Medicine, Medicine Everywhere

by Ronit Abramson

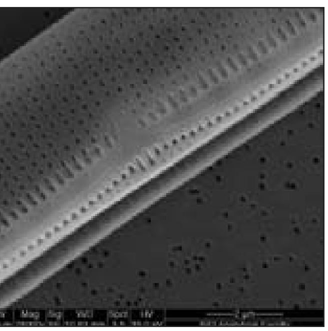
For many years, the toilet bowl has been the recommended venue for medication disposal. It may sound like a good solution, keeping pets and children from accidentally ingesting harmful drugs—but recent studies have shown that flushing our unwanted drugs isn't good for the environment or humans. ISEF winner Ronit Abramson takes a look at how seemingly harmless things, like taking a Tylenol, can have an impact on the environment.

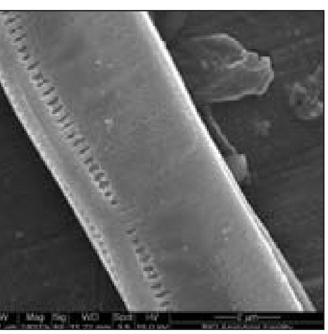
Two years ago, when I saw a newspaper editorial arguing for a disposal system for unused pharmaceuticals, the issue of pharmaceuticals in waterways was rarely mentioned in the media. Preliminary data from a survey of pharmaceutical products in American waterways, conducted by United States Geological Survey (USGS) scientists, had just been quietly released. But for the public, the problem had largely not been realized.

Most people assume that once you swallow a pill, it is absorbed by your body. While our bodies do use some of the medication, between 30 and 90 percent passes through the body and is flushed into the sewage system. In addition, estimates by the Pharmaceutical Research and Manufacturers of America suggest that between three and seven percent of dispensed medications go unused. In many cases these are also washed down the sink or toilet. Although wastewater is treated before being released into the environment or recycled back to people's homes, the process does not remove all drug residues, allowing drugs to end up in our lakes, rivers, oceans, and drinking water.

Discarded medicines are also contained in runoff from local landfills. This polluted rainwater empties into waterways directly or via storm drains.

Another source of pharmaceutical runoff comes from medicines administered to animals. In livestock and fish, antibiotics are commonly used to reduce infections, and synthetic hormones to stimulate growth. These drugs are excreted as waste that is either washed away into natural waterways, or collected and used as fertilizer for crops, where it seeps into the soil and runs off into bodies of water.





A diatom cell before antibiotic exposure (top) and after (bottom). Note the loss of the cell's normal texture after exposure.

Altered States

Individual quantities of these drugs may be small, but some are slow to degrade and often become chronic pollutants in waterways. Pharmaceuticals have been detected in bodies of water worldwide. A recent Associated Press investigation found that at least 46 million Americans have traces of pharmaceuticals in their drinking water.

Continuous exposure to low levels of drugs can affect the behavior and physiology of aquatic organisms, such as triggering fish to mate during the wrong seasons, so that offspring are born in winter when they cannot survive the cold temperatures. Even over-the-counter drugs such as acetaminophen (the active ingredient in Tylenol) or ibuprofen (Advil and Motrin) have turned up in bodies of water, and can alter pigments of aquatic plants so that the cells are unable to conduct photosynthesis.

We know that overuse of antibiotics leads to the development of antibiotic-resistant bacterial infections, yet we could be getting a small dose of antibiotics with every sip of water we take. The growth of antibiotic-resistant bacteria in our waterways could eventually render bacterial diseases worldwide untreatable and uncontrollable.

Consider E. coli found in contaminated water supplies or uncooked poultry. If you are infected, the standard treatment is antibiotics. But if that bacterial cell has been growing in a body of water containing antibiotics, or in a chicken that has been drinking antibiotic-contaminated water, it is increasingly possible that antibiotics will be ineffective against your illness.

When I began studying the topic, most research on the effects of pharmaceutical runoff on organisms had been conducted via simple observation of ecosystems, for example, downstream from a pharmaceutical production plant or hospital. Some such studies revealed male fish with female organs, and sick and decaying plant life. These anecdotal observations were then confirmed by lab experiments that controlled all other variables except the addition of drugs to the water.

Chemical analyses of water composition, however, are conducted with laboratory equipment that is both costly and limited in availability. Government organizations such as the USGS and city environmental health departments have assumed most of the responsibility for testing and maintain the protocols necessary to conduct the analyses. But if pharmaceuticals are such a significant aquatic pollutant, then why isn't there more widespread testing? I was amazed at how shocked people were when I raised the issue, and how many times I was fervently interrogated by those who didn't realize that pharmaceuticals could actually be polluting our water supply.

Canary in a Coalmine

For a science fair project, I decided to investigate biological indicators, living organisms that can detect pollutants in the environment. I had heard my biology teacher talk about bio-indicators before, but I had just filed it away as one of the definitions I would have to learn to pass freshman biology. Now it began to click: Bio-indicators could eliminate the extravagant costs and complicated analysis procedures plaguing current testing methods. And bio-indicators are better evaluators of cumulative changes in water composition because they go through entire lifecycles in water conditions, while abiotic testing—chemical testing methods—provide only a snapshot of current conditions.

A rudimentary example of a bio-indicator is the canary in a coalmine, in which a canary was sent into the mine to indicate when poisonous gases made it too dangerous for miners to descend. Coral reefs are modern day bio-indicators of the health of our oceans, sensitive to temperature and oxygen-level changes. Bio-indicators demonstrate the effects of a pollutant on organisms, whereas abiotic testing only suggests that the contaminant is present.

I began studying different organisms that have been used as bio-indicators. My biology textbook contained a magnification of a sample of stream water showing the many organisms suspended in a single drop. One of them was a diatom, a single-celled photosynthetic alga. The intricate formations in the highly magnified microscope pictures were what first caught my eye, but then I learned that diatoms are found in virtually all water sources. They are the basis of many aquatic food chains and have been used to indicate the presence of metals in water. I found a report saying that certain aquatic plants showed distinct changes when grown in water containing a mixture of pharmaceuticals; however, I could not find any previous research on the use of diatoms as bio-indicators of pharmaceuticals.

After reviewing the procedures of other diatom studies and petitioning help from scientists around the country—who had expertise ranging from aquatic ecosystem dynamics to the nanostructure of algal cell walls—I designed a procedure for my project. It was simple and homemade, but all mine. I created microcosms, or "mini-ecosystems," to mimic a freshwater stream environment and introduced varying amounts of pharmaceuticals. I then took samples of the diatom communities in each microcosm, observing the changes in species present in the population, as well as changes that occurred on the cell wall surface. The most significant finding was a diatom species that, when exposed to the antibiotic ampicillin, grew with a smooth surface, with its usually patterned pores visually absent.

Raising Awareness

I entered my findings in the Greater San Diego Science and Engineering Fair and, while low-tech and home-grown, my project started to change people's views. For some it was a completely new concern. Others were interested in the potential for more widespread testing that my project created. Throughout the judges' extensive questioning, I was able to defend my claims with scientific research and showed that not only were these drugs affecting diatoms, but also that the diatoms showed potential as bio-indicators.

The many hours of hard work that went into building my project were worth it. I won the top award at my regional fair, and advanced to the California State Science Fair and the Intel Science and Engineering Fair. My project had begun with an interest in an issue and progressed into a real science research project. Pharmaceutical runoff is an important issue, and I was able to educate people about the need for more widespread testing and prevention efforts. Perhaps someday, my research will enable anyone to go to a nearby stream and, by looking at the diatom community, determine whether pharmaceutical products may be present.

I continued my project this year at the Scripps Institution of Oceanography at the University of California, San Diego, working alongside graduate and doctoral students who showed me the realities of working in a university lab—from the dynamics of sharing lab equipment when several experiments are running simultaneously, to the patience and analytical mindset required when results don't turn out as expected. I used a scanning electron microscope for my subsequent research, and am currently working with scientists on the use of algae to produce an alternative fuel source.

I have realized my passion for science and research, and am working to help other students discover the incredible opportunities in science research through outreach to local San Diego schools. Science holds the potential for many solutions to world problems, but it is up to the next generation to discover them. And a science fair is a great way to start. **i**

Ronit Abramson at ISEF.

Ronit Abramson is a senior at Canyon Crest Academy in San Diego, CA. She is the 2008 Arctic Ambassador for the San Diego Zoo, traveling to Canada as part of an international group to study polar bears and climate change. She is Co-Chair of the Student Advisory Board for the Greater San Diego science and engineering fair, as well as president of the Inquiry Club, an organization that encourages students to pursue research opportunities in science and engineering.