and the Chesapeake Bay. Dr. Lawrence said improvements should include tighter regulation and monitoring of animal-intensive agriculture, which tends to produce lots of manure. More broadly, he believes more careful and conservative application of fertilizer on farms would help.

CONCLUSIONS

The Chesapeake Bay is a treasured and complicated ecosystem. With a watershed that houses roughly 17 million people spread out over 64,000 square miles in six states plus the District of Columbia, there are a tremendous variety and number of sources of pollution in our rivers, streams, and Bay. Most of this pollution comes from our actions, and that this pollution can hurt not only our water quality but also our own health.

The Chesapeake Bay suffers from too much nutrient pollution. This coupled with global warming and increasing water temperatures is creating a system that is increasingly attractive to algae and bacteria, both of which can impact human health. One potentially dangerous species of bacteria, *Vibrio*, appears to be causing a rising number of infections in Virginia and perhaps also in Maryland. Mercury from manmade sources, primarily power plants, is pervasive in our rivers, streams, and the Bay. In fact, concentrations in fish are so high that the states have issued advisories for most of the Bay's rivers and streams recommending limited consumption. Nitrates can be found in levels exceeding safe public drinking water standards in many rural wells. The big picture is that water pollution is something that damages not only aquatic grasses, oysters, and fish. It may also put at risk the health of the Chesapeake region's citizens.

Although some of the facts about the Bay's condition sound bleak, there are some encouraging signs, too—including a rebound in the number of blue crabs. President Obama's May 12, 2009, Executive Order that declared the Chesapeake a "national treasure" and committed the federal government to a stronger role in its cleanup is another hopeful sign. As EPA considers over the next few months what steps the federal government should take to restore the Bay's health, the Chesapeake Bay Foundation urges the agency and Bay area states to take strong action to reduce pollution and its potential threat to human health.

Specifically:

- EPA should create a strong and enforceable cap (called a Total Maximum Daily Load or TMDL) on nitrogen, phosphorus and sediment pollution entering the Bay. This TMDL must have teeth and include penalties for parties that violate the pollution limit.
- EPA should start requiring numeric limits for nitrogen, phosphorus and sediment pollution in municipal stormwater permits. These limits should be set at levels consistent with water quality standards that protect the health of receiving water bodies.
- EPA should deny the issuance of permits for sewage plants, factories, power plants, construction projects, and other potential sources of additional nutrient and mercury pollution.

Our Bay and its rivers and streams support an intricate web of life. Cleaner water will mean not only a healthier environment; it will also help ensure healthier swimmers, boaters, anglers, and rural families.

END NOTES

- ¹ Data on beach advisories, shellfish bed closures, and fish consumption guidelines provided by the Maryland, Pennsylvania and Virginia departments of health and environment.
- ² U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program Science and Technical Advisory Committee report, *Climate Change and the Chesapeake Bay*, published in September 2008, Preliminary estimates. p.5.
- ³ See note 2 above.
- ⁴ U.S. EPA Chesapeake Bay Program *Bay Barometer 2008* report, http://www.chesapeakebay.net/content/publications/cbp_34915.pdf. p.5.
- ⁵ *Vibrio vulnificus* information: CDC website: http://www.cdc.gov/nczved/dfbmd/disease_listing/vibriov_gi.html. And WebMD: <http://emedicine.medscape.com/article/232038-overview>.
- ⁶ *Vibrio parahaemolyticus* information: http://www.cdc.gov/nczved/dfbmd/disease_listing/vibriop_gi.html.
- ⁷ *Vibrio cholera* information: CDC website: http://www.cdc.gov/nczved/dfbmd/disease_listing/cholera_gi.html.
- ⁸ Most of the cases were *V. vulnificus* or *V. parahaemolyticus*: Interview on April 2, 2009, with Dr. Clifford Mitchell of Maryland Department of Health and Mental Hygiene. Virginia information: April 2, 2009, email from Michelle Peregoy, spokeswoman for the Virginia Department of Health's Office of Epidemiology.
- ⁹ History of *Vibrio* research and description of *Vibrio* lifecycle: March 7, 2009, interview with Dr. Rita Colwell, former director of the National Science Foundation from 1998 to 2004 and currently Distinguished University Professor at the University of Maryland, College Park and the Johns Hopkins Bloomberg School of Public Health.
- ¹⁰ Anwar Huq, Rita Colwell and colleagues, *Ecological Relationships Between Vibrio cholerae and Planktonic Crustacean Copepods*, published in January 1983 in the journal *Applied and Environmental Microbiology*. pp. 279-283. Vol. 45, No. 1.
- ¹¹ Rosa R. Mourino-Perez and colleagues, *Growth of Vibrio cholerae O1 in Red Tide Waters off California*, published in 2003 in *Applied and Environmental Microbiology* pp. 6923-6931. Vol. 69, No. 11.
- ¹² Interview with Dr. Rita Colwell, March 7, 2009.
- ¹³ Concentration of *Vibrio* an important factor in infection risk: interview with Dr. Anwar Huq, Research Professor at the University of Maryland Pathogen Research Institute, March 23, 2009.
- ¹⁴ Reported vibrio infection data from the Virginia Department of Health. 2008 figures are provisional.
- ¹⁵ Reported *Vibrio* infection data from the Maryland Department of Health and Mental Hygiene. 2008 figures are provisional. According to the state agency, this means the numbers have been reviewed and are not likely to change, but have not been completely finalized and approved. Reporting requirements changed in 2003. Before January 20, 2003, non-cholera *Vibrio* infections were reportable by laboratory directors. After January 20, 2003, these infections were reportable by health care providers.

- ¹⁶ *Vibrio* mortality figures from the Virginia Department of Health and the Maryland Department of Health and Mental Hygiene.
- ¹⁷ An unknown number of cases could have come from people eating or handling shellfish from out of state: Interview with Dr. Clifford Mitchell, Director of Environmental Health Coordination at Maryland Department of Health and Mental Hygiene, April 2, 2009.
- ¹⁸ U.S. EPA Chesapeake Bay Program's Science and Technical Advisory Committee 2008 report, *Climate Change and the Chesapeake Bay*. p. 33.
- ¹⁹ J.B. McLaughlin and colleagues at the Alaska Department of Health and Social Services, *Outbreak of Vibrio parahaemolyticus Gastroenteritis Associated with Alaskan Oysters*, published in October 2005 in *New England Journal of Medicine*. pp. 1463-1470. Vol. 3589, No. 1.
- ²⁰ Jaime Martinez-Urtaza and colleagues, *Environmental Determinants of the Occurrence and Distribution of Vibrio parahaemolyticus in the Rias of Galicia, Spain*, published in *Applied Environmental Microbiology* in January 2008. pp.265-274. Vol. 74, No. 1.
- ²¹ Interview with Dr. Rita Colwell, March 7, 2009.
- ²² Maryland Department of Natural Resources web site on harmful algal blooms: <http://www.dnr.state.md.us/Bay/hab/microcystis2.html>.
- ²³ U.S. Centers for Disease Control website: <http://www.cdc.gov/hab/cyanobacteria/facts.htm>.
- ²⁴ Peter J. Tango and Walt Butler, *Cyanotoxins in Tidal Waters of the Chesapeake Bay* published in 2008 in the journal *Northeastern Naturalist*. pp. 403-416. Vol. 15, No. 3.
- ²⁵ Worse blue-green algal blooms in the 1960s: Maryland Department of Natural Resources website: <http://www.dnr.state.md.us/bay/hab/microcystis.html>.
- ²⁶ Telephone interview with Dr. Clifford Mitchell of the Maryland Department of Health and Mental Hygiene, April 2, 2009.
- ²⁷ Peter J. Tango and Walt Butler, *Cyanotoxins in Tidal Waters of the Chesapeake Bay* published in 2008 in the journal *Northeastern Naturalist*. pp. 403-416. Vol. 15, No. 3.
- ²⁸ See note 27 above.
- ²⁹ See note 27 above.
- ³⁰ See note 27 above.
- ³¹ Location and number of blooms in 2008: Maryland Department of Natural Resources "Eyes on the Bay" website: http://mddnr.chesapeakebay.net/hab/HAB_archive.cfm#picview. Email from Catherine Wazniak of the Maryland Department of Natural Resources, April 17, 2009.
- ³² Location of bloom in Virginia in 2008: Email from Bill Hayden, Public Affairs Director Virginia Department of Environmental Quality, April 17, 2009.
- ³³ Trends difficult to discern: Interview and March 19, 2009, email from Peter J. Tango, Chesapeake Watershed Monitoring Coordinator for U.S. Geological Survey, March 23, 2009. Telephone interview with Dr. Clifford Mitchell, April 2, 2009.
- ³⁴ See note 27 above.
- ³⁵ See note 27 above.
- ³⁶ Increase likely due mostly to more searching: Email from Dr. Peter Tango, March 20, 2009.

- ³⁷ U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program Scientific and Technical Advisory Committee report, *Climate Change and the Chesapeake Bay*, published in 2008. p. 32.
- ³⁸ See note 37 above.
- ³⁹ Data provided by Pennsylvania, Maryland, and Virginia departments of health and environment.
- ⁴⁰ Interview with Dr. Geoffrey Scott, director of NOAA's Center for Coastal Environmental Health and Biomolecular Research, March 23, 2009.
- ⁴¹ Beach testing procedures, Maryland Department of the Environment website: <http://www.marylandhealthybeaches.com/>.
- ⁴² Interview with Dr. Thaddeus K. Graczyk, Associate Professor at the Johns Hopkins Bloomberg School of Public Health, April 3, 2009.
- ⁴³ See note 42 above.
- ⁴⁴ Deidre Sunderland, Thaddeus K. Graczyk, and colleagues, *Impact of bathers on levels of Cryptosporidium parvum oocysts and Giardia lamblia cysts in recreational beach waters*, published in *Water Research* in 2007. Data from figures two and three.
- ⁴⁵ Interview with Kathy Brohawn, Chief of the Shellfish and Beaches Program at the Maryland Department of the Environment, April 3, 2009.
- ⁴⁶ EPA newsletter, "Water Headlines for April 20, 2009...EPA Conducts Studies to Improve Safety of Swimming at Beaches" <http://www.epa.gov/nheerl/near/>.
- ⁴⁷ *Blood Mercury Levels in Young Children and Childbearing-Aged-Women, 1999-2002*, published, November 4, 2004, *MMWR Weekly*.
- ⁴⁸ J.M. Hightower and D. Moore, "Mercury levels in High-End Consumers of Fish," *Environmental Health Perspectives*, 2003. And Virtanen, J.K., et al, "Mercury, Fish Oils and Risk of Acute Coronary Events and Cardiovascular Disease," *Arteriosclerosis, Thrombosis, and Vascular Biology*, 2005.
- ⁴⁹ U.S. EPA Mercury Study Report to Congress, 1997.
- ⁵⁰ Fish consumption guidelines from Maryland, Virginia, and Pennsylvania departments of health and environment.
- ⁵¹ National mercury information from EPA web page.
- ⁵² Mercury Deposition In Pennsylvania: *2006 Status Report* by James A. Lynch, Hunter C. Carrick, Kevin S. Horner, Jeffrey W. Grimm. Lake contamination estimate: extrapolating from the "1 gram onto a 20-acre lake" statistic based on the deposition in PA. The figure of one gram per 20-acre lake is based on a 1992 study by the Minnesota Pollution Control Agency that found that virtually all of the mercury in Minnesota lakes is the result of atmospheric deposition (through precipitation and dry deposition on particulate matter), at a rate of 12.5 micrograms per square meter per year.
- ⁵³ See note 52 above.
- ⁵⁴ EPA national listing of fish advisories: <http://www.epa.gov/waterscience/fish/advisories/2006/index.html>.
- ⁵⁵ Joshua C. Gibson and Julie A. McClafferty, Virginia Tech University, *Chesapeake Bay Angler Interviews—Identifying Populations at Risk for Consuming Contaminated Fish in Three Regions of Concern*, prepared for EPA Chesapeake Bay Program, 2005.

- ⁵⁶ Virginia Department of Environmental Quality, *Virginia Mercury Study*, 2008: http://www.deq.state.va.us/export/sites/default/regulations/pdf/Final_hg_Report_11_12_corrected_no_append.pdf.
- ⁵⁷ Ann Faulds, Nancy Connelly and colleagues, *Patterns of Sport Fish Consumption at Six Pennsylvania Sites Along the Tidal Portion of the Delaware River With Special Emphasis on Shore Anglers*, prepared for the Pennsylvania Coastal Zone Management Program, 2004.
- ⁵⁸ Interview with Dr. Robert Lawrence, director of the center for a Livable Future at the Johns Hopkins Bloomberg School of Public Health, March 13, 2008.
- ⁵⁹ Interview with Conrad “Dan” Volz, Director of the Center for Healthy Environments and Communities at the University of Pittsburgh’s Graduate School of Public Health, March 25, 2009.
- ⁶⁰ See note 59 above.
- ⁶¹ Leslie A. DeSimone and colleagues at U.S. Geological Survey, *Quality of Water from Domestic Wells in Principal Aquifers of the United States, 1991-2004*, released in March 2009 <http://pubs.usgs.gov/circ/circ1332/includes/Circular1332.pdf>.
- ⁶² Private wells not tested by the government: U.S. Centers for Disease Control and Prevention website on drinking water: <http://www.cdc.gov/healthywater/drinking/private/wells/faq.html>.
- ⁶³ See note 61 above.
- ⁶⁴ See note 61 above.
- ⁶⁵ Linda M. DeBrewer and colleagues of the U.S. Geological Survey, *Temporal Trends in Nitrates and Selected Pesticides in Mid-Atlantic Ground Water*, published in 2008 in the *Journal of Environmental Quality*. pp. S-296-308. Vol. 37.
- ⁶⁶ Bruce D. Lindsey and colleagues at U.S. Geological Survey, *Factors Affecting Occurrence and Distribution of Selected Contaminants in Ground Water from Selected Areas in the Piedmont Aquifer System, Eastern United States, 1993-2003*, released in 2006.
- ⁶⁷ Interview with Bruce Lindsey, hydrologist with the U.S. Geological Survey in Pennsylvania. March 9, 2009.
- ⁶⁸ Center for Rural Pennsylvania, *Drinking Water Quality in Rural Pennsylvania and the Effect of Management Practices*, released in January 2009: http://www.ruralpa.org/drinking_water_quality.pdf.
- ⁶⁹ Interview with Bryan Swistock, hydrologist at Penn State University College of Agricultural Sciences, March 20, 2009. Email from Swistock, April 30, 2009.
- ⁷¹ Mary H. Ward of the National Institutes of Health and colleagues, *Workgroup Report: Drinking Water Nitrate and Health—Recent Findings and Research Needs*, published in *Environmental Health Perspectives*, November 2005. pp. 1607-1614. Vol 113, No. 11.
- ⁷² EPA Consumer Fact Sheet on Nitrates: http://www.epa.gov/OGWDW/contaminants/dw_contamfs/nitrates.html.
- ⁷³ Telephone interview with Lauri Lebo, spokeswoman for the Pennsylvania Department of Environmental Protection, April 21, 2009.
- ⁷⁴ See note 68 above.
- ⁷⁵ See note 68 above.
- ⁷⁶ Interview with Dr. Robert Lawrence, director of the Center for a Livable Future at the Johns Hopkins Bloomberg School of Public Health, March 13, 2009.

HOW THIS REPORT WAS COMPILED

Chesapeake Bay Foundation Senior Writer Tom Pelton wrote this report after interviewing more than 20 experts on water pollution, bacteria, and human health and after reviewing scientific papers and requesting data from Virginia, Maryland, and Pennsylvania health departments and environmental agencies. The opinions in this report are those of the scientists interviewed and quoted.

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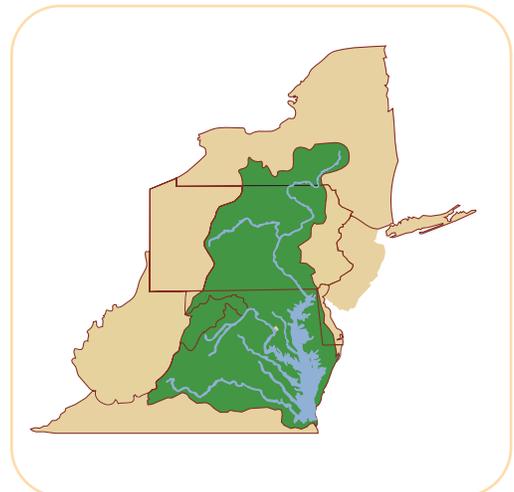
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CHESAPEAKE BAY WATERSHED



The Chesapeake Bay's 64,000-square-mile watershed covers parts of six states and is home to more than 17 million people.