A Grisly Archive of Key Cancer Data

Meticulous medical records of former East German uranium workers tell a horror story, but they could help settle some long-standing arguments about risks from low-level radiation

Oberrothenbach, Germany—On a warm afternoon, the lake near here looks like the perfect place for a picnic. Set in a green valley amid the Ore Mountains of former East Germany, it's a few minutes' stroll from this tiny village of 370 people. The lake is surrounded by a picturesque meadow and cornfield. But as you get closer a barbed wire fence comes into view, and a small sign with the words: "No Trespassing! Industrial Premises." It was put up in the late 1980s because local people complained that their animals were dying from drinking the lake water—and it's a clue that things aren't as tranquil around here as they seem.

Let's begin with the lake: It contains an estimated 22,500 tons of arsenic—enough to kill everyone in Europe—plus huge amounts of lead, iron, cadmium, sulfuric acid, low-level radioactive materials, and other poisons. And the lake is just a small part of the environmental assault this region has suffered: 500 million tons of chemical and low-level radioactive waste are spread over 1200 square kilometers.

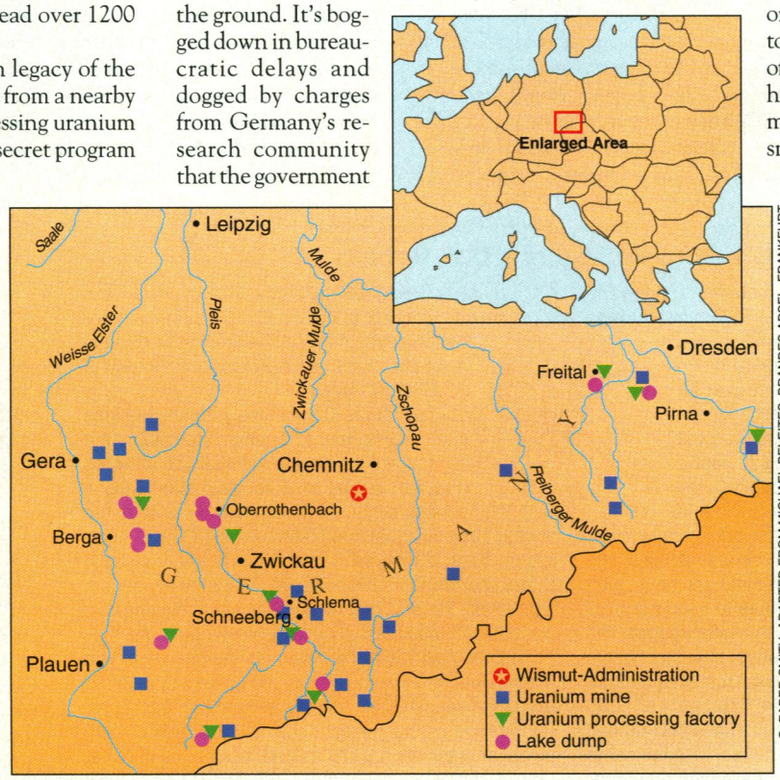
This toxic detritus is a grim legacy of the cold war. The lake was a dump from a nearby "yellow cake" factory for processing uranium ore—part of a massive, highly secret program to supply uranium for the Soviet Union's atomic bomb program. But there's more to the legacy: meticulous—and, until recently, secret—medical records on the 450,000 uranium workers who labored in the region around Oberrothenbach. The records belonged to Wismut, the Soviet-German company that ran the uranium operation, and came to light after the fall of East Germany's communist regime in 1989. They indicate that at least 20,000 miners had already died or were then suffering from lung disease induced by exposure to radiation and dust.

Analyzing the archive will require a "gigantic undertaking," says radiologist Horst Kuni from the University of Marburg, but scientists have high expectations for what it may reveal. Munich physicist Eckhard Krüger describes the archive as "the world's biggest treasure chest of data on radiation and human health." The records could help settle the long-standing debate about cancer risk and low-level radiation. They may hold clues to possible gender differences in cancer risk. And they could provide valuable information about the combined effects of radiation and toxic chemicals. In short, the archive may rank in scientific importance alongside the records of survivors of the Hiroshima and Nagasaki atomic bombs.

The German government plans to sponsor a series of research projects that will use the records to get at some of these questions. The main part of the work—an epidemiological study of the miners—will be the largest ever on people exposed to low-level radiation. In fact, it will be bigger than all other studies of underground miners put together.

But, much to the frustration of many scientists, the research hasn't yet gotten off the ground. It's bogged down in bureaucratic delays and dogged by charges from Germany's research community that the government has avoided involving scientists who don't support its strongly pronuclear views. Says Edmund Lengfelder, a radiologist at the University of Munich, about the ministry sponsoring the studies (which is responsible for environmental, nuclear energy, and radiation issues): "They don't want to cut the legs off the chair they're sitting on."

In a country where the future of nuclear energy is the subject of vigorous debate, it's not surprising that these charges have ignited controversy. But the Wismut records have a special significance in Germany that goes well beyond the scientific community: They're testimony to a very painful past.



C. FABER SMITH, ADAPTED FROM MICHAEL BELEITES, BRANDES APSEL, FRANKFURT

Epicenter. A large region south of Leipzig is now studded with disused uranium mines, abandoned yellow cake factories, and toxic waste dumps.

Sacrifices for the cause

Like other revelations about East Germany's recent past—such as the workings of the feared Stasi (the secret police) and the drugging of athletes—the story of Wismut started to leak out in the late 1980s even before reunification, when a young East German zoological preparer named Michael Beleites risked his neck to document what had been going on. Beleites, who lived in the town of Gera—right in the middle of the Wismut area—published his findings as a church document called *Pechblende* on a smuggled, hand-operated press.

But it was only after the collapse of the communist regime in 1989 that the full horror of the operation became gen-erally known from eyewitness accounts and official documents.

What Beleites uncovered was a horror story with roots going back to the period immediately after the Second World War, when the Soviet Union was desperate to break the U.S. monopoly on the atomic bomb. To do this they needed uranium—and in southern East Germany they found rich deposits and even some operating mines. Working feverishly, by the mid-1950s the Soviets had built Wismut into a huge enterprise employing 150,000 people, most in underground mines and some in factories

that extracted uranium from the ore and processed it into yellow cake. Although there were many forced laborers in the early years, coercion quickly proved to be unnecessary—with food and work in short supply after the war, workers were lured by high salaries and access to well-stocked company stores, privileged housing, and other "extras" like cheap cigarettes and "Bergmannschnapps," a 32% alcohol brew nicknamed miners' death.

In the early years, all that mattered was getting the most ore in the shortest time—a credo that led to nightmarish conditions in the mines. The air was full of radon and other radioactive breakdown products of uranium, most of which are alpha emitters—highly potent carcinogens when inhaled, since they continuously irradiate tissues along the respiratory tract. Miners were also exposed to high levels of dust, which helped transport radioactive particles into the lungs, and to a slew of chemical poisons, especially arsenic. It was only in the mid-1950s that Wismut began to introduce ventilation and "wet drilling" techniques to keep down the dust—safety features that were introduced much earlier in other countries. But the workers often turned off the ventilation to cut down on noise, and more regular use of safety measures came about only gradually.

The result: "kumpels sterben früher"—miners die young—as the local wisdom went. About 15,000 died of silicosis, a deterioration of lung tissue caused by inhaling dust, and about 6000 of "Schneeberger's disease," a form of lung cancer named after one of the region's mining towns, according to figures from the Berufsgenossenschaft, the organization that provides insurance for the miners. Karl Martignoni, scientific director of the Federal Office of Radiation Protection and coordinator of the government studies, says that new lung cancer cases will continue to arise for years to come, and he estimates that the final number will be in the range of 10,000 to 15,000. The University of Marburg's Kuni, who has treated people from the affected region, points to other diseases that might come from occupational exposure—for example, kidney disease, especially among workers in the processing factories, and other types of cancer—but says that the available data are still sketchy.

When East Germany's communist government fell in 1989, the local people demanded an airing of Wismut's records. "Everyone assumed the files would show how Wismut knowingly sent thousands of people to their deaths, and went to incredible lengths to cover it up," says Beleites. And they also feared that in the chaos following the government's collapse the collection might get broken up or even deliberately destroyed. Enter Joachim Krause, a chemist and environmental expert for the Protestant Church in Sachsen, a center of political opposition to the communist regime. The West German government asked Krause to ensure that the archive was preserved.

A treasure trove of data

Over the next 6 months Krause traveled to the dozens of Wismut-associated hospitals and clinics in the region, compiling a complete list of the records and arranging for their safe-keeping. He found files on about 450,000 workers in all—yearly medical exams, lung x-rays, hospital visits, all recorded "with German precision," as Martignoni told *Science*. There were also detailed autopsy reports and preserved samples of lung tissue from nearly all the miners who died of lung cancer. The archive also contained an item that says a lot about how Wismut operated: the "Erzgeld" [ore money] files—lists of extra payments and privileges given to workers exposed to the most radiation.

HEINRICH DRACH

Risked his neck. Michael Beleites publicized Wismut's operations even before the regime fell.

This makes the Wismut archive the world's biggest data collection on low-level radiation and health—and potentially one of the most valuable for studying the associated cancer risks. Until now, risk estimates have been based largely on data from the Hiroshima and Nagasaki survivors, who were exposed to a single, high dose of whole body radiation. But the body may not respond the same way to localized, low radiation doses, or to the same dose spread out over a long time. "We have all these models about how to modify the Hiroshima data to make it fit low-dose situations [such as that in uranium mines]," says Marvin Goldman, a radiation biologist from the University of California, Davis, and a member of the U.S. National Council on Radiation Protection (NCRP). "The jury is still out on what the right model should be." But, he adds, the Wismut archive contains precisely the kind of data that could help settle the debate. In particular, the data could lead to better risk estimates for radon, a radioactive gas that is one of the most important sources of exposure to natural radioactivity for the general population, notes Warren Sinclair, executive director of the NCRP.

But it's not just the size of the archive that makes it valuable. For one thing, it contains data on many thousands of women that could shed light on possible gender differences in cancer risks. "In the early years a significant proportion of workers exposed to the highest [health] risks were women," says Joachim Breuer of the Berufsgenossenschaft. The "Erzengel"—which means both ore angels and archangels—worked in the mines doing everything except the drilling itself, such as driving underground trains and laying track. Early on they also made up most of the workforce in the yellow cake factories. Says Jay Lubin, a radiation epidemiologist and uranium mining expert at the National Cancer Institute (NCI): "There's no information on the effects of radon in women, none at all. This would be extremely important, not only in mining populations but also how it translates into domestic radon it would be a very unique contribution if women could be followed in these numbers."

Some researchers also believe the Wismut data may shed light on the combined effects of radiation and toxic chemicals, an area that is poorly understood. "One unit of radiation means something different now than it did in 1950, because of the synergy between different carcinogens," says Lengfelder at the University of Munich. "It's very misleading to look at radiation and neglect the chemicals." Adds radiation biologist Albrecht Kellerer, also at the University of Munich: "With these very high exposures [of the Wismut miners]—and they were extremely high—the question of synergism is urgent and important."

Planned studies

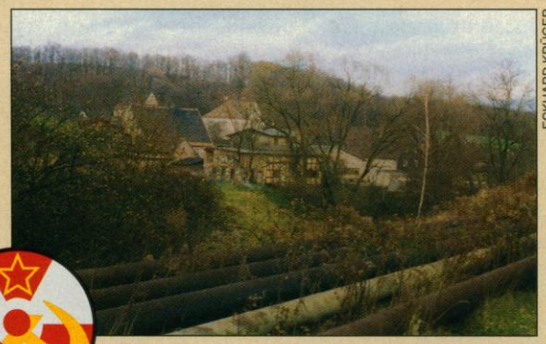
The research planned by the German government will focus on the medical fate of the miners. Epidemiologists will follow up on 100,000 miners, some who have already died and others who are still living, asking whether as a group they show increased incidence of any specific diseases.

The first part of the study will entail collecting and computerizing the medical data. Much of this work is already being done by the Berufsgenossenschaft, which is using the Wismut records to track down the 200,000 living ex-miners and factory workers and offer them medical care, giving priority to workers exposed to the highest risks. "What's so unusual here," says the organization's Breuer, "is that we have a huge group of people and their background stories, and on top of that we'll be monitoring their health for the rest of their lives and adding the results into the database." This information, along with data on miners who have already died, will form the basis for the epidemiological studies.

The next task will be to figure out which diseases are linked to the mining, and then to determine the culprit. Says Goldman: "You're looking at events that happen naturally, look-

Widespread Contamination, Widespread Risk

As epidemiologists get ready to study the medical records and the fate of former uranium workers in eastern Germany (see accompanying article), people living in the region are concerned that the massive uranium mining and processing operation has also left the general population with a legacy of health hazards. And public health concerns are heightened by the fact that, while uranium mines are usually located in remote regions, the former East German mines are smack in the middle of one of Europe's most densely populated areas.



ECKHARD KRÜGER

Not idyllic. Pipes carrying uranium waste pass houses on their way to lake.

One of the biggest potential health risks comes from exposure to radon, a breakdown product of uranium. Some homes are partially built out of earth from the mines, while others sit right on top of old mines. The result: Thousands of homes have radon levels above the recommended limit of 250 Bequerels per cubic meter of air. Indeed, one home registered 115,000 Bequerels.

The widespread contamination of the region with toxic chemicals such as arsenic, heavy metals, and strong acids and bases, poses another potential threat to public health. Villages like Oberrothenbach that have toxic lake dumps nearby have another problem—sand from the lake's shores which is laced with chemicals and radionuclides such as radium. Until 1990, when the shores were covered over, villagers in Oberrothenbach tried to stay indoors on windy days because the vicious sand storms caused painful burning in the nose and throat.

So far, the government has planned only one research project on public health hazards in the region. Researchers will investigate whether the apparently high rates of lung cancer in two villages are linked to high domestic radon levels. But some researchers argue that more should be done. Wolfgang Köhnlein, a radiation epidemiologist at the University of Münster, suggests starting by looking at statistics like the incidence of childhood cancer—"a sensitive indicator that something may be going on"—and at general mortality data. The task might be less daunting than it sounds, because people in the region's small villages have traditionally not moved away. Birth and death records from the local hospitals would therefore be a promising place to start.

Lurking behind concerns about the environmental and public health hazards afflicting the general population is a touchy question: Who will pay for the cleanup and the medical costs? The federal government says it will spend around 15 billion DM (about $9 billion) to clean up the mines, factories, and dumps that belonged to Wismut—the company that ran the uranium operation—but critics say the amount is unrealistically low. And it isn't clear who will pay for cleaning up the rest—the contaminated land that Wismut "returned" to the communities years ago, the polluted water supplies, and the homes with high radon levels.

To many former East Germans, this hard side of the Western system comes as a bitter dose of reality. Says Sebastian Pflugbeil, physicist-turned-senator in Berlin and one of the dissidents who helped bring out the Wismut story before reunification: "This so-called Aufklärung [bringing out the truth about Wismut] has been a bad experience, one we [East Germans] hadn't expected." Adds Joachim Krause, a chemist who played a key role in securing the Wismut medical records after the East German regime collapsed: "I can't avoid the nasty thought that if you...look at the whole problem then you have to be ready to solve it—the cleanup, the health problems—and you have to be prepared to pay for it."

–P.K.

ing for increases in frequency. The arguments are all statistical. That's why the size of the study [the number of people and length of observation] is so important." To make a cause-and-effect connection, data from the miners will be compared to data on a group of nonminers closely matched in age, gender, socioeconomic status, lifestyle, and so on.

But there's a big "if" in all this: Can researchers figure out how much radiation each worker was exposed to? There are useful measurements for the later years, but less and less data going back in time. All that remains from Wismut's first decade are some data on radiation levels in the mines, together with geological data and technical information such as what ventilation systems were used in which mines—information that could be of help in estimating worker exposures during the all-important early years when exposures were highest. But the catch is that these records are in Moscow, and the Russians are asking "a fantastic price" for their return, says the University of Munich's Kellerer, who is advising the government on the Wismut studies.

To estimate radiation exposures in workers who have died, researchers will rely on Wismut's personnel files detailing where a miner worked and for how long, together with any information about radiation levels in that particular mine. It's an approximate method, but often the best that can be done in studies of miners, according to NCI's Lubin.

For miners who are still living, the prospects of making accurate individual dose estimates are much better, thanks to a battery of new "biological dosimetry" techniques. "These methods can be used retrospectively, to look at a person's cumulative exposure," says Goldman, although he points out that some of them are still "laboratory oddities... which haven't hit the market yet." For the Wismut studies, the government is pinning big hopes on a method that determines cumulative exposure to radon by measuring the accumulation of its more long-lived breakdown product, Pb-210, in the skull. Another possibility, says Goldman, is to measure electron spin resonance signals in tooth enamel—since the enamel doesn't turn over during a person's lifetime, it registers all the radiation it ever encountered.

Delay and controversy

All of this is still in the planning stage, however—and that's a source of frustration to many scientists. More than a year ago, the government invited German researchers to apply for research contracts. But none was awarded, and the selection has been delayed until later this year. There's also no formal agreement yet on data sharing between the government and the Berufsgenossenschaft, which is collecting the health data. "We scientists are beginning to get impatient," says Kellerer. "If not for the Berufsgenossenschaft, nothing would have been done." Part of the problem may be inertia. Says Martignoni: "Public pressure is decreasing. People in the west are fed up with problems in the east. They say it always costs money. And easterners are overwhelmed with more immediate problems."

But slowness isn't the only thing the government is being criticized for—there's also controversy over how it's set up the studies. Decisions about the Wismut projects—what should be done, how it should be organized, and who should do the work—are made by the ministry of the environment, which is also Germany's nuclear regulatory agency, with input from their standing scientific advisory committee. But, says physicist Krüger: "[It's] missing the involvement of anyone who is critical of low-dose effects and risk estimates, critical about nuclear energy."

Critics also point out that there's been no peer review of the research plan, a common practice in the United States. And they argue that there are built-in conflicts of interest in the planning of the Wismut studies because the same scientists who advised the government on what projects should be done can apply for funds to do them. Kellerer, one of the scientific advisers, recognizes the problems with these arrangements but says that separating the tasks completely is difficult in Germany because there simply aren't enough researchers in radiation and epidemiology.

One solution some scientists favor is to involve researchers from outside Germany, either as reviewers or as direct participants in the work. Says Krüger: "There should be an internationally sponsored and monitored research effort, similar to what was done with the Japan data. Most important, it should involve independent scientists."

But the controversies surrounding Wismut go beyond nuclear energy, to the trauma of "a dark and difficult chapter of history," says Kellerer. Wismut was more than a uranium operation—it was an all-powerful state within a state, with its own secret police, Communist Party, and propaganda machine, dedicated to concealing what was happening. If this weren't hard enough to come to grips with, "we also need to face the fact...that most people went along and at least passively supported [Wismut]. That's what made the whole thing possible," says Beleites.

–Patricia Kahn

Patricia Kahn is a science writer based in Heidelberg, Germany.

RADIATION RISKS

Researchers Eager to See Soviet Data

In the early days of the cold war, Soviet atom bomb workers poured so much radioactive sludge into the Techa River in Siberia that today—40 years later—the entire waterway is untouchable. A person who managed to penetrate a wire fence and stroll on the river banks would enter a zone where radiation levels reach 1 rem per hour. That's enough to give a person in one morning the dose a U.S. worker is allowed to receive in a year. Nearby, other disasters—the explosion of a storage tank and the evaporation of a waste lagoon—have spread radionuclides over 27,000 square kilometers. Like the devastation left by uranium mining and processing in former East Germany (see previous story), this massive environmental mess is part of the legacy of Stalin's race to build the bomb. And in the aftermath of the cold war, scientists are learning the full extent of the damage—particularly the human toll.

Some of the most interesting data from the region has been put together by a group of Russian doctors, who disclosed recently that for decades they have been collecting health data on thousands of people in the military area of Chelyabinsk, near the Techa River. They now hope to collaborate openly with Westerners to reconstruct one of the largest accidental human "experiments" in history.

The Chelyabinsk tragedy ranks in scale with the best-known of all in the nuclear era: the atom bomb blasts in Japan. But, unlike the Japanese, who were exposed to a short, intense burst of radiation, the peo-ple of Chelyabinsk were exposed to low doses over a long period from a variety of environmental sources. Like the East German records, the data from Chelyabinsk could therefore be important in settling a bitter debate over whether the Japanese data overstate or understate the risks from lower radiation dose rates. For this reason, experts of every stripe in the United States are eager to get their hands on the files. By any measure, says Marvin Goldman, a biophysicist at the University of California, Davis, "this is a potential gold mine of data," if the information can be validated.

The data were collected by a team headed by Mira Kossenko, a Russian physician at the Institute of Biophysics Branch Number 4 (Chelyabinsk). Until recently, this information on one of the world's worst environmental catastrophes had not been given to the public. But in May, breaking a decades-long silence, Kossenko presented her findings at a conference organized by Russian doctors and the Physicians for Social Responsibility (PSR), a U.S. group that focuses on nuclear risks. In December, she published the results for the first time in PSR's journal, reporting that she had found 37 cases of leukemia in an exposed population of 28,000.* According to Kossenko, this represents a statistically significant increase in deaths, as compared with two control populations nearby that were not on the Techa River. However, after analyzing the doses these people received, she concluded that their risk of getting leukemia was much lower than that for survivors of the Hiroshima-Nagasaki blasts.

These findings support a benign view of certain radiation effects—namely, that a given dose of radiation is less risky if received over an extended period of time. That will be potentially good news for the U.S. Department of Energy (DOE): The United States is now poised to spend billions of dollars to clean up its own nuclear weapons sites to prevent environmental exposures of the low-dose-rate type, but it is currently pegging the cleanup to safety standards based on the high-dose-rate effects seen in Japan. Perhaps for this reason, DOE, manager of the U.S. nuclear weapons program, is eager to fund more research on the Chelyabinsk data. But leaders of PSR argue that DOE has too much at stake to serve as a sponsor. Speaking for PSR, David Rush, an epidemiologist at Tufts University, said, "DOE involvement presents a conflict of interest."

Ironically, the weapons community may be best qualified to solve some of the deep-rooted problems remaining in the Chelyabinsk data—such as poor information on individual exposures. Goldman, himself a DOE-funded scientist, claims DOE people have the world's greatest expertise in estimating doses, and he favors a collaboration between DOE's technicians and epidemiologists at other agencies. By using new indices—such as the electron spin resonance of tooth enamel or fluorescence-labeled chromosome aberrations—it ought to be possible, Goldman says, to reconstruct biological events that occurred even 30 to 40 years ago. But at the moment it's not clear who, if anyone, will be reconstructing the Chelyabinsk doses.

The Russians are preoccupied just now with mere survival, and their government may not be eager to investigate the Chelyabinsk tragedy in great detail—particularly if it leads to demands for reimbursing the injured. Meanwhile, according to Goldman, who visited Branch Number 4 of the Biophysics Institute last year, other mundane perils lurk. For example, many irreplaceable records are stored at Chelyabinsk on paper in cardboard files, and Russian researchers are fond of tobacco. He would hate to see the gold mine go up in smoke. He, among others, is eager to see the Russians transfer their data to computerized form, where they would be safer and easier to share with Western scientists.

–Eliot Marshall

*"Estimate of the Risk of Leukemia to Residents Exposed to Radiation as a Result of a Nuclear Accident in the Southern Urals," by Mira M. Kossenko, Marina O. Degteva, Nelly A. Petrushova, in *The PSR Quarterly* **2**, 187 (December 1992).