PHIL HATCHER-MOORE

IN THE SHADOW OF NUCLEAR SINS

Decades of weapons testing in Kazakhstan has left a legacy of poor health that researchers and residents are still grappling with.

BY WUDAN YAN

The statues of Lenin are weathered and some are tagged with graffiti, but they still stand tall in the parks of Semey, a small industrial city tucked in the northeast steppe of Kazakhstan. All around the city, boxy Soviet-era cars and buses lurch past tall brick apartment buildings and cracked walkways, relics of a previous regime.

Other traces of the past are harder to see. Folded into the city's history — into the very DNA of its people — is the legacy of the cold war. The Semipalatinsk Test Site, about 150 kilometres west of Semey, was the anvil on which the Soviet Union forged its nuclear arsenal. Between 1949 and 1963, the Soviets pounded an 18,500-square-kilometre patch of land known as the Polygon with more than 110 above-ground nuclear tests. Kazakh health authorities estimate that up to 1.5 million people were exposed to fallout in the process. Underground tests continued until 1989.

Much of what's known about the health impacts of radiation comes from studies of acute exposure — for example, the atomic blasts that levelled Hiroshima and Nagasaki in Japan or the nuclear disaster at Chernobyl in Ukraine. Studies of those events provided grim lessons on the effects of high-level exposure, as well as the lingering impacts on the environment and people who were exposed. Such work, however, has found little evidence that the health effects are passed on across generations.

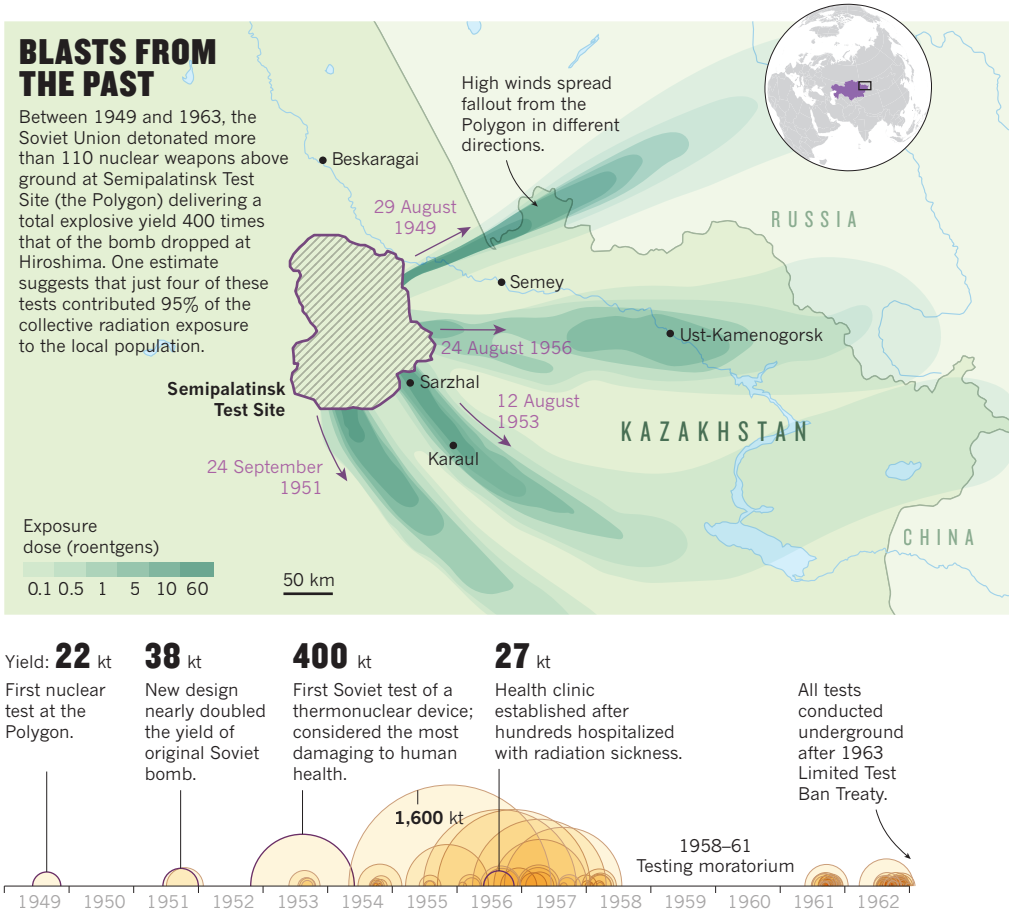
People living near the Polygon were exposed not only to acute bursts, but also to low doses of radiation over the course of decades. Kazakh researchers have been collecting data on those who lived through the detonations, as well as their children and their children's children. The effects aren't always obvious or easy to trace. But researchers are now starting to see some subtle impacts that linger 30 years after the Polygon closed. Studies show elevated risks of cancer, and one published in the past year suggests that the effects of radiation on cardiovascular health might be passed down from one

Berik Syzdykov at his home in Semey, Kazakhstan. He was born with anomalies after his mother was exposed to radioactive fallout while pregnant.

generation to the next.

Even as they tease out health impacts from the data, researchers in Kazakhstan also have to navigate the fear that has gripped residents living in the fallout zone. People blame the tests for a range of problems. But these links are not always supported by evidence. Understanding the testing's dark legacy remains of utmost importance for the families still seeking health-care assistance from the Kazakh government. The latest genetic technologies, such as next-generation sequencing, could assist in this process. And by improving understanding of the risks from long-term exposure, research in Kazakhstan could help to inform current debates about proposals to expand nuclear power to reduce carbon emissions.

"The Polygon tests were a great tragedy," says Talgat Muldagaliev, deputy director of the Scientific Research Institute for Radiation Medicine and Ecology in Semey, "but we can't go back. Now we need to study the consequences."



SOURCES: PLUME: HTTPS://GO.NATURE.COM/2V3MR7; TESTS: HTTPS://GO.NATURE.COM/2OYFBJT

DEADLY EXPOSURE

Valentina Nikonchik was playing outside in Semey on 12 August 1953 when she heard a deafening boom, fell to the ground and fainted. She had witnessed the first detonation at the Polygon of a thermonuclear device, a second-generation nuclear weapon releasing a force equivalent to 400 kilotonnes of TNT — more than 25 times the power of the bomb dropped at Hiroshima. The 1953 nuclear test is considered to be the most damaging at the Polygon in terms of human exposure (see 'Blasts from the past').

Up to that point, the Soviet Army had already been conducting tests at the site for four years. They had dropped bombs from aircraft and platforms to study the effects of blasts on buildings, bridges, vehicles and livestock. But they were either ignorant of, or indifferent to the idea that the high winds on the exposed Kazakh steppe might carry fallout into neighbouring communities. In 1963, representatives of the Soviet Union signed the Limited Test Ban Treaty, which ended above-ground testing. The underground tests that continued up to 1989 might have contributed to some exposure risks, but the atmospheric tests during the Polygon's first 14 years are considered the most dangerous in terms of acute exposure.

Absorbed doses of radiation are often measured in grays. High doses, starting at about 1 gray, are enough to kill cells and damage tissues. People exposed above this level frequently get radiation sickness, a condition characterized by vomiting, diarrhoea or bleeding. Depending on the exposure and the extent of cell death, people can die within hours to weeks of being irradiated. In August 1956, an above-ground test at the Polygon caused more than 600 residents in the industrial city of Ust-Kamenogorsk, approximately 400 kilometres east of the test site, to be rushed to the hospital with radiation sickness. There are no records of how many people in the city died as a result.

Radiation is also problematic for rapidly dividing cells, such as those in developing fetuses. Women near the Polygon who were exposed to radiation were more likely to give birth to children with chromosomal diseases, including Down's syndrome and congenital disabilities[1].

But for others, the effects might not show for years or decades. That was the case for Nikonchik. Years after the blast knocked her over, she found out that she had heart disease and thyroid issues that she and her doctors think are linked to the tests. "Back then, when I was a kid, we weren't thinking about the effects on health that this testing could have," she said.

After the August 1956 test that caused radiation sickness in residents of Ust-Kamenogorsk, the Soviet military established a top-secret medical clinic to care for those in need and to serve as a base of operations for researchers collecting health data on those who had been exposed. To hide its purpose, the army named it Anti-Brucellosis Dispensary No. 4, after a bacterial disease spread by farm animals. Those who sought out medical care were examined, but were never told exactly what was wrong.

In 1991, following Kazakhstan's independence from the Soviet Union, officials from Moscow sent a special committee to Semey to open up the dispensary. Some records were destroyed. Other classified files were returned to Moscow. Even today's researchers are unaware of what those records contained. The dispensary was renamed the Scientific Research Institute of Radiation Medicine and Ecology (IRME), which inherited the remaining classified health-data files. In addition to continuing epidemiological studies on the effects of nuclear radiation on human health, the IRME has a small clinic for treating people whose family members were affected by tests, and a mobile medical unit.

Over the years, those who sought care from Dispensary No. 4 or the IRME were logged in the state's medical registry, which tracks the health of people exposed to the Polygon tests. People are grouped by generation and by how much radiation they received, on the basis of where they lived. Although the registry does not include every person who was affected, at one point it listed more than 351,000 individuals across 3 generations. More than one-third of these have died, and many others have migrated or lost contact. But according to Muldagaliev, about 10,000 people have been continually observed since 1962. Researchers consider the registry an important and relatively unexplored resource for understanding the effects of long-term and low-dose radiation[2].

Geneticists have been able to use these remaining records to investigate the generational effects of radiation. In the late 1990s,

Kazakh researchers went to Beskaragai, a town in the periphery of the Polygon that had been heavily irradiated. They collected blood samples from 40 families, each spanning three generations, and sent them to Yuri Dubrova at the University of Leicester, UK, for analysis. Dubrova, a geneticist, specializes in studying the impact of environmental factors on the germ line, the DNA found in sperm and eggs that can be passed on to offspring. He was intrigued to study the Polygon families, to start unpicking the appearance of mutations across generations.

In 2002, Dubrova and his colleagues reported that the mutation rate in the germ lines of those who had been directly exposed was nearly twice that found in controls[3]. The effects continued in subsequent generations that had not been directly exposed to the blasts. Their children had a 50% higher rate of germline mutation than controls had. Dubrova thinks that if researchers can establish the pattern of mutation in the offspring of irradiated parents, then there could be a way to predict the long-term, intergenerational health risks. "That's the next challenge," he says. "We think techniques like next-generation sequencing could potentially provide us with real information about the impact of human mutations."

HEART OF THE MATTER

When Zhanar Mukhamedzhanova was 19, she started feeling weak at work. She thought it was strange — her job as an accountant wasn't very labour intensive — so she went for a check-up at a regional clinic in Semey. Her systolic blood pressure was above 160, fairly high by medical standards. Although Mukhamedzhanova has lived most of her adult life in the city, she spent her earlier years in the Abai region, an inhabited area close to the Polygon that was one of the most heavily contaminated by the nuclear tests. Both her parents witnessed the tests at first hand; her father died from a stroke at 41 and her mother died from heart issues at 70. Mukhamedzhanova's older sister has high blood pressure, and her younger sister has cardiac insufficiency, a condition in which the heart is too weak to send enough blood around the body. Although such issues are relatively common in the general population, there is some evidence that the incidence in those exposed to radiation, and their offspring, might be higher.

For instance, last November, Lyudmila Pivina at Semey State Medical University and her colleagues found that long-term, low-dose radiation can lead to cardiovascular problems such as high blood pressure. They looked at health outcomes in approximately 1,800 people, including second- and third-generation Polygon survivors. When they focused on individuals whose parents lived in areas that were exposed to radiation from 1949 to 1989, they found that the risks of hypertension went up in correlation with the amount of radiation someone's parents received — a discovery that they found surprising[4]. This multigenerational cardiovascular risk has not been clearly established in populations whose parents and grandparents were affected by the blasts at Hiroshima or Nagasaki, says Jim Smith, a radiation researcher at the University of Portsmouth, UK.

The difference could come down to the pattern of exposure. With long-term, low-dose radiation, cells will accumulate mutations as they constantly try to repair the damage done to their DNA. Bernd Grosche, a retired radiation epidemiologist formerly with Germany's Federal Office for Radiation Protection in Oberschleissheim, says that's why it is important to look at populations that have received different kinds of exposure, to understand the full extent of the effects on human health. With the availability of the registry in Kazakhstan, Grosche says, it would be negligent not to analyse it.

"Every catastrophe has a beginning and end, but in the case of radiation, that end is still unknown."

But studying environmentally exposed populations is challenging, says Cari Kitahara, a cancer epidemiologist at the National Cancer Institute in Bethesda, Maryland, mostly because of the need to collect detailed exposure data on a large number of individuals. Kitahara is studying the effects of radiation on the health of medical radiation technicians, in whom exposure is easier to track. Others are studying uranium miners and nuclear workers, who are exposed to low doses of radiation over time. Whereas many radiation technicians are women, and most miners and nuclear workers are men, the Polygon population is remarkable in that it represents the general population.

One of the biggest challenges of studying the effects of radiation on health is that it's often difficult to attribute a particular health issue solely to radiation, says Yuliya Semenova, a researcher at Semey State Medical University who studies the generational effects of the Polygon tests. Because cancer and high blood pressure are common maladies, cohort studies — which typically follow a population over time — can help to tease out what specific factors might contribute to them, she says. Semenova and her colleagues plan to use the registry to develop epidemiological studies that can better elucidate the connection between radiation and disease.

Researchers who study the Polygon population, however, don't yet know the full extent of the damage that long-term and low-dose radiation can inflict on human health. And the more time passes, the more difficult it can become to tease out the effects of radiation from those of other environmental factors. "Every catastrophe has a beginning and end," says Muldagaliev, "but in the case of radiation, that end is still unknown."

INVISIBLE LEGACY

Cheerful sculptures made from car tyres greet visitors to a two-storey orphanage tucked away in a residential part of Semey. On the first floor is a room with cream-orange-coloured walls that caretakers call the Sunshine Room. Inside, a three-year-old boy named Artur rolls on the floor and slowly fumbles his way into a chair — he's had three corrective operations that have just about enabled him to walk. His older brother, born with hydrocephaly (excess fluid in the brain, which enlarges the head), was left at the same orphanage but has since been transferred. In a nearby cradle lies Maria, a two-year-old who cannot walk, crawl or sit up. She snorts and gasps when she cries, as if struggling to breathe. The caretakers don't know exactly what's wrong with her, or whether she will live to adulthood.

The children with disabilities who have passed through this facility and others around the region are often presented as a visible reminder of the Polygon's legacy. Many of the eight children in the Sunshine Room in November had parents who grew up in highly irradiated villages, says Raikhan Smagulova, a caretaker at the orphanage. And some doctors have recommended that adults who have been exposed to radiation abstain from having children. But there is scant evidence and much debate as to whether past exposures contribute to severe congenital disorders. It is a question, like so many others in Semey, that requires more research and will be challenging to answer definitively, says Muldagaliev.

For many residents of the region, the effects will probably be less visible than congenital disabilities. But they might be more insidious, troubling generations to come with poor health.

The focus that others, including researchers and film-makers, have placed on the legacy of the Polygon over the years is a double-edged sword. It brings international attention to the plight of those affected by radiation. But it also engenders stigma, Semenova says. For some, the negative attention can be stifling: rather than being known as the birthplace of some of Kazakhstan's most famous poets and artists, Semey is known mostly for its dark past.

"It's a stamp on the city," says Symbat Abdykarimova, a neuropathologist at the orphanage. "We want to feel proud of Semey, since we live here. But many international journalists come and want to talk about the Polygon. We're trying to avoid a situation where we are only known for that." ■

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