Brianna Rego was born in Antigua, Guatemala, grew up in Idaho, and is a graduate student in history of science at Stanford University. A paper she published in 2009 on the tobacco industry's research on polonium—part of her Ph.D. thesis—was distributed to members of Congress by the National Center for Tobacco-Free Kids to help the passage of landmark legislation on smoking.

PUBLIC HEALTH

Radioactive Smoke

The tobacco industry has known for decades how to remove a dangerous isotope from cigarettes but has done nothing about it. The government now has the power to force a change

By Brianna Rego

In November 2006 former KGB operative Alexander Litvinenko died in a London hospital in what had all the hallmarks of a cold war–style assassination. Despite the intrigue surrounding Litvinenko's death, the poison that killed him, a rare radioactive isotope called polonium 210, is far more widespread than many of us realize: people worldwide smoke almost six trillion cigarettes a year, and each one delivers a small amount of polonium 210 to the lungs. Puff by puff, the poison builds up to the equivalent radiation dosage of 300 chest x-rays a year for a person who smokes one and a half packs a day.

Although polonium may not be the primary carcinogen in cigarette smoke, it may nonetheless cause thousands of deaths a year in the U.S. alone. And what sets polonium apart is that these deaths could be avoided with simple measures. The tobacco industry has known about polonium in cigarettes for nearly 50 years. By searching through internal tobacco industry documents, I have discovered that manufacturers even devised processes that would dramatically cut down the isotope's concentrations in cigarette smoke. But Big Tobacco consciously decided to do nothing and to keep its research secret. In consequence, cigarettes still contain as much polonium today as they did half a century ago.

The situation may be about to change, however. In June 2009 President Barack Obama signed the Family Smoking Prevention and Tobacco Control Act into law. The legislation brings tobacco for the first time under the jurisdiction of the Food and Drug Administration, allowing the agency to regulate certain components of cigarettes. Forcing the industry to finally remove polonium from cigarette smoke would be one of the most straightforward ways to start making cigarettes less deadly.

IN BRIEF

Tobacco plants accumulate small concentrations of polonium 210, a radioactive isotope that mostly originates from natural radioactivity in fertilizers.

Smokers inhale the polonium, which settles in "hot spots" in the lungs and can cause cancer. Its effects may lead to thousands of deaths a year in the U.S. alone.

The tobacco industry has known for decades how to virtually eliminate the polonium from cigarette smoke but kept its knowledge secret and failed to act.

The Food and Drug Administration now has the authority to regulate tobacco and could begin to use it by forcing manufacturers to reduce polonium content.

Photograph by Kevin Van Aelst

HOT SPOTS

THE FIRST HINT that polonium 210 was making its way into the lungs of smokers came almost by chance. In the first half of the 1960s the health effects of radiation, and in particular of radioactive fallout, were very much on the minds of scientists—as well as on the minds of most other people. At the time, radiochemist Vilma R. Hunt and her colleagues at the Harvard School of Public Health were developing a technique to measure very low levels of radium and polonium, the two elements discovered by Pierre and Marie Curie in 1898. As Hunt recalls, one day in 1964 her gaze was wandering around the lab when it paused on the cigarette ash of one of her colleagues. On a whim, she decided to test the ash with her new technique.

When she saw the results, she was astonished to find no signs of polonium. Trace concentrations of radioactive isotopes are common in the environment and contribute to the natural radiation background. No other organic material Hunt had researched, including plants, had tested negative for polonium when radium was present. But at the temperatures of smoldering tobacco, polonium turns into vapor. So, she suddenly realized, the missing polonium must have gone up in smoke! And that meant smokers would inhale it directly into their lungs.

Hunt, along with her Harvard colleague Edward P. Radford, published the discovery—with direct measurements of polonium in cigarette smoke—in *Science*. Soon others at Harvard were studying polonium both in cigarettes and in the lungs of smokers. In 1965 radiobiologist and physician John B. Little examined lung tissue from smokers for signs of polonium. The task was not easy. Getting tissue samples from living smokers would have been too invasive, so he had to work on cadavers. "The problem is that the mucosal lining of the lung after someone dies decays within two to three hours," he says. He had to extract it soon after death, which involved many dashes to the hospital at all times of day and night. Little was able to demonstrate that polonium did in fact collect in specific areas of the lung. Because of the way our airways branch into bronchi, bronchioles and alveoli, the radioisotopes settle and concentrate at the points of bifurcation. There they form "hot spots" of radioactivity, emitting alpha particles.

Over the next 10 years scientists continued to research polonium in cigarette smoke and also how the radioisotope gets into the tobacco plant itself—and thus at what stage of the cigarette-manufacturing process it could be most effectively taken out. Polonium 210 is a decay product of lead 210; in their 1964 paper Radford and Hunt had speculated on two possibilities: either the daughter isotopes of natural atmospheric radon 222, including lead 210, settled on the leaves, or lead 210 in fertilized soil was absorbed through the plant's roots. As it turned out, both were true.

Researchers at the U.S. Department of Agriculture took up the question of polonium from fertilizer. A 1966 experiment by the USDA and the Atomic Energy Commission tested two different kinds of fertilizers, a commercial "superphosphate" one and a special mix made from chemically pure calcium phosphate. The differences were remarkable. The commercial fertilizer had about 13 times more radium 226 than the special mix, resulting in nearly seven times more polonium in the leaves. Edward Martell of the National Center for Atmospheric Research in Boulder, Colo., revisited this issue in 1974. Martell suggested that soils containing uranium-rich phosphate fertilizer would release radon 222 into the surrounding atmosphere, raising its concentration above normal levels. The radon would then decay into lead 210, which would deposit on the growing plants, sticking to the thousands of little hairs called trichomes that cover tobacco leaves.

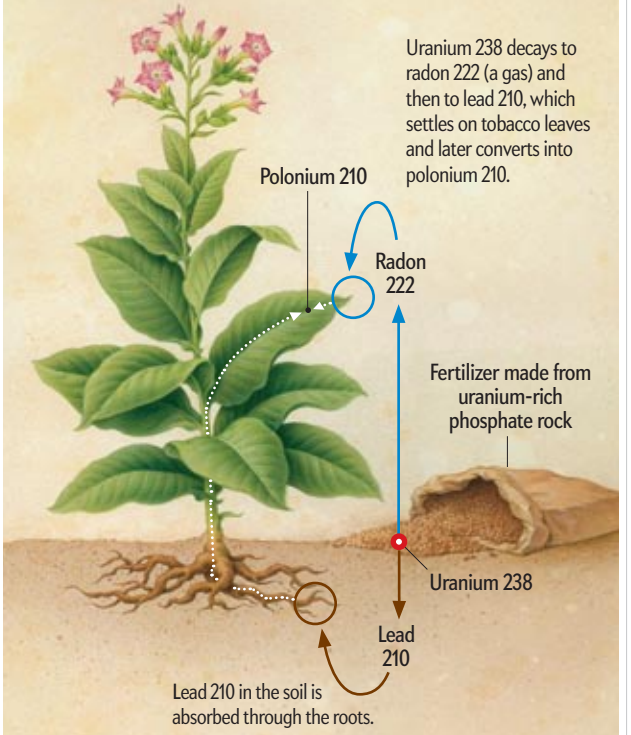
Like the Harvard group, Martell was also concerned with the buildup of polonium 210 in particular areas of the lung. It had been generally accepted for some time that exposure to radiation from radon "daughters" was the principal cause of elevated cancer risk in uranium miners. Thus, he reasoned that because of smokers' chronic exposure to low, concentrated doses, polonium 210 was likely the primary cause of their lung cancer and perhaps—as he suggested later—of other types of cancer as well.

As in the case of miners, the danger would come not with a high dose at any given time but, rather, with continued exposure

PROBLEM/SOLUTION

How Polonium Creeps into Tobacco

Polonium 210 is one of many decay products of uranium. Uranium occurs naturally in the soil—but in much higher concentration in phosphate rock from which fertilizer is made. Researchers have discovered two pathways leading from uranium to polonium in tobacco: through the air and through the roots.



The Solutions

Research by tobacco manufacturers has shown that combinations of the following measures could virtually eliminate polonium 210 from cigarette smoke:

- Add chemicals to tobacco so polonium 210 does not vaporize and get inhaled
- Switch to low-uranium fertilizer
- Wash leaves after harvest
- Use ion-exchange cigarette filters to capture polonium
- Genetically engineer the tobacco plant to have "hairless" leaves

Illustration by Cherie Sinnen

to small doses over an extended period. A smoker stockpiles his or her supply of polonium with each drag; therefore, the high exposure associated with a lifetime of smoking would leave the smoker at a risk for cancer despite the relatively low dose of polonium 210 per cigarette. In 1974, after forcing polonium into the tracheas of hamsters, Little and fellow Harvard scientist William O'Toole were able to confirm that hypothesis: 94 percent of hamsters in the highest-exposure group developed lung tumors with doses so small that their tissues showed no inflammation.

Since then, of course, other components of cigarette smoke have also been found to be powerful carcinogens, and today most experts would probably say that the main ones are chemicals such as polycyclic aromatic hydrocarbons and nitrosamines. Still, conservative estimates based on risk from radiation exposure suggest that polonium 210 may be responsible for 2 percent of smoke-induced lung cancers, and thus for several thousands of deaths a year in the U.S. alone. Moreover, some experts point out that the effects of radiation damage and of other carcinogens probably exacerbate one another. To Big Tobacco, polonium seemed dangerous enough to require extensive studies.

"NO COMMERCIAL ADVANTAGE"

IN CONTRAST to external scientists, industry scientists never publicized or published their research on polonium. But in the 1990s historic lawsuits brought by 46 U.S. states against the industry forced manufacturers to admit that smoking is dangerous and addictive, and resulted in the release of millions of internal documents. Thousands of those documents showed that polonium had long been widely discussed in the tobacco industry, all the way up to its highest ranks.

The original Radford and Hunt paper appeared only a few days after the surgeon general's landmark warning on the risks of smoking issued on January 11, 1964. In the immediate wake of these two announcements, internal memos show that the tobacco manufacturers were concerned that they might suffer a public affairs disaster if what they knew about polonium came to light. Aware of this risk, the industry soon began to devote extensive manpower and money to developing internal research programs on polonium, which operated behind closed doors.

ANSWER POLL AND SEE DECLASSIFIED DOCUMENTS
ScientificAmerican.com/jan2011/polonium

A flurry of Philip Morris documents from the late 1970s and early 1980s revealed that scientists and executives debated whether the company should publish its own research. That debate happened during a lull in external scientific publications—outside the industry, interest in polonium in tobacco has been intermittent—and the tobacco men were wary of disturbing that peace.

In 1977, for instance, scientists at Philip Morris had completed a draft of a paper entitled "Naturally Occurring Radon-222 Daughters in Tobacco and Smoke Condensate," which the authors wanted to submit to *Science*. The director of product development emphasized in a 1978 memo to another Philip Morris scientist that he was wary of publishing the manuscript. That scientist responded: "It has the potential of waking a sleeping giant," he wrote. "The subject is rumbling, and I doubt we should provide facts." What worried Philip Morris's legal department was that despite differing numbers, the proffered manuscript essentially agreed with published research: there is polonium in tobacco, and it *is* harmful. By the middle of July, on advice of the legal department, the manuscript was denied approval for publication.

The tobacco manufacturers, however, continued to monitor external research on the subject and to explore potential solutions to the polonium problem. The industry debated the drawbacks and benefits of various ways to reduce polonium in cigarette smoke, among them adding materials to tobacco that would react with lead and polonium to prevent their transfer to smoke and developing a filter that would block polonium vapor.

Another straightforward option, following Martell's research in the 1970s, was to simply wash the tobacco leaves with a dilute solution of hydrogen peroxide. Yet other ideas included using fertilizers with limited uranium 238 daughter isotopes and removing lead-collecting trichomes from the cured tobacco leaf. "We went as far as trying to genetically modify the tobacco plant" so that the leaves would be smooth, says William A. Farone, a former director of applied research at Philip Morris who later became a whistleblower against the industry's practices and now works as a consultant for the FDA. In 1975 USDA scientist T. C. Tso estimated that 30 to 50 percent of polonium could easily be removed from fertilizer and that washing could eliminate another 25 percent. Adding to that the effects of a filter, the polonium content of tobacco could have been almost completely eliminated. But as a memo from R. J. Reynolds put it, "Removal of these materials would have no commercial advantage."

As is often the case in history, however, the industry's refusal to face a problem has only delayed it. After the Family Smoking Prevention and Tobacco Control Act passed in June 2009, the American Cancer Society lauded it for requiring the tobacco industry to disclose the "poisons in its products." This legislation offers the first opportunity to challenge and force the tobacco industry to act on the results of their years of study.

Polonium would be an excellent first "poison" to ban from tobacco. It is a single isotope, rather than a complex ingredient of smoke. Other poisons—such as tar or carbon monoxide—are difficult to keep out of the smoke, but polonium is not. The industry's four decades of research could give the FDA a head start toward getting concrete results. Moreover, some of the same steps that would reduce polonium concentrations in smoke—such as washing tobacco leaves—might also help remove toxic metals such as lead, arsenic and cadmium. This is precisely the kind of regulation and change the FDA now has the power to enforce.

The World Health Organization has made clear that smoking is the most avoidable cause of death. It estimates that 1.3 million people die of lung cancer worldwide every year, 90 percent because of smoking. If polonium had been reduced through methods known to the industry, many thousands of those deaths could have been avoided. The industry's lawyers made the conscious choice not to act on the results of their own scientists' investigations. But it is the customers who have had to live with—and die from—that decision. SA

MORE TO EXPLORE

Polonium-210: A Volatile Radioelement in Cigarettes. Edward P. Radford, Jr., and Vilma R. Hunt in *Science,* Vol. 143, pages 247–249; January 17, 1964.

Puffing on Polonium. Robert N. Proctor in *New York Times*; December 1, 2006.

The Cigarette Century: The Rise, Fall, and Deadly Persistence of the Product That Defined America. Allan M. Brandt. Basic Books, 2007.

Waking a Sleeping Giant: The Tobacco Industry's Response to the Polonium-210 Issue. Monique E. Muggli et al. in *American Journal of Public Health,* Vol. 98, No. 9, pages 1643–1650; July 16, 2008.

The Polonium Brief: A Hidden History of Cancer, Radiation, and the Tobacco Industry. Brianna Rego in *Isis,* Vol. 100, No. 3, pages 453–484; September 2009.