Fifteen years after the world's worst nuclear accident, the entire population of Belarus is involuntarily taking part in a decades-long experiment on how radiation affects human health

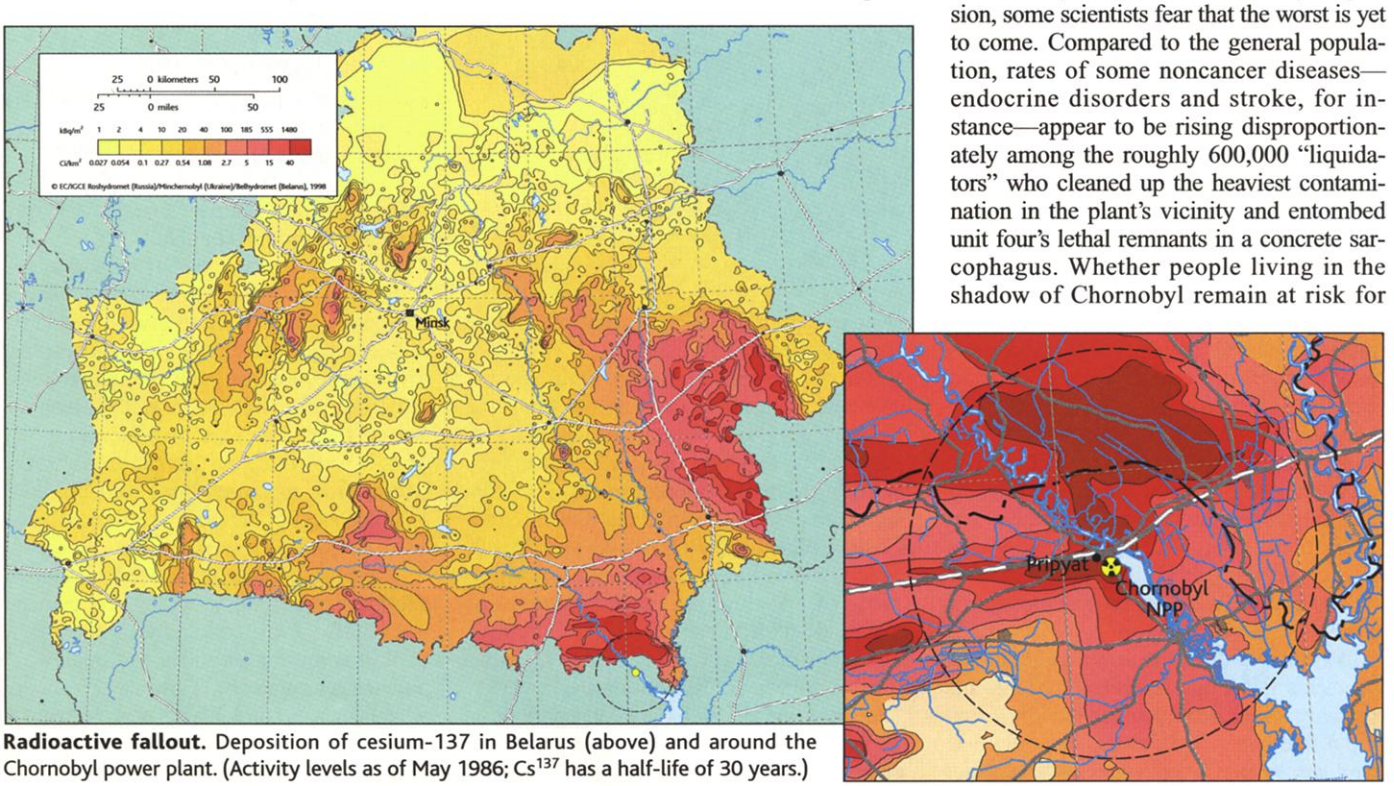
Living in the Shadow Of Chornobyl

MINSK, BELARUS, AND KYIV, UKRAINE—Early on a warm, sunny morning on 26 April 1986, Valeriy and Natasha Glygalo went to buy groceries at the open-air market of Pripyat, a Ukrainian town near the Belarusan border. Despite the splendid weather, Natasha began to feel strange: She had an odd, bitter taste in her mouth. Valeriy, a nuclear physicist and safety officer at the Chornobyl Nuclear Power Plant, missed that early clue to the unfolding disaster. "I was smoking and didn't taste anything," he says. Moments later, however, a babushka told them that an explosion had rocked the power station just a few kilometers south of Pripyat. With mounting dread, Valeriy rushed to the edge of town, where from the top of a bridge he could see clearly the gigantic duplex housing the plant's third and fourth reactors. Unit four lay in ruins, as if it had been bombed. Glygalo remembers staring numbly as flames, fed by the graphite rods that had moderated the fission reaction in the uranium fuel assembly, licked above the ruins and smoke poured into the sky. "We never conceived of something like this happening," he says. The fumes swept toward Pripyat and its 50,000 residents, who were inhaling the invisible radioactive particles that coated the town.

The world's worst nuclear accident had begun at 1:23 that morning, when Chornobyl's unit four exploded and sent a plume of radioactive particles 2 kilometers into the air. As the cloud raced northwest, it rained radioactive particles on a swath across Belarus, Poland, the Baltic nations, and into Scandinavia. Over the next 10 days, the reactor pit belched a staggering 100 million to 200 million curies of fission products, about 100 times the amount of radiation released by the atomic bombs dropped on Hiroshima and Nagasaki. Much of it settled on northern Ukraine, southern Belarus, and Russia's Bryansk region, defiling millions of hectares of land. The Chornobyl catastrophe, as it's called in Russian, triggered political unrest in Belarus and Ukraine and halted nuclear power projects, sparking an energy crisis that may well have applied the coup de grâce to a dying Soviet Union.

Chornobyl took a substantial human toll as well. Two plant personnel were killed instantly by the blast, while 28 firefighters and plant workers died horribly days later from radiation poisoning. In Belarus, more than 700 children under the age of 14 have been treated for thyroid cancer—a disease that occurs spontaneously in only one in a million children. "These are incredible numbers," says Japanese thyroid disease specialist Akira Sugenoya, whose 5-year stint working in Belarus has helped convince Western experts that the numbers are real and attributable to a massive exposure to radioactive iodine (see p. 425). Although the disease has one of the highest cure rates of any cancer, four Belarusan children are known to have died after their tumors spread to other organs. What's more, thyroid cancer cases among adolescents in Belarus are still on the rise.

Fifteen years after the Chornobyl explosion, some scientists fear that the worst is yet to come. Compared to the general population, rates of some noncancer diseases—endocrine disorders and stroke, for instance—appear to be rising disproportionately among the roughly 600,000 "liquidators" who cleaned up the heaviest contamination in the plant's vicinity and entombed unit four's lethal remnants in a concrete sarcophagus. Whether people living in the shadow of Chornobyl remain at risk for

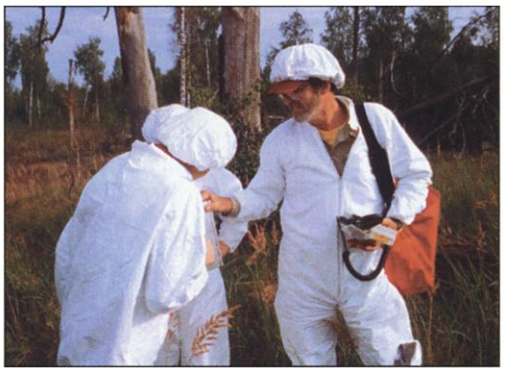


Radioactive fallout. Deposition of cesium-137 in Belarus (above) and around the Chornobyl power plant. (Activity levels as of May 1986; Cs^{137} has a half-life of 30 years.)

Genetic Studies of Wildlife in the Hot Zone Reach Different Conclusions

SLAVUTYCH, UKRAINE—For several months in 1986, Sergei Gashchak was a "liquidator," participating in the hellish work of decontaminating helicopters and trucks used to put out the burning Chornobyl reactor and clean up the aftermath. Since then, he says, "many people who worked with me in the zone [have become] sick." Yet 4 years after the accident, Gashchak, trained as a biologist, returned to the hot zone to study how to reduce exposures of livestock to radioactivity.

Now he's part of a new U.S.-Ukraine laboratory studying wild animals in the exclusion zone. In the 15 years since most people were evacuated from the zone, it has become a refuge for wildlife: Moose, wild boars, endangered black storks, and other species less abundant in other parts of Ukraine are thriving here. "The zone is an excellent place for conservation," Gashchak says. "In the future we may even be able to create an area for wildlife sightseeing." According to radioecologist Ron Chesser of Texas Tech University in Lubbock, "Only the clicks and whistles of our electronic equipment indicate that the habitat is contaminated with radioactivity."



Damage assessment. Ron Chesser in the exclusion zone, roughly a 30-km radius around the plant.

But the zone's vibrant wildlife masks a debate over the genetic health of animals exposed to lingering contamination from Chornobyl. In the early 1990s, a team led by Rose Goncharova and Nadezhda Ryabokon of the Institute of Genetics and Cytology in Minsk found that the chromosomes of bank voles living in contaminated areas were riddled with breaks and rearrangements; the amount of damage roughly correlated with the measured absorbed dose. Even bank voles in control regions near Minsk had DNA damage, although on a lesser scale. "When we began to find an increased level of mutations in control regions, we were shocked," says Ryabokon. Further studies revealed that maps of cesium contamination in Belarus published at the time were flawed: The so-called clean regions, the researchers found, were contaminated, too. Although many scientists believe that low-level exposures are not harmful, the DNA damage, Ryabokon says, suggests that "we have real evidence of biological effects of very low doses of chronic exposure."

Early studies by a team led by Chesser and Texas Tech colleague Robert Baker also indicated genetic damage in animals exposed to high levels of radioactivity. In a 1996 *Nature* paper, they reported mutations in the cytochrome b gene among bank voles in the exclusion zone. However, the team—which is supported by the U.S. Department of Energy—retracted the paper when it was unable to substantiate any increased mutation rate among animals in the zone using improved techniques. Chesser is dubious of the Belarusan team's findings. "If the dose rates near Minsk created chromosome damage to the extent they reported, then the risks due to radiation should be enormous," he says.

Goncharova and Ryabokon suggest that voles in the zone, exposed to intense radiation over 30 generations since the accident, have become "radioresistant": a genetic selection for mechanisms that not only enable individuals to survive in the hot zone but to suffer minimal chromosomal damage. But Chesser and his colleagues tested that theory by bringing in unexposed animals from clean parts of Ukraine and keeping them in cages in the exclusion zone for 30 days. They found no evidence of chromosomal damage or genetic mutations in the imported animals, indicating that they are no more susceptible to radiation than the local animals.

Some high-tech gadgetry is now being brought to bear on the study of wildlife in the zone. In July 1998, the Ukrainian and U.S. governments unveiled an International Radioecology Laboratory in Slavutych. In subsequent months they outfitted it with millions of dollars' worth of brand-new instruments: everything from drying ovens and liquid nitrogen sample containers to a liquid scintillation analyzer for measuring radioactive strontium. But the United States did not kick in operating money for the lab, so for now it's underutilized: The only team that can pay its own way to come to the lab this summer is the Texas Tech group. Goncharova and Ryabokon, meanwhile, don't even have enough funding to continue their experiments, let alone upgrade their only pieces of equipment: two microscopes made in the 1960s in the German Democratic Republic. **–R.S.**

health problems is a subject now under intense scrutiny. And at Chornobyl's epicenter, an international effort is about to embark on an unprecedented engineering project that aims to prevent further release of radionuclides from the sarcophagus (see p. 422).

Chornobyl still haunts the people of Belarus and Ukraine. "The psychological effects are devastating," says physicist Mikhail Malko of the Institute of Physical and Chemical Radiation Problems in Minsk. "Many women feel they will give birth to unhealthy babies or babies with no future. Many people feel they will die from Chornobyl."

Putting a lid on it

On a warm, cloudless day earlier this month, a German shepherd basks in the sun near the bridge leading from Pripyat to the Chornobyl Nuclear Power Plant. Other than the two Ukrainian soldiers guarding a post next to a red-and-white-striped gate that blocks unauthorized access to the town, the lazy dog is the only sign of life in this urban wasteland. The people are gone.

Within hours after Natasha Glygalo got a mouthful of bitter air 15 years ago, she, her son Roman, and nearly all other residents of Pripyat were whisked away by train to nearby Chernihiv or bused to other cities across Ukraine where they had relatives. Some 800 Chornobyl personnel, including Valeriy Glygalo, stayed behind to take stock and deal with the accident. Glygalo was not the only scientist who struggled to come to grips with the enormity of what had oc-

Fifteenth anniversary. Chornobyl's unit four reactor, on fire on 26 April 1986.

CREDITS: (TOP TO BOTTOM) ROBERT BAKER; AP PHOTO/TASS

curred. "It was impossible to imagine that a reactor simply couldn't exist," says nuclear physicist Konstyantyn Rudya, who was working in Chornobyl's unit two reactor building at the time of the blast.

Although radiation monitors in Finland and Sweden had alerted the world to the explosion, Soviet authorities cast a shroud of secrecy over the cleanup and the subsequent studies carried out inside the evacuated "exclusion zone," roughly 30 kilometers in radius, around the power station. Running the show was the Soviet military and the country's premier nuclear research laboratory, the Kurchatov Institute in Moscow. Helicopters dumped sand and boron on the seething remnants of the reactor core to quench the fire—a strategy that backfired, because it raised the temperature so high that the nuclear fuel melted and released even more radionuclides into the environment. Thousands of soldiers dispatched to the zone performed tasks ranging from the mundane—bulldozing more than 1 million cubic meters of contaminated topsoil for disposal as nuclear waste—to the surreally brave: timed dashes onto the roof of the unit three building to shovel chunks of unit four's core into the maw of the destroyed reactor.

Besides putting a lid on reactor four, Communist Party officials studiously maintained a news blackout. But from the start, odd occurrences began to tip people off to what had happened. For example, researchers at the Institute of Genetics and Cytology (IGC) in Minsk had left some unexposed film on a lab bench the night before the accident. The next day, they found their film spotted. "We couldn't understand what happened until we found out about the accident a few days later," when researchers began to whisper about a nuclear explosion, says IGC director Nikolai Kartel. "For a long time we just heard rumors."

Abandoned. "No entry" sign near Gomel (*above*); Bartolomeevka's lonely cemetery, former supermarket, and World War II statue (*right photos*).

A few days after muted celebrations to mark 1 May, recalls IGC geneticist Rose Goncharova, the institute's former director Lubov Khotylyova gathered her senior scientists and explained that the accident had been much worse than the government was letting on. While several institutes started investigating the harm inflicted on the Belarusan popu-

Dealing With a Slumbering Hulk

CHORNOBYL—The black concrete sarcophagus that covers the wreckage of Chornobyl's unit four reactor looks like a fitting mausoleum for the estimated 190 tons of nuclear fuel still in its bowels. But it was never meant to be an eternal resting place. Although designed to last a century, the structure, thrown up in 6 months after the April 1986 explosion, is eroding faster than expected. "The sarcophagus is unstable," says Viktor Baryakhtar, director of the Institute of Magnetism in Kyiv. Even if the sarcophagus does not collapse under its own weight, scientists envision dozens of freak scenarios—ranging from monster snowfalls to earthquakes—that could bring the structure tumbling down. Such a disaster would spread clouds of radioactive dust into the environment and spark an international outcry. "The public response could be even bigger than the response was to the explosion," says Baryakhtar.

Now, after years of false starts and political and scientific wrangling, the Ukrainian government has settled on a permanent solution. A commission headed by Ukrainian Prime Minister Viktor Yuschenko decided earlier this month to erect an arched structure, as big as a baseball stadium, to cover the sarcophagus. "Nothing like this has ever been done before," says Baryakhtar. Indeed, "building it will be a formidable challenge," says Mike Durst, a nuclear engineer with the Pacific Northwest National Laboratory in Richland, Washington. But some Ukrainian experts are unhappy with the decision, arguing that it does not address their government's long-term goal of removing the fuel from inside the belly of the beast and storing it in sealed containers.

Crumbling sarcophagus. Engineers plan to replace the concrete shell because of concerns about its stability.

The sarcophagus, and the estimated 20 million curies of radioactivity it harbors, is a bizarre physics laboratory that has provided disturbing insights into the behavior of molten uranium fuel. "We have all the elements from the periodic table inside the shelter," says Myroslav Holovko of the Institute for Condensed Matter Physics in Lviv, Ukraine. Working over the past decade out of a former kindergarten in Chornobyl, more than 100 scientists with the Interdisciplinary Scientific and Technical Center (ISTC) "Shelter" have risked their lives to probe the warren of rooms beneath the reactor, tracing where the molten uranium fuel flowed after the reactor exploded. At first they believed that up to 50 tons of fuel had gone missing, perhaps dispersed in the environment. But recent studies have reduced that uncertainty to a few tons.

One of the team's more urgent tasks has been to assess the risk that the fuel-containing masses (FCMs)—formed when the lavalike fuel mixed with concrete and other building materials before solidifying—might achieve criticality and explode. This risk increases when water, which speeds up fission reactions, seeps into the sarcophagus. Indeed, following heavy spring rains, detectors in the sarcophagus often register sharp increases in neutron flux. "We observe this phenomenon every year," says ISTC Shelter's Viktor Krasnov. "But these are deeply subcritical reactions," he adds. Nevertheless, Shelter scientists take no chances: They have set up pumps that spray a neutron-quenching solution of gadolinium nitrate at the neutron sources. So far at least, that has quelled the reactions.

Over the past few years, studies of the FCMs have suggested that fears of a full-blown explosion are overblown.

CREDITS: R. STONE

lation, Khotylyova asked her staff to prepare a major research program on Chornobyl's effect on wildlife. By August, Goncharova and her colleagues were out collecting bank voles and other animals in central and southern Belarus (see p. 421).

Some institutes closer to the blast found themselves thrust into a scary new role. Located only 30 kilometers north of the exclusion zone, "our institute had a very bad fate," says Vladimir Baginsky, director of the Institute of Forestry in Gomel. A few days after the accident, a five-person team led by Ivan Bulavik hurriedly set up experimental plots near the zone and took plant and soil samples. The land was already becoming contaminated, but they would have something resembling baseline data when more fallout rained down in subsequent days. They risked their lives, says Baginsky: "Graphite was falling on them," he says, "but Bulavik would be too modest to admit this."

That May, Bulavik met with his Ukrainian and Russian counterparts to sketch out a research program on how the forests were affected by the huge doses of radioactivity. In the coming months, they discovered that the forests had concentrated far more radionuclides than had the surrounding farmlands, which were more readily cleansed by rain. "The forest played the role of a vacuum cleaner," Baginsky says. And contradicting models based on nuclear accidents in the Ural Mountains, the Gomel modelers predicted that radionuclide accumulation in the forests would worsen over time. By the mid-1990s, "we observed that the forest began to be contaminated more and more," as trees continued to soak up more radionuclides from the soil, says Victor Ipatyev, the former director of the forestry institute who 2 months ago was appointed president of the National Academy of Sciences of Belarus. He estimates that nearly 2 million hectares of forest are contaminated. Depending on prevailing winds, forest fires could spread the radionuclides far from contaminated areas.

Rehabilitating the forests seemed out of the question until a few years ago, when institute researchers found that certain forest undergrowth plants—such as raspberry and hazel—preferentially remove radionuclides from the soil, which in turn reduces contamination in the trees. These preliminary findings have not been put into practice yet.

Early on, such studies were kept under tight wraps by Soviet officials, who hammered home the message that only a few villages in northern Ukraine had been affected by the accident. Indeed, for nearly 3 years, it was forbidden in Belarus to even speak publicly about Chornobyl. The situation dramatically changed on 20 March 1989, when all the republic's newspapers simultaneously published maps depicting cesium contamination in Belarus, setting off a firestorm of anger and demonstrations against the party.

Unforeseen consequences

In a pine grove near the village of Bartolomeevka lies a peaceful cemetery, each gravesite surrounded by meter-high wrought-iron fences. No new graves will be dug here for some time, because all the residents of this tiny village 50 kilometers northeast of Gomel—like those of 400 other villages in Belarus—were resettled in less contaminated areas around 1990. But for the former residents of Bartolomeevka and other villages and towns downwind from Chornobyl, help

"It's possible, in principle, to achieve criticality," although the odds are vanishingly low, says Alexander Zhidkov, director of the materials science division at ISTC Shelter. Such a chain reaction would threaten only personnel inside the sarcophagus, he adds. Concern has instead shifted to the dust in the sarcophagus, which is on the rise. "The destruction of the lava is much faster than we believed 10 years ago," says Baryakhtar.

About 95% of the dose to sarcophagus personnel comes from submicrometer-sized FCM particles, which are "almost impossible to filter," says Zhidkov. He and his colleagues have found that these particles may be escaping into the atmosphere through the 1000 square meters of holes in the sarcophagus. "This is a global problem," he asserts. "These particles can be disseminated around the world."

To deal with this and other threats, the Ukrainian government held a design competition for a second-generation sarcophagus in 1992 but was dissatisfied with the proposals it received. The government then assembled a consortium, dubbed Alliance, to design a structure that would not only isolate the remains of unit four but also allow the sarcophagus to be dismantled and the FCMs to be safely buried. Many Western and Ukrainian experts approved the $2 billion design that Alliance came up with in 1995. However, the project was sidetracked when the European Bank of Reconstruction and Development (EBRD), which was considering Ukrainian demands for hundreds of millions of dollars to close two other Chornobyl reactors still in operation, refused to sink billions more into a new shelter.

So Ukraine and the EBRD went back to the drawing board, soliciting cheaper designs from several new consortia. When Chornobyl was finally closed a few months ago, the Ukrainian prime minister's commission selected the arch as its favored design. To minimize workers' radiation exposure, the 260-meter-long, 140-meter-tall arch will be built next to the sarcophagus, then slid along rails over the top of it—not an easy task. "Difficult engineering problems must be solved," says Durst, the project manager for the Chornobyl Shelter Implementation Plan—run by the Battelle Memorial Institute, Bechtel Group Inc., Electricité de France, and the Chornobyl Nuclear Power Plant. EBRD has agreed to pay the estimated $800 million cost of the structure and has begun soliciting bids for a contract to design and build it by 2007.

Hot property. Abandoned house in Chornobyl.

CREDIT: R. STONE

But some experts disparage the arch. "It's a Hollywood production by the West to say, 'We're helping Ukraine,' " charges Kostyantyn Rudya, scientific director of the International Chornobyl Center of the Cabinet of Ministers of Ukraine. "But this is not a final solution. There will be no money left for fuel removal." Anatoly Nosovsky, director of the Slavutych Laboratory of International Research and Technology, favors scrapping the arch and spending the EBRD money to remove and bury the contents of the sarcophagus. But he doubts that will happen: "The shelter is more a political issue than a scientific one." That view is echoed by ISTC Shelter director-general Oleksandr Klyutchnykov, who claims that "the main purpose from the West's point of view is to insulate the sarcophagus from the environment and forget about it for the next 200 years."

Baryakhtar defends the arch as "the best proposition." And Durst says that removing the dangerous fuel was never part of the deal, although the arch will permit this to be done in the future. Still, many experts maintain that this crucial step must be carried out sooner rather than later. Says physicist Ihor Yukhnovs'kiy, head of the Ukrainian parliament's science committee: "We have to diffuse this big bomb." **–R.S.**

came too late: They received heavy doses of radiation before they were moved out.

Perhaps the biggest surprise in the first few years after the explosion was that a spate of leukemia cases, predicted from Japanese atom bomb survivor studies, never materialized. "This was completely different from our expectations," says Vladimir Ostapenko, director of the Research and Clinical Institute of Radiation Medicine and Endocrinology in Minsk. "We were preparing not only scientifically but medically for leukemia." Most scientists now believe that the amount of cesium-137 absorbed by the general population was not high enough to trigger leukemia, says endocrinologist Shunichi Yamashita of the University of Nagasaki in Japan, an expert with the Chornobyl Sasakawa Project. And although Russian scientists have found a higher risk for leukemia among the liquidators, some of whom received cumulative doses of up to 5 sieverts—10 times the radiation dose needed to suppress the immune system and blood cell production—many researchers say that better screening could account for these elevated numbers. "It occurred to us that judging what would happen based on pre-Chornobyl experiences was useless," Ostapenko says.

But there were unhappier surprises revealed by robust medical record keeping. Before the Chornobyl explosion, of the 15 former Soviet republics only one had a population registry of birth defects: Belarus. Since 1979, Gennady Lazjuk's Institute for Hereditary Diseases in Minsk has run the registry and thus had a good baseline for drawing comparisons between lightly contaminated regions such as Minsk (less than 1 curie per square kilometer), moderately contaminated regions (1 to 15 curies per km^2), and heavily contaminated regions (more than 15 curies per km^2). In all three areas, birth defects skyrocketed after Chornobyl: about a 50% increase in both the lightly and moderately contaminated regions, and 83% in the heavily contaminated regions. These birth defects include polydactyly—extra fingers or toes—and shortened limbs.

Western critics have pointed out that much of this rise in birth defects could be due to more assiduous screening after the accident, or from exposures to chemical pollutants. Lazjuk, along with collaborators in Japan and Europe, acknowledges that better screening undoubtedly pumped up the figures, and he doubts that any increases in birth defects seen in lightly and moderately contaminated regions were due to Chornobyl. But with Soviet industrial output falling off after the breakup of the Union in 1991, he dismisses the notion that chemical exposures played a role in the sharper rise in the most contaminated areas, which persisted until 1995. After eliminating confounding factors, Lazjuk's group concluded that radiation exposure accounted for a 12% increase in birth defects in the heavily contaminated areas. Western scientists had predicted rises of anywhere from 1.5% to 7%.

"Lazjuk's data are beautiful," says Goncharova, who notes that a major shortcoming is the dearth of data on how much radiation the parents absorbed. That makes it impossible to say with certainty that radiation was responsible. Nor is the picture likely to get any clearer: This year, the Belarus government did not come up with funds to support birth defects surveillance and research.

The thyroid mystery

The government waited more than a week to hand out iodine pills to people in the affected regions in an attempt to saturate the thyroid and prevent it from taking up radioactive iodine. By then, it was too late. Even so, "we didn't expect much of an increase in thyroid cancer," says Sir Dillwyn Williams, a thyroid cancer expert at the University of Cambridge in the United Kingdom. Radioactive iodine had been used extensively to treat Graves' disease, and studies showed no increased risk of thyroid cancer. And studies of Japanese atom bomb survivors and Marshall Islanders exposed to fallout from an atom bomb test suggested that a few additional cases of thyroid cancer might be seen about 10 years after the accident, which would fall off within a few years. Instead, the number of childhood thyroid cancer cases began rising within a year after the accident.

CREDIT: R. STONE

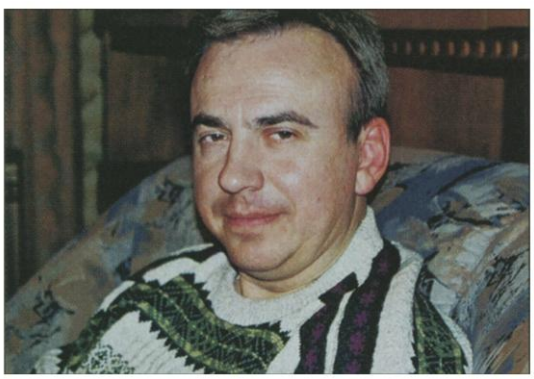
Ordeals of a Dissenter

GOMEL, BELARUS—Yuri Bandazhevsky slumps in an armchair in his apartment. He looks haggard, having recently spent half a year in jail awaiting trial. "It is very difficult," he says. "I have been isolated from people and from work."

For several years, Bandazhevsky, a pathologist and the former rector of the Gomel Medical Institute, a research and teaching center, has argued that the cesium-137 accumulating in the Belarus population poses a serious health threat, particularly to children. He claims that he and other researchers at his institute have found evidence that the cesium damages heart muscle and suppresses the immune system. And the threat will persist, he says: With a half-life of 30 years, it will take more than a century for most of the cesium to decay. When his team published its findings in 1995, the former minister of health wrote a laudatory preface to their monograph.

That collegial relationship soon changed. When the government over the next few years failed to take steps to reduce exposure to cesium by decontaminating inhabited areas—an unnecessary step, the government maintained, as Chornobyl experts had rejected the Gomel team's findings—Bandazhevsky began to speak out. In spring 1999, he questioned the Ministry of Health's spending on Chornobyl and argued that more funding should go to Gomel, the most contaminated region. In July 1999 he was arrested, accused of taking bribes from students seeking admission to his institute, imprisoned, and stripped of his post.

Most Belarusan Chornobyl experts will not comment publicly on Bandazhevsky's case for fear of retribution. However, after a few Western scientists sounded the alarm, Amnesty International designated Bandazhevsky a prisoner of conscience, and the American Association for the Advancement of Science (publisher of *Science*) last fall issued a human rights alert questioning whether the Belarusan authorities "have any evidence to support [the bribery] charge."



Prisoner of conscience? After Yuri Bandazhevsky challenged government cleanup policy, he was arrested and jailed on bribery charges. He is now on trial.

Bandazhevsky's trial is now under way, despite a blow to the prosecution last year when a key witness recanted his testimony. If convicted, Bandazhevsky could face 5 to 15 years in prison. Meanwhile, the jury is out on his scientific findings. "If cesium were so potent, I wouldn't be speaking with you now," insists physicist Mikhail Malko of the Institute of Physical and Chemical Radiation Problems in Minsk. Nonetheless, he says, Bandazhevsky's work merits further scrutiny. **–R.S.**

Rewards of a Volunteer

MOZYR, BELARUS—A dozen sweaty teenagers practice a choreographed folk dance around a painted wooden set depicting an old-fashioned stove, or *pechka*—the center of any Eastern European village home. They are preparing for an exhibition this summer that will take several members of their 200-person ensemble to Japan, far from this town some 100 kilometers northwest of Chornobyl.

Akira Sugenoya watches the performance with a big grin. An expert on autoimmune diseases of the thyroid, Sugenoya is helping to organize their trip. Sugenoya first came to Belarus in 1991 and has spent most of the last 5 years here—a record no thyroid expert from outside the former Soviet Union has matched.

Sugenoya credits a midlife crisis for bringing him to Belarus. In the late 1980s, Sugenoya says he realized that he had spent too much time on research and too little with patients. But he had a good job at the Shinshu University School of Medicine—a job that, in the Japanese psyche, he couldn't just quit.

Then in 1991 he saw a documentary on Chornobyl; 2 months later he was in Minsk. What he saw there disturbed him. In 20 years in Japan, he had seen five cases of thyroid cancer in children. In Belarus he was confronted with dozens of cases, and the few good doctors in the country "couldn't deal with it," he says.

After several trips to Belarus, Sugenoya retired from the university in 1995, guessing that his pension would last 5 years in his temporary home. He set up shop at the Minsk Thyroid Oncology Center before moving to the Gomel State Cancer Center, where he helped train doctors in surgical techniques. He soon developed a reputation throughout the country and last fall became the third foreigner awarded the top medal in Belarus, the Skorina Prize.

Man on a mission. Akira Sugenoya has spent the past 5 years treating thyroid cancer cases in Belarus.

Sugenoya says the Mozyr dance troupe has helped transform his attitude about Chornobyl. Several years ago, before Sugenoya became involved with the ensemble, the troupe was flown to Japan for a charity show. "The attitude was to invite sad, miserable victims of Chornobyl," Sugenoya says. And Belarus officials exploited this, instructing the ensemble's adult leader to implore the children "to not look so lively so that it would be easier to raise money," says Sugenoya. But when he met them, he felt the teenagers offered an uplifting message. Intent on nurturing that feeling, his Chernobyl Medical Fund has helped arrange this summer's exhibition in Japan. "He has helped give these children hope for the future," says Shunichi Yamashita of the University of Nagasaki.

With his pension nearly finished, Sugenoya plans to return to Japan in June. He knows that thousands more people in Belarus—including some of the children in the Mozyr ensemble—could develop thyroid cancer and that the last chapter of the terrible accident is far from written. But Sugenoya feels he has made a difference. **–R.S.**

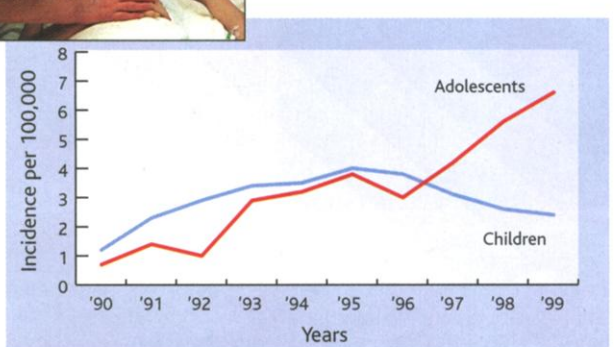
This was so surprising, says Williams, that "there was a general reluctance in the West to believe the data." Some scientists attributed the rise to better screening, others to the misdiagnosis of benign nodules. Many Belarusan scientists are still unhappy with how the West viewed their data in those days. "People who thought that the increase in thyroid cancer was due to better screening were crazy," says Malko.

Few now doubt the trends. "We learned a lesson," says one Western expert. Although childhood thyroid cancer cases peaked in 1995, the incidence among adolescents has more than doubled since 1996. Because children are classified as adolescents when they turn 15, this group now includes all the children exposed to the radioactive iodine. There's fresh hope that the childhood and adolescent thyroid cancer wave is cresting. Yamashita and his colleagues studied 20,000 Belarusan children who were born in the 3 years before the explosion, were in the womb during the explosion, or were born 3 years afterward. Their findings, which will be presented at a Chornobyl anniversary conference in Moscow next month, show that thyroid cancer appears only in those born before the explosion.

The unusual dynamics of the thyroid cancer incidence are prompting a flurry of research. "The mechanism of this cancer has not been unveiled yet," Sugenoya says. To speed studies, Williams and Cambridge colleague Gerry Thomas, in collaboration with the governments of Belarus, Russia, and Ukraine, have set up a thyroid tumor tissue bank in each of the three countries. The tissue bank—sponsored by several heavyweights including the U.S. National Cancer Institute (NCI), the European Commission, the World Health Organization, and the Sasakawa Memorial Health Foundation—now holds DNA and RNA from more than 280 thyroid tumors from patients younger than 19 at the time of the explosion. "This will allow us to look for a specific signature of radiation-induced cancer," says Yamashita.

"All of our projects are addressing this mystery," says Ostapenko, whose institute is collaborating with NCI and various European centers to study thyroid cancer. "We have a sad joke," he says. "Why should people look for test animals for radiation research when there is a natural laboratory here?" Indeed, he and others are bracing for a Chornobyl-driven rise in breast and prostate cancer down the road.

In Belarus, this natural experiment is becoming harder to sustain, scientists say. Government funding for Chornobyl research is drying up, and earlier this month, as Belarus and Russia celebrated their 5-year anniversary as a union, researchers with the National Academy of Sciences learned



Puzzling numbers. Unexpected rise in childhood thyroid cancer is now showing up in adolescents, as exposed children turn 15. Seventeen-year-old thyroid cancer patient in 2000 (*inset*).

CREDITS: (TOP TO BOTTOM) MUTSUMI STONE; EFREM LUKATSKY/AP; SOURCE: THYROID CANCER CENTRE, RESEARCH AND CLINICAL INSTITUTE OF RADIATION MEDICINE AND ENDOCRINOLOGY, INSTITUTE OF PHYSIOLOGY, MINSK

that they would be receiving a 20% pay cut, to about $60 per month—endangering their ability to stay in science at all. They are reluctant to air their concerns publicly, fearing reprisals from the government of President Alyaksandr Lukashenka—so loathed by many researchers that rather than utter his name, they refer to him as "the top person in our government."

Researchers in Ukraine, meanwhile, have been more fortunate. With the country's economy booming, their salaries were doubled this year to $120 per month. And their government has aggressively courted Western support for Chornobyl research. In 1998, these efforts paid off with the creation of a radioecology laboratory in the exclusion zone and surrounding territories. Now Ukraine's Cabinet of Ministers is negotiating with China and Japan to launch a research center to study the population of Slavutych, a town built after the Chornobyl accident to accommodate the power plant's workers.

The center will probe the long-term health of residents, many of whom lived in Pripyat until the accident and received high radiation doses immediately after the explosion. Of particular interest to scientists are the 7000 or so Chornobyl engineers and scientists who work in and around the sarcophagus each day, and the 6000 to 7000 liquidators now living in Slavutych. "My dream is to have a research agreement ready by the end of this year," says Valeriy Glygalo, the one-time liquidator who is now director of the Cabinet of Ministers' International Chornobyl Center for Nuclear Safety, Radioactive Waste, and Radioecology in Kyiv. The residents of Pripyat are gone, but they are clearly not forgotten. **–RICHARD STONE**

CELL BIOLOGY

Do Centrosome Abnormalities Lead to Cancer?

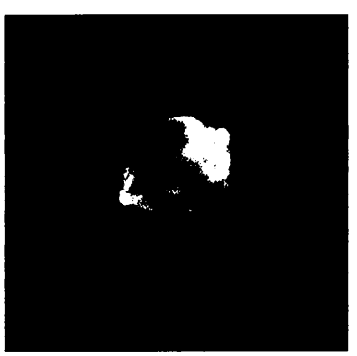
Evidence suggests that at least some cancers arise because centrosome malfunction causes chromosome damage and missorting

It may be small and inconspicuous, but the structure called the centrosome plays a big role in the cell. One key duty: helping to organize the mitotic spindle—the collection of protein filaments that pull the duplicated chromosomes apart during cell division, thereby ensuring that the two daughter cells each get a complete set. Without the centrosome, normal division of human cells could not occur. But accumulating evidence hints that this structure has a dark side as well. When the centrosome malfunctions, cancer may result.

Researchers have known for decades that cancer cells are rife with chromosomal abnormalities. Some cells lack one or more chromosomes, for example, while having extra copies of others. "Virtually every cancer cell has an abnormal chromosome complement, whereas virtually every normal cell has the [normal] diploid number," says cancer researcher Bert Vogelstein of Johns Hopkins University School of Medicine. The conventional wisdom has been that this aneuploidy, as it's called, is a late event in cancer development—the result of all the other disruptions in cancer cells. But now, "more and more it's coming out that [aneuploidy] is an early change and may be driving malignancy," says Vogelstein, whose own work has been pointing in that direction.

Contributing to this new view of aneuploidy is the realization that many types of cancer cells have abnormalities in their centrosomes—in particular, the cells often have extra copies. The supposition now is that the extra centrosomes lead to chromosome missorting and damage, thus causing the aneuploidy. Aneuploidy, in turn, may result in the loss of tumor suppressor genes or the gain or activation of cancer-causing oncogenes. "Once you have multiple centrosomes, that could increase the error rate [in chromosome replication and sorting], and those errors could be very dangerous," says centrosome researcher Greenfield Sluder of the University of Massachusetts Medical School in Worcester.

Researchers caution that the progression from centrosome derangements to aneuploidy to cancer isn't yet firmly established. Moreover, centrosome abnormalities likely aren't the only route to aneuploidy. For example, problems with the telomeres—the protective structures capping the ends of the chromosomes—have been implicated in the aneuploidy seen in some cancer cells. And two reports in the April issue of *Nature Cell Biology* suggest that mutations in a gene called *APC*, which are known to predispose to colon cancer, contribute to the chromosomal instability associated with that malignancy. But if centrosome abnormalities underlie at least some of the aneuploidy seen in cancer, they might be useful as diagnostic or prognostic indicators to help clinicians distinguish highly malignant cancers from those that are less dangerous. They might also point to possible new therapeutic strategies aimed at restoring normal centrosome function.



Centrosomal chaos. The mouse mammary cancer cell (left) has multiple centrosomes (red) and has generated four sets of spindle microtubules (green), which will lead to abnormal partition of the chromosomes (blue) in the daughter cells. At right is a normal dividing mammary epithelial cell.

CREDIT: W. BRINKLEY AND T. GOEPFERT

Hints of centrosome involvement

Early in the 20th century, a prescient microscopist named Theodor Boveri suggested that centrosome malfunction might lead to cancer. But the idea was more or less forgotten until about 5 years ago. At that time, Kenji Fukasawa, then in George Vande Woude's lab at the Frederick Cancer Research and Development Center in Frederick, Maryland, and colleagues found that cells lacking a critical tumor suppressor gene, known as *p53*, have multiple centrosomes instead of the normal one or two.

In work described in the 22 March 1996 issue of *Science* (p. 1744), the researchers reported that in cell culture, this centrosome amplification apparently disturbs mitotic fidelity, causing the cells to end up with abnormal chromosome complements. Because *p53*'s loss or inactivation is thought to contribute to the development of many human cancers, these findings suggested a new way that lack of a functional *p53* gene might lead to cancer: by disturbing centrosome function and thereby generating aneuploidy.

Two years later, a team led by Dennis Roop and William Brinkley of Baylor Col-