Bodily Secrets: Radiation and Reading the Body

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The Province of Chelyabinsk and the neighboring Province of Sverdlovsk, deep in the Russian continent, used to be off-limits to foreigners. In the United States that would be like placing a ban on the states of Montana, Wyoming and a good part of Idaho. The travel restriction was lifted in the early 1990s, but the city of Chelyabinsk is still no tourist destination. I met no other foreigners while I lived in Chelyabinsk, a Russian steel-town of a million people and million more yards of rusting pipe and heavy machinery. In the courtyard of my apartment building, a neighbor inquired where I was from. She was asking, she said, because the last person who had lived in my rental unit was from her hometown of Turgan and, it turned out, he knew her relatives. Perhaps we too might have a common connection? When I asked her if she had family in Chicago, a wave of dread crossed her face before she forced a laugh.

That look gave me a first glimpse of the vast and sweeping Russian nuclear security regime, of which Chelyabinsk is a small part. Security regimes are strange affairs. They sort knowledge and appear to prioritize and hide the most significant information. But that is a mirage. No security system does that. The most sequestered, top-secret information can be banal and inconsequential, while what is important to know can be right there, hidden by its very ordinariness. Even so, security regimes attract researchers who seek to break the code and learn the guarded secrets. Placing a territory in a classified zone is a sure way of drawing attention to that place. Living in Chelyabinsk while researching a closed nuclear city, I got distracted by security and secrets. It took me a long time to ask the most obvious questions: Why draw attention with security restrictions to something you want to keep secret? Was the security zone deflecting notice from something else, and if so, where did the real secrets lie? I got caught believing in the veracity of the security state. It took an old woman and her body to get me to see the real secrets. She taught me that the bigger story was right before me, in the bodies of the people I met, so close I could reach out and touch them.

I was in Chelyabinsk in order to find out more about Ozersk, a pretty little city in a northern birch and pine forest surrounded by clear, blue lakes. The town is clean, orderly, green, with stately apartment buildings and shoreline summer cottages. At least, that is reputedly what Ozersk looks like. I wasn't able to enter Ozersk, or even get close to it. One of ten formerly closed Soviet nuclear cities, Ozersk on writing is now a closed Russian city, home to Russia's first plutonium plant, which currently reprocesses spent nuclear fuel for commercial reactors around the world. Both making plutonium and reprocessing fuel produces a great deal of radioactive waste. Ozersk is surrounded by a tall cyclone fence topped with barbed wire and patrolled by guards at gateposts, in boats on the lake, and on foot in the surrounding forests. During the Cold War, to enter the closed city, a person needed a thorough background check and a pass. A restricted buffer zone lined with missiles ringed Ozersk. The town was on no published map, and for the 90,000 people who lived there their address was officially the steel town of Chelyabinsk some forty miles away. Ozersk was, in short, located in the center of a security network so vast, so cosseted with restrictions and defensive installations that, as I learned more about it, I came to feel sorry for Gary Powers, sent confidently, blithely, like a lamb to slaughter to fly a U-2 over this armed archipelago. Zenit rockets downed Powers' plane on May 1st, 1960 just after he flew over Ozersk, then called by the few in the know (and Powers wasn't one), Chelyabinsk-40.

When I started visiting the Chelyabinsk Province sixteen years after the end of the Cold War, I was surprised to find that the habit of secrecy and intrigue was still going strong. When I showed up places, I encountered a mini-whirlwind about me. People knew who I was before we had been introduced. Like a patient whom no one will tell has cancer, I felt there was important information I should know, but wasn't privy to. I had strange encounters. An official at the archive invited me to her home, fed me borsch, told me about her marriage, extra-marital affairs, raising her children, and then announced that, at the archive, I was to pretend not to know her. Yet, a few days later, while working in the archive's reading room, she invited me out for coffee, and as we strolled down the street she told me that her home, office and cell phones were bugged, and that if I needed to talk to her, I had to take her for a walk. I asked her why she was under surveillance. She said she had a top security clearance and access to a lot of state secrets. She lifted her chin, proud of her government's trust (and then mistrust) in her.

Secrets! That is what historians yearn for, long-guarded secrets that make headlines. History holds the promise that buried in archival storehouses are mysteries that will illuminate dark corners of the past which even people living through those events did not know. This quest gives historians authority and relevancy. Uncovering secrets was my mission too, but as I worked through declassified files over the years, I learned a lot of details about life at this epicenter of the Cold War arms race, but I did not uncover any real secrets. What was there to learn? The most closely-guarded knowledge—the location of the plant, formulas for bombs, and volumes of fissile material and radioactive waste—had long been fished out by spies, intelligence agents, journalists and other historians. I could not enter Ozersk, but I could zoom through it on Google Earth. I could find the formula for making a nuclear weapon in published sources and then order on line enough radioactive materials to make a dirty bomb.[i] Why all the intrigue?

It took me several years to realize that the greatest mystery was not in the archives and had never been there. I had thought I was going to expose the history of the national security state as it was being invented by those living at ground zero of the arms race. Strangely, seeking to peer through this elaborate security apparatus distracted me for a long time from seeing a major part of the story of the Maiak plutonium plant, which I missed because questions of access and secrecy loomed so large. Thinking back on it, the young archivist who handed me files, which I had not requested, about people living on the highly radioactive Techa River, should have clued me in. Surprised at the unexpected files, I looked up to notice that the young woman's eyes bulged and her fingers were swollen and blue. Had I yet any literacy in reading bodies as medical texts, I might have recognized these symptoms possibly caused by an overactive thyroid and asked her whether her unsolicited help had something to do with an illness associated with the plutonium plant. But I did not ask the archivist why she was surreptitiously aiding me. Instead, I continued on my way, pursuing my original research question, not wanting to get off track.

Seeking to talk to some former plant workers and neighbors of the plant, I got in touch with an Ozersk-based human rights lawyer, Nadezhda Kutepova. She connected me with over a dozen pensioners who had worked at the plant and were willing to tell me their stories, or parts of it. Unable to visit the closed city, in the summer of 2010, I took up residence in nearby Kyshtym, a small city of heavy log houses on an isthmus between two northern lakes. I settled into a cottage to live. I also had a key to an office in a crumbling sanatorium for senior citizens. The spare, rectilinear room served as a neutral location for me to meet the veterans of the plutonium plant. I needed a "neutral" location because the owner of my borrowed cottage did not want me to meet guests there, as the neighbors might take note of my activities. That was the political climate. I was doing nothing illegal, but the idea of talking about the former nuclear arms complex made a lot of people nervous, including some of the people who came to see me.

One man, Sergei, walked in for our interview, folded his arms over his chest and kept them there. He proclaimed that he didn't know why he had come or what the point of our meeting was. As a young conscripted soldier, Sergei had been sent to clean up radioactive debris and ash after a major explosion of an underground radioactive waste storage tank in September 1957, but he didn't want to talk about any of this with me. He told me he had signed security oaths designed to keep state secrets especially from American spies. There I was speaking Russian with a thick American accent and holding our meeting in a "neutral" location. Who was to say I wasn't a spy?

Certainly not Sergei. After a few minutes, he got up and departed, in a huff. That left me alone with a handful of older women. Researching this sensitive topic, I often ended up speaking to women, not men. My story is biased that way. Like a morning spent at the bathhouse, sharing emotional intimacy with a stranger of the same gender came easily for many of the women with whom I spoke. Perhaps for that reason, after Sergei left we relaxed and got down to business. But to my chagrin, it turned out that our business was not state secrets, but secret body parts—their genetic legacies, reproductive histories and physical maladies. The women appeared to be far less concerned than Sergei about my nationality and the plant's security regime and more attentive to dog-eared papers they fingered in their laps. The papers were medical reports and legal petitions, and they wanted very much for me to look at them. But I was not interested in their papers. Instead I wanted them to tell me about their lives working at the plant and living in or near the closed city. I wanted to know what it felt like to be locked up in a zone, cut off from the larger world. I asked questions along those lines.

Anna Miliutina was eager to talk. Spry and energetic, Miliutina did not look her 80 years. She started at the plutonium plant while it was still in the construction phase, in 1947. For several decades, she worked as a shop clerk in the closed city, but in the late sixties, she wanted to make more money and retire sooner so she took a job at the plant in production. Walking into a porcelain-lined tunnel to clock in for her first shift, the plant's security and safety regime impressed her.

> "First we went to the hygiene control station, took off all our clothes and walked undressed into another room where we were given jumpsuits and cassettes to measure radiation. At the end of the day we gave back our cassettes and they returned our clothes. In the corridor was a soldier who let you into the workshop. We had numbers that indicated where you were allowed to go. There and nowhere else. We took a shower every day after work. When you left, the radiation

monitor checked you and might hold you back. If I got too large a dose, I didn't know. They didn't tell you."[ii]

"I had just started to work at the factory and there was an accident in 1968. It was a critical reaction. The first shift had cleaned it up. Maybe. Or maybe in the morning I did the cleaning. There were ten meters to clean, not a lot of space. So that was how I was related [to radioactive contamination]."

"Were you afraid?"

"No, no, no. What did we understand? How did we know we would get sick? Now I know. I cleaned it up. They threw a powder on the floor. If it was wet, they sopped it up. If it was acid, they washed. They had that kind of order."

"Those events, of course, did not give us health. That accident [in 1968], which I cleaned up, meant I got a lot of radiation which I think is what gave me this chronic radiation disease, which doesn't show up on me [in the tests]."

Miliutina shuffled through her papers, worn, thumbed. She showed me a letter rejecting her requests for compensation and another denying her diagnosis of Chronic Radiation Syndrome (CRS), a complex of symptoms assaulting multiple organs of the body. Soviet doctors first created the diagnosis of CRS in the mid-fifties when they noticed that young plant operators, who had started working at the plutonium plant in perfect health, were falling ill with a host of symptoms—chronic fatigue, loss of appetite, severe anemia, premature aging, aching joints, brittle teeth and bones—to name a few. They guessed that the prisoners and employees who first came down with these symptoms had been exposed for long periods to doses of radioactive isotopes which, while not enough to cause the immediate symptoms of severe radiation illness, mounted over several years to a general, debilitating malaise. A dozen of the first young women diagnosed with CRS grew too sick to work and died in their early thirties. Soviet doctors studying monthly blood tests learned to detect when workers were at risk of CRS, and they ordered the endangered workers transferred to cleaner working environments.[iii]

Miliutina felt she should be included on the list of people with CRS, a diagnosis which would entitle her to compensation payments and state-paid medical treatment. As Miliutina pressed her papers on me, I attempted to direct her back to facts about her life, as I was intent on answering my research questions. Miliutina ignored my queries: "In the end, I was insulted," she continued, "I did not get proper liquidator's status. I have gone everywhere and they will not give me this status." She showed me copies of the compensation law. She read from it aloud. I cut her off with my own questions—"which year did she start work; what was her job title?" I did not want her contemporary medical records, but a record of her past, and I wanted Miliutina's life story as unmediated and transparent as possible. Instead, Miliutina came out with sentences that I suspected she had uttered many times before. "We had twenty Chernobyls. It was a war. For others it wasn't a war, but for us it was."

Pulling out a new set of papers, she showed me how the radio-biology clinic had evaluated her with a dose of 24 to 27 nanocuries. That number meant nothing to me, and again I tried to return her attention to the 1960s. In that quiet office in Kyshtym we grappled; I steering Miliutina away from her papers and medical history and back to her biography, she returning to them. An interview is a negotiation. Both the interviewer and the subject have something they want to get out of it. I was dissatisfied with my end of the exchange. I'm sure Miliutina was too.

Another woman, Luibov Kuzminova started talking. She was, at age 75, very beautiful. Her face a soft peach centered on indigo eyes. In 1946, Kuzminova worked as an agronomist in Metlino, a little hamlet along a small lake with a handsome church and old stone mill. 1946 was the year Soviet officers of the NKVD construction enterprise started building the Maiak plutonium plant, seven kilometers distant. In 1949, having run out of underground storage containers, the plant director ordered engineers to dump all the plant's waste, including a high-level radioactive slurry mixed with toxic chemicals, into the little Techa River. If ingested, the high-level radioactive waste was fatal in micro quantities. The Techa flowed past the plutonium plant and pooled into ponds, lakes and swamps along its soggy course. Metlino was the first hydrological way station downstream from the plant. "We didn't know." Kuzminova recalled, "We drank and washed. We didn't know it was all dirty."

She narrated her biography as medical and reproductive record:

> "I was married in 1956. We had trouble conceiving. Then I managed to get pregnant but had first a miscarriage, then a stillborn. Finally I gave birth to three children in 1959, 1960 and 1963. The first child died at a year and a half of leukemia. The other two lived. They are sick a lot. My husband worked in the lab at the plant. He died in his fifties. I have female problems, and I have had a lot of operations."

In the 1950s, plant radiation monitors realized that farmers living along the Techa River, into which engineers had dumped 3.2 million curies of high-level waste from 1949-1951, were dangerously exposed.[iv] After several years of drinking and washing with contaminated water, villagers had similar symptoms to those of the first plant workers. In subsequent years, plant doctors carried out exams on 7,900 people in the downstream communities and clandestinely diagnosed over 900 cases of CRS.[v] Many of the 28,000 people, also exposed but not tested, might also have had the syndrome.

Like Miliutina, Kuzminova held tattered medical records, which she also pushed toward me, with the same effect on me as Miliutina's. Seeing my disinterest, Kuzminova put her papers aside, stood up, and before I could stop her, unbuttoned her shirt to show me the scars on her belly. Unlike the medical records, these markings finally drew my attention. She lifted her shirt to reveal thick chalk lines of the surgeon's knife scrawling a crosshatch—left and right, up and down—on her abdomen. The marks looked as if they were graphically attempting to void her torso. I didn't know if the cause for those many surgeries were the isotopes from the plant, but her pain, recorded in those bodily etchings, was simply, exhaustingly there. I could no longer doubt it, but confronted with this rendering of a body in pain, I wished it would go away.[vi]

Miliutina wanted me to see her documents and Kuzminova her body in order to grant them a diagnosis—Chronic Radiation Syndrome or some other medical verdict—so that they could feel justified, released from having to make an argument about their status as unwitting victims. I have no degree in law or medicine, nor did I have the authority to evaluate and certainly none to see that justice was done. Plant researchers and officials said the women were not sick from plutonium production, but the women said they were. Who was I to say which side was right? There we sat at cross-purposes. I wanted the women's life stories, and, unfairly, I wanted them without interfering self-interest. They wanted to hear they were right in their decade-long quest for status as victims. They sought my help getting that recognition, and to do so they needed a diagnosis.

But the diagnosis of Chronic Radiation Syndrome was a moving target. In the years that followed the Soviet government's release of information about the Techa River disaster, a furious debate flared up around the bodies of people who claimed they were sick from the plant's radioactive waste. Some doctors, backed by public interest groups, said villagers and former workers suffered illnesses associated with long-term, low-doses of radiation. Other scientists, largely underwritten by nuclear weapons establishments, said the plaintiffs were in fact sick from poor diets, alcoholism, inbreeding, conventional illnesses and stress. They argued that in suing for compensation, the plaintiffs were looking for handouts. I puzzled over the debate. Why so many opinions? Had they not studied these questions for years. Why could science not be able to determine why the plaintiffs were sick?

The controversy derived in part from the insensibility of radioactive isotopes. These ghostly historical agents shadowed the bodies of workers and villagers in ways nearly impossible to recover as historical record. Imperceptible isotopes require sensitive devices read by trained technicians to make them legible. Monitoring of regular workers at the Maiak plant came to be fairly well controlled by the 1960s, but radiologists estimated exposures of temporary workers (often soldiers and prisoners) and farming neighbors rarely and haphazardly. Clearly, hazardous radioactive isotopes were still in play even when there was no radiologist there to measure them, yet that record was sketchy at best. Meanwhile, medical researchers largely dominated this debate. They had measuring devises to count the isotopes and that gave them authority to make pronouncements on the health of bodies when they intersected with radioactive contamination. I had read a lot of these studies. I knew how many questions they begged, how equipment failed and data was incomplete.[vii] I knew about the debates over whether there could be "permissible doses" of hazardous chemicals and radioactive substances or whether these "tolerance thresholds" merely had to exist in order for industries producing toxic products and waste to continue. The disputes, in short, over the effects of ingested plutonium and other highly toxic isotopes were highly politicized, and uncertainty prevailed.[viii] How then was I to account for these gaping silences in the record: the missing unaccounted for radioactive iodine, cesium, plutonium, strontium slipping mysteriously through ecosystems, up food chains and into human blood streams? In my research I had encountered ghosts, spirits of the forest, spectral nationalized identities, and other historical agents that I could not see, but this problem was of a different order. Though invisible, the isotopes were not ephemeral. They had a very real material existence.

Here were the most elusive secrets of the Maiak plutonium plant, secrets which had nothing to do with formulas for bomb cores or blue prints for reactors, but instead involved the mysteries that resided in the bodies of people who had been exposed for decades to the plant's radioactive waste. How much they had ingested and what kind of damage the bouquet of invisible radioactive isotopes had done to their health—that was the enigma, which after decades of research, no one in the United States or the Soviet Union had convincingly solved. Bodies, it turns out, did not give up their secrets as easily as sequestered archives. The bodies of the women I talked to were archives of a fashion, ones that carefully stored strontium 90 and plutonium in bone marrow, radioactive iodine 131 in thyroids, cesium 137 in endocrine glands, hearts, spleens, soft tissue and muscle. The problem is that unless the levels are very high, humans have very poor skills to read these corporal repositories.

In the early 1990s, when American doctors first visited the medical research institutes associated with the Maiak plant, they were impressed. Bruce Amundson, a senior cancer researcher, made a trip in 1992 to Ozersk, where he was amazed to find the vast body of research on people who had lived on the Techa. The Russian doctors had a thick file on thousands of people who lived along the Techa River. "In our open society," he told a reporter, "we made a conscious decision not to study our offsite [exposed] population. In a closed society, the Soviets were able to carry out extensive, secret studies over the same period. They are way ahead of us in understanding what may have happened to their people."[ix] Unlike medical researchers near the Hanford plutonium plant, Soviet doctors had kept a close eye on people exposed to the plant's radioactive waste. From the early sixties, Soviet researchers took blood and urine samples from residents in radiated territories. They had a warehouse of medical files on people in contaminated territories along the Techa River.[x] Patients had never been told of their exposures, but their Soviet medical handlers had been tracing them through their bodies for decades.

With this Soviet medical data and the new post Cold War spirit of cooperation, American and Russian scientists eagerly began to collaborate. The US Department of Energy pumped millions of dollars into Russian nuclear research installations, which were short of money in the failing post-Soviet economy. American and Russian scientists visited each other's nuclear sites. Most Americans, however, did not go to the Urals to learn from Soviet science, which they considered inferior. They largely came for the valuable Soviet "data sets," the medical files of three generations living on radiated territory, a collection of medical data unique in the world.[xi] American doctors had no registry like it anywhere in the United States.

American researchers also did not have a medical equivalent of Chronic Radiation Syndrome. To them it was a doubtful diagnosis. Researchers in the US had largely focused on a few cancers and thyroid disease as effects of exposure to radioactive isotopes. There was no equivalent in the American medical lexicon for the vague complex of symptoms, which CRS described.[xii] Largely, as American scientists came to lead joint research projects, the term disappeared from the medical literature and gradually started to dissolve from the post-Soviet landscape too.[xiii] By 2004, Russian researchers downsized their original diagnosis of 937 cases of Chronic Radiation Syndrome in the downstream Techa River population to 66 cases.[xiv] Miliutina and Kuzminova were angry because they felt that they and others were squeezed out of this diagnosis, which had, after the Americans arrived, become a shrinking quantity.

Long after meeting Miliutina and Kuzminova, I started to wonder about the discrepancy in Russian medical verdicts before and after collaboration with American researchers who were supported by Department of Energy funds. Despite the Russian doctors' greater wealth of data and experience in curing people suffering from long term low doses of radiation, the Americans' notions of "exposure," and "thresholds," and their more limited range of probable health effects (i.e. a handful of possible cancers) had prevailed.[xv] Why?

In large part the gap in the diagnosis of Chronic Radiation Syndrome before and after the arrival of the Americans is due to the very different uses of medicine in the Soviet and American nuclear research establishments. The medical research division of the Manhattan Project was set up during WWII with secrecy in mind. Historian Peter Bacon Hales argues that medical researchers were charged with determining whether radiation exposure would noticeably weaken or sicken workers in a way that would expose the project's secret. As Stafford Warren, chief of the medical division wrote General Leslie Groves, "If scientific workers in any part of the project should receive enough radiation or should absorb enough radioactive material to produce physiologic damage, it would be impossible either to keep the project secret or to procure enough employees to carry on with it."[xvi] The function, Peter Bacon Hales writes of the medical section was auxiliary, "to prevent, not injuries, but lawsuits resulting from injuries."[xvii]

During the Cold War, American researchers continued to worry about the "threat" of "public exposure."[xviii] American researchers had access to radiation levels and estimates of employee exposures, and they monitored radiation as best they could. Using laboratory experiments on animals and humans, they debated "permissible doses" and thresholds above which, they postulated, could cause bodily harm. The threshold notion held that below a certain level, radiation was harmless. Atomic Energy Commission policy swiveled around this understanding, as the point of the threshold was to keep workers' exposure at safe levels and so maintain that nuclear installations, properly monitored, were safe. Some workers exceeded these thresholds during accidents. They were brought in to plant clinics and run through tests to try to determine how much a worker had ingested or taken externally on the body. Doctors looked for signs of severe radiation syndrome, symptoms that show up soon after exposure. They did not, however, search bodies that were exposed over many years to low doses for long-term symptoms because they believed that as long as exposures were kept within the threshold, there would be little to no effect. As a consequence, American researchers simply did not ask many questions about the long-term effect of low doses of radiation on the body. For American researches, the way to tell if workers had been overexposed was to search, not the body, but the environment. The focus, for American scientists, on exposures and so monitoring of the plutonium plant and the surrounding environment, meant they overlooked bodies of people exposed in contaminated environments.[xix]

In the Soviet Union in the first decade of radio-biology, doctors at the prisoner-built, accident-prone Maiak plant faced a very different and immediate problem. They were not at all concerned about making an argument to a worried public about the safety of nuclear installations. In Soviet society, officialdom had rarely to answer to public scrutiny, and nuclear installations were so sequestered that officially they did not exist, having no presence on published maps or in public discussions. Instead, what vexed plant managers was how to keep valuable, rare, trained employees working despite daily exposures to an alarming volume of fission products? Hungry prisoners and soldiers built the Maiak plant in a rush, and it suffered many more accidents than its American equivalent at Hanford. This meant that far more workers were exposed on a daily level than at the American plant. Keeping workers healthy for Soviet doctors was especially difficult because the security officers who ran the plant did not allow doctors access to production and monitoring records which could clue them in to how much of what kind of isotopes their worker-patients had been exposed.[xx] Blocked from knowing their patients' doses and from data collected on environmental monitoring, Soviet researchers instead looked for symptoms of radiation exposure on the body. If they could figure out how to read it, the body could serve as a map that could decode an individual's working environment and recover exposures in the past.

From 1950-1990, Soviet doctors at the Maiak plant took tens of thousands of blood tests and performed thousands of medical checkups.[xxi] Some workers underwent 10 to 15 blood tests a year. In the circumstances of extreme secrecy and ignorant of radiation levels, Soviet doctors, unlike their American counterparts, could hold no notion of thresholds or other universal standards to estimate health effects. Instead their practice turned around the specificity of the bodies they attended. Some bodies, they noticed, showed few signs of distress after chronic exposures; others working in the same conditions grew gravely ill. Soviet doctors became adept at detecting minute changes in blood cells and slippages in workers' cognitive and physical abilities, which they learned signaled the onset of Chronic Radiation Syndrome. In the first decade, they diagnosed over 2,000 cases of CRS, 23% among the plant staff.[xxii] In order to convince supervisors to remove these workers from hazardous shops, the doctors had to come up with a lot of evidence, which, banned from entering the plant, they took from workers' bodies. They linked symptoms to, not exposures from the ambient radioactive environment (for they did not know them), but to changes in the body which, as they learned to decode them, became a way of charting radioactive contamination as it surged from the Maiak plant.

Evaluating these two approaches, you could draw the conclusion that excessive Stalinist secrecy meant Soviet doctors fell behind western doctors working with greater access to information in an open society. Without information, Soviet doctors in their closed society practiced blindly, which is why the American methods of evaluating radiation exposure and health were superior. That was largely the conclusion American researchers came to in the 1990s. In the post-Cold War period when everything Soviet was considered backward, the assumption that Soviet radiation medicine had little value made perfect sense. It is useful, however, to look at how American assumptions embedded in the practice of health physics had evolved out of an industrial-medical trajectory that had plucked bodies from the environments in which they had grown ill.

In the 18th and 19th centuries, doctors and patients in the United States and Europe believed that disease was linked to the landscape. Disease was seen as an imbalance in the body related to changes in a complex of environmental and social factors. There were, for example, healthy places and sickly ones. Bodies were considered permeable and susceptible to environmental vapors, fogs, winds, and temperature. Nineteenth century doctors kept records of weather, barometer, and humidity in order to understand the health of their patients.[xxiii] In the late 19th century, germ theory changed this understanding of disease. Instead of tracing illness to a variety of environmental and bodily factors, germ theory located single external agents as the source of illness. A germ could be anywhere and penetrate the body regardless of ecological factors, and so germ theory made disease placeless, forging a trend in medical research that turned away from the study of how environmental factors determined health.[xxiv] In the 20th century, as doctors focused their research on singular causes of disease in bodies outside of place, other professionals—agronomists, hydraulic engineers, soil scientists, among many—stepped in to study the environment.[xxv] In this way, as a subject of attention, the body and the environment were divorced from one another.

In the forties, American researchers were concerned about worker health as plant operators came in contact with industrial-sized quantities of radioactive isotopes for the first time at the Hanford plutonium plant in eastern Washington, and they used methods which grew out of the field of toxicology, which had, in turn, taken lessons from germ theory.[xxvi] Industrial hygienists did not determine occupational illness based on a workers' health complaints. Rather they fixed on measurements of toxins in the factory environment which could be attached to a harmful physiological development; for example lead, known to cause bodily harm found both in factory air samples and workers' blood samples made for a bullet-proof case.[xxvii] Following the same method, in 1944, American researchers first tried to trace and count the deposition of radioactive isotopes in bodies of test animals and then human subjects. This was a frustrating experience because they could not detect trace elements of radioactive isotopes, but only larger "threshold" doses. For decades they worked on devising machinery sensitive enough to count isotopes buried in organs and bone marrow, with only limited success.

Another way to determine how large a dose a worker might be getting was to estimate exposure. At the Hanford Plant, researchers put in place a monitoring program, attaching pencil-shaped radiation detectors to workers' bodies, and placing monitoring devices in shops and labs. Taking lessons from industrial hygienists in the chemical industry, environmental researchers went outside, setting up filters, taking samples to study the spread and concentration of radioactive isotopes in soils, air, water, plants and animals. Soil scientists looked at how a particular radioactive isotope, say Cesium 137, soaked into soils, found its way to the roots of plants and then into the plants' fruits.[xxviii] Ichthyologists studied fish swimming in water laced with suspended radioactive isotopes.[xxix] Meteorologists examined the path of isotopes in air currents. These “pathway” studies found that particular radioactive isotopes acted in unique ways depending on the specific environment—the mix of alkaline, sand, rock and mineral in soils, the temperature and force of plumes in rivers, the vagaries of wind and precipitation in air. Yet, because scientists of the ecology had divided into divergent disciplines and, likewise, from scientists studying human bodies, this knowledge of the particular ways radioactive isotopes worked in unique environments scarcely made its way into medical studies of radiation's effect on the body.

American researchers were looking for cause and effect: singular radioactive isotopes assaulting singular bodily organs to produce stand-alone diseases. That was how industrial hygienists had developed argumentation to prove, in rare cases, that workers were sick from exposures to toxic chemicals on the job.[xxx] It was important in the United States for doctors and lawyers to be able to prove in court that a certain agent (and not others) caused bodily harm. Early nuclear workers complained of health problems, which they suspected had something to do with their jobs, but newly-minted “health physicists,” like industrial hygienists before them, generally assumed that workers dissembled and exaggerated their symptoms.[xxxi] How a worker felt could not be diagnosed.[xxxii] In the American tradition of toxicology, from which radiation biology or “health physics” emerged, only a link between a quantifiable exposure (i.e. a certain dose of radioactive iodine) with a known physiological effect (thyroid cancer or disease) constituted an occupational illness.

Doctors at Hanford, like Maiak doctors, took blood samples from plutonium plant employees and administered medical checkups, but they were not looking for a broad set of symptoms, as were Soviet doctors, that might clue them in to medical problems associated with long-term exposure. Doctors working within the Atomic Energy Commission (the precursor to the Department of Energy) generally believed that if a body stayed within exposures outlined by the “permissible dose,” despite the fact that the official permissible dose declined steadily from

1942 to the end of the century, that body was safe.[xxxiii] The archival record shows how American doctors were loath to link a worker's poor health or untimely death to the Hanford plant's leaking fission products and even more so to relate the effect of the plant's radioactive effluence on the bodies of neighbors. Anxious about medical-legal precedents and liability, they did not connect a worker's exposure with occupational deaths until the 1990s. While the Hanford Plant was functioning, it had, officially, no recorded fatalities from radioactive isotopes.[xxxiv]

Historian Linda Nash describes how the splintering of body and environment into various fields "made it difficult to draw connections between environmental change and changes in human health."[xxxv] Indeed, Hanford health physicists coupled the record of a radioactive terrain with bodies of the surrounding public only in the early sixties, and then rarely.[xxxvi] In one 1963 study of twelve people living closest to the Hanford plant, when researchers found high depositions of radioactive iodine in two children, they assured the parents that the children's doses were well within "permissible doses." They did not tell them they calculated the dose for workers in the nuclear industry, not for civilians or far more vulnerable children.[xxxvii]

The Soviet diagnosis of Chronic Radiation Syndrome described a broad category of symptoms which were difficult to distinguish from symptoms of many major illnesses such as heart disease, hepatitis, rheumatism, and tuberculosis.[xxxviii] CRS never became a diagnosis in the American medical tradition in part because it would never hold up in court. There was no way in the American medical-juridical understanding of occupational illness to separate the complex of symptoms describing CRS from other illnesses with similar symptoms. American research was focused on notions of stand-alone diseases from singular entities, like germs producing TB or singular toxins or radioactive isotopes causing cancer. Except for a few geneticists working in the late forties, I have found no evidence that American researchers thought in terms of radioactive isotopes assaulting multiple organs to weaken immune systems and cause a multiplex of debilitating symptoms.[xxxix] Most researchers just didn't think that way. Their focus was on exposures, not on bodies and their symptoms, as researchers recorded long lists of estimated doses and depositions in isolated organs. To an amazing degree, in the studies that emerged from American nuclear installations—bodies of patients and certainly bodies in pain—are wholly invisible.

Historian Christopher Sellers situates a form of this "body blindness" in the early American environmental movement of the sixties. The first activists, failing in court to draw a line between the coterie of vague human health effects associated with a chemical sensitivity to DDT turned instead to proving in court damages to animals and birds as "property" and natural resources. Winning these early court cases over contaminated environments, activists established the Environmental Defense Fund, but in so doing, Sellers argues, they turned their back on the humans threatened by environmental disasters to focus on land, animals, and property.[xl] Cancer research shows a similar body blindness. Most cancer research has focused on the cure rather than environmental causes of cancer, which accounts for two-thirds of all cancers. Insurance companies will pay for genetic testing on women with breast cancer, but they refuse to use the body as an archive to analyze breast tissue for chemical carcinogens.[xli] This is not just an American problem. Employers and insurers worldwide are notoriously reluctant to treat the body as a source of evidence. Zhang Haichao, a migrant worker in China, was exposed to silica dust at the Zhendon Abrasion Proof Material Company in the Henan Province. He contracted silicosis, but the official occupational disease hospital repeatedly refused to certify him as suffering from silicosis, diagnosing Zhang instead with tuberculosis, which called for no compensation. To prove his case, Zhang had to go to extremes. He persuaded a doctor to perform a live lung biopsy to confirm his silicosis, although a simple x-ray had shown the disease clearly.[xlii] A failure to see bodies and to use them as archival maps of exposure helps explain the emphasis on cures, not the environmental causes, of a growing number of deadly diseases.

In the late 1980s and early 1990s, as the Department of Energy declassified tens of thousands of documents, the records detailed the colossal volume of radioactive waste dumped into the interior western environment during the Cold War. When Americans living near the Hanford plant claimed that they and their offspring were ill with a variety of illnesses, which they blamed on the plant, tellingly DOE-funded researchers targeted the first large-scale studies of people living near the plant, not on bodies, but on "dose estimates" from environmental studies. These estimates, calibrated from years of ambient levels of radioactive isotopes, guessed the doses residents received, then they ran those numbers against estimated exposures of Japanese survivors of the Hiroshima and Nagasaki bombings to come up with the probability of the "downwinders" getting a couple of telling cancers and thyroid disease.[xliii]

The Atomic Bomb Casualty Study serves to this day as the gold standard in determining for American medical and juridical panels probable causalities of illness from radiation exposure.[xliv] Of course, the one-off explosions in damp and coastal Japan differed greatly from the slow-drip of exposures of a different cocktail of radioactive isotopes on the volcanic soils of the arid and continental Columbia Basin. Japanese in the fifties had very different diets and daily habits than residents of eastern Washington, but medical researchers rarely took those differences into account. Rather they made models estimating doses across landscapes and their effects on bodies in ways that saw the bodies and landscapes as interchangeable.[xlv] This is remarkable considering all hydrologists, ichthyologists, meteorologists, and soil scientists had discovered in four decades of research at the labs at Hanford about the locally contingent pathways of radioactive isotopes in the environment. Despite this research, medical researchers assumed that radioactive isotopes from two blasts in Japan in 1945 would behave the same way as different quantities of radioactive isotopes leaking gradually into the eastern Washington for decades. For that reason, regulatory and legal rulings concerning Hanford have produced the bizarre conflicting diagnoses that while the federal government found the Hanford Nuclear Reservation to be severely contaminated and in need of a 100 billion dollar cleanup, federal courts determined that people living downwind and downstream of Hanford were not affected.

Those kinds of rulings offer the moment when the bodies of exposed people disappeared, dissolved into the heavy physical and mental labor of trying to make insensible isotopes stand up and be counted. That is what had long puzzled me as I read through the published medical studies of the people exposed near the Hanford and Maiak plants. The bodies—how they felt, their complaints, what they experienced as pain or illness—played no role in these records. There simply were no bodies, just counts of various isotopes, dose estimates, and various probabilities of the emergence of cancer in numerous organs extracted from a statistically configured composite body.

Invisibility takes a lot of work. The medical studies of the 1990s in the United States and then later in Russia, did just that, de-materializing the bodies exposed to the world's first plutonium plants' radioactive waste. As I had pushed away my interview subjects' medical records, I too exhibited this same body blindness. Unable to judge, I did not know what to do with the vague complaints of my interview subjects. When Kuzminova raised her shirt to show me her scars, tellingly I wanted nothing more than to make her body go away.

I puzzled over how to get past the obfuscating data and make those bodies appear again. One day I had an encounter that focused my thinking about bodies and health effects. While living in the cottage on the outskirts of Kyshtym, I got to know a neighbor, Ludmilla, who had a garden of potatoes she tended carefully. It was an unusually dry summer and every day, she and a friend, both in their sixties, carried buckets from the well to the garden to water their potato plants until they collapsed toward evening on a bench, fanning themselves. Sometimes I joined them in their watering, and Ludmilla gave me eggs and green onions in exchange. Ludmilla introduced me to her daughter, a slight woman with a pinched, worried face. I never caught her name. The daughter came to visit me unexpectedly one evening in my cottage. She said she wanted to meet an American. She had never met a foreigner before and she thought she'd like to because she felt she didn’t belong in Kyshtym. Over tea, she told me about her life; that she had a low-paying job; that she and her son lived in an apartment with no plumbing, just a courtyard outhouse; that she was tired of it all.

I asked her the age of her son. “Twenty-one,” she said, “You know, the fellow who drives me here.” I was astonished. I had taken her son, balding, blanched and withered, to be her husband, an older husband. He looked like he'd been born at least a decade before his mother. She admitted his health was poor, due, she thought, to a copper-smelting factory within 200 meters of their apartment building. I calculated other risks that might factor. Kyshtym took a good hit over the decades from the radioactive effluent of the Maiak plant. As well, the young man was born in 1989, at the start of Russia’s long economic crisis, a decade in which food, clothing and health care were in scant supply.[xlvi] A complex of factors likely sped the son past his mother in aging. His precise diagnosis will probably never be known, which does not change the fact that he is clearly very ill. There is yet no medical study, historical inquiry or epidemiological mapping that can place that boy back in his courtyard under the smelting plant’s gray fog trailing lead and arsenic, while he dug in earth over which clouds laced with fission products had rained. That sort of history is yet nowhere to be had, but the prematurely aged young man’s body might just give clues to such a history if there were a way to read bodies as historical texts.

This is a new frontier of scholarly inquiry, one which seeks to re-animate and re-create historically voided bodies, in a way that does not dismiss bodies in pain.[xlvii] For, the landscape most overlooked on the panorama of nuclear sacrifice zones, is the landscape of the body. Human bodies—porous, renewing and transforming—are as much a repository, a dump of manmade waste products, as are rivers, ground water, soils, plants and animals. Think of the tourists, people like myself, who engaging in dark tourism, explore ghost towns, battlefields, and depopulated nuclear zones. The last stop of this tour should be reflective, a tour of human bodies, for they are the long-haul truckers of the vast transformations of human history. Human history, in other words, is changing human bodies. Yet this bodily archive has scarcely been breached. In the search for secrets, the mysteries are right here with us.

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[i]Kathleen Day, "Sting Reveals Security Gap at Nuclear Agency," *Washington Post*, A1, 12 July 2007.

[ii] Author interview with Anna Miliutina 21 June 2010, Kyshtym. After a major accident in 1957, plant managers gradually introduced a safety regime of sanitation and monitoring. "Stenogrammy na vtoroi Ozerskoi gorodskoi partkonferentsii, 30 Nov. 1957, Ob'edinennyi Gosudarstvennyi Arkhiv Cheliabinskoi Oblasti, Cheliabinsk, Russia (OGAChO) 2469/1/117, 205, 238.

[iii] Valentina Pesternikova Nadezhda Okladnikova, Margarita Sumina, and Victor Doshchenko. "Occupational diseases from radiation exposure at the first nuclear plant in the USSR," *The Science of the Total Environment* 142 (1994): 9-17; and Angelina Gus'kova, *Atomnaia otrasl' strany: Glazami vracha* (Moscow 2004), 82.

[iv]See *Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters (*New York: Oxford University Press, 2013), 187-196. On the dangers of their exposure, see G. Thompson, "Unmasking the Truth: The Science and Policy of Low-dose Ionizing Radiation," *Bulletin of the Atomic Scientists* 68, no. 3 (May 1, 2012): 44–50. On the revised totals, see M. O. Degteva, N. B. Shagina, M. I. Vorobiova, L. R. Anspaugh, and B. A. Napier, "Reevaluation of waterborne releases of radioactive materials from the Mayak Production Association into the Techa River in 1949-1951," *Health Physics,* 2012 Jan; Vol. 102 (1): 25-38.

[v] V. N. Novoselov, and V. S. Tolstikov, *Atomnyi sled na Urale* (Cheliabinsk: Rifei, 1997), 171.

[vi] Elaine Scarry, *The Body in Pain: The Making and Unmaking of the World*, 1st ed. (Oxford University Press, USA, 1987), 1-7.

[vii] Mira Kossenko, a former radio-biologist at the Maiak Plant, noted that the dose measurements taken over the years by Soviet monitors on the Techa River were deemed so unreliable by

Japanese researchers, that they refused to use the data. Author interview with Mira Kossenko, May 13, 2012, Redwood City, CA.

[viii] S. A. Roach and S. M. Rappaport, "But They Are Not Thresholds: A Critical Analysis of the Documentation of Threshold Limit Values," *American Journal of Industrial Medicine,* 17 (1998); 727-753; and ; and Gregg Mitman, Michele Murphy, Christopher Sellers, "Introduction, A Cloud Over History," in Landscapes of Exposure, *Osiris,* vol. 19, 2004, 13.

[ix] Karen Dorn Steele, "U.S., Soviet downwinders share legacy of Cold War," *Spokesman Review*, 13 July 1992, A4.

[x] For a filmmaker's view of the archives, see the documentary film, *Chelyabinsk: The most contaminated spot on the planet,* Slawomir Grunberg.

[xi] For the promotional brochure advertising the data, see Ministry of Health of Russia, *Muslyumovo: Results of 50 Years of Observation*, (Chelyabinsk, 2001).

[xii] From 2000-2004, the DOE did fund some studies that looked into the linkage between ionizing radiation, multiple sclerosis and Parkingson's. In areas, such as Spokane County, downwind from Hanford, researchers found a significant elevation in the frequency of multiple sclerosis. Walter B. Eidbo and Merle P. Prater, "Linkage— Multiple Sclerosis and Ionizing Radiation." See also the work of Swedish researchers looking at diagnostic and occupational exposure to hospital xrays, Olav Axelson, Anne-Marie Landtblom, and Ulf Flodin, "Multiple sclerosis and ionizing radiation."DOE presently has a low dose medical research program in conjunction with NASA. Most of this research is related to genetics (http://lowdose.energy.gov/about_projects_doe_nasa.aspx). In 2007, the DOE funded studies of low dose exposure to radiation and made progress in determining "dose-dependent changes in gene and protein expression, which differ from those at high dose exposures." (DOE FY2007 accomplishments, 196). Just as scientists were finally making progress in distinguishing specific bodily changes from low-dose exposures, DOE funding for this research was steadily

reduced between 2011 and 2013. The research was deemed “completed,” yet the DOE has issued no final reports of this research. Rod Adams, “Why was DOE’s Low Dose Radiation Research program defunded in 2011,” *Atomic Insights*, 26 November 2013, atomicinsights.com. For a review of this literature and a plea for more research, see C. K. Hill, “The Low-Dose Phenomenon: How Bystander Effects, Genomic Instability, and Adaptive Responses Could Transform Cancer-Risk Models,” *Bulletin of the Atomic Scientists* 68, no. 3 (May 1, 2012): 51–58.

[xiii] Ibid.

[xiv] Angelina Gus'kova, *Atomnaia Otrasl' Strany: Glazami Vracha* (Moscow 2004), 111.

[xv] Despite the fact that The National Academy of Sciences' Board on Radiation Effects Research Biological Effects of Ionizing Radiation (BEIR) VII Committee concluded in 2005 that "there is no threshold of exposure below which low levels of ionizing radiation can be demonstrated to be harmless,” and that in addition to cancer “other degenerative health effects have been demonstrated” from low dose exposure, these insights have not been incorporated into regulation or law suits.

[xvi] Peter B. Hales, *Atomic Spaces: Living on the Manhattan Project* (Urbana: University of Illinois Press, 1997), 281.

[xvii] Ibid, 284.

[xviii] H. M. Parker to S. T. Cantril, “Action Taken on Report on Visit to Site W, April 9-April 13, 1945 by G. Failla,” 10 July 1945, HW-7-1973, DOE Public Reading Room (PRR), Richland, WA, and Parker, Control of Ground Contamination, 19 August 1954 HW 32808, PRR.

[xix] Scott Kirsch writes how in 1962 the dissenting AEC scientist Harold Knapp caused problems within the AEC by proposing to run tests on children and milk cows downwind of the Nevada Test Site. Other researchers were monitoring the environment around the test site, but Knapp was asking to do something different. He proposed to collate data of exposed people with their places

of exposure. This proposition caused a ripple of protest within the agency, and Knapp was denied access to the monitoring results of the Nevada tests. Scott Kirsch, "Harold Knapp and the Geography of Normal Controversy: Radioiodine in the Historical Environment" in *Landscapes of Exposure: Knowledge and Illness in Modern Environments*, eds. Gregg Mitman, Michelle Murphy, and Christopher Sellers (University of Chicago 2004), 167-181.

[xx] Gus'kova, *Atomnyi otrasl',* p. 87; and Novoselov and V. S. Tolstikov, *Atomnyi sled na Urale,* 247.

[xxi] V. N. Novoselov, and V. S. Tolstikov, *Taina "Sorokovki," (*Ekaterinburg: "Ural'skii rabochii", 1995), 247-48.

[xxii] V. Larin. *Kombinat "Maiak" - problema na veka*, (Moskva: KMK Scientific Press, 2001), 202-03.

[xxiii] Gregg Mitman, "In Search of Health: Landscape and Disease in American Environmental History," *Environmental History* 10, no. 2 (April 1, 2005): 184–210.

[xxiv] Siddhartha Mukherjee, *The Emperor of All Maladies: A Biography of Cancer*, 1st ed. (Scribner, 2010).

[xxv] Linda Nash, "Finishing Nature: Harmonizing Bodies and Environments in Late-Nineteenth-Century California," *Environmental History* 8, no. 1 (January 1, 2003): 25–52.

[xxvi] See the National Archive of Atlanta, Record Group 326. The first medical studies emanating from the Manhattan Project were filed under "toxicology," and radiobiology generally was encoded "T," short for toxicology. On borrowing from industrial safety standards, see Barton C. Hacker, *The Dragon's Tail: Radiation Safety in the Manhattan Project, 1942*-1946 (Berkeley 1987), 51.

[xxvii] Linda Nash, "Purity and Danger: Historical Reflections on the Regulation of Environmental Pollutants," *Environmental History* 13, no. 4 (October 1, 2008): 644.

[xxviii]For one of the earliest studies, see Jacobson and Overstreet, "Absorption and Fixation of Fission Products and Plutonium by Plants," June 1945, Bancroft Library, Special Collections, Ernest O Lawrence Papers (EOL), Berkeley, CA, reel 43, (box 28), folder 40

[xxix] "Summary Medical Research Program," National Archives, Atlanta, (NAA), 326-87-6, box 24, 'Fish Program.'

[xxx] MD PhD Christopher Sellers, "Discovering Environmental Cancer: Wilhelm Hueper, Post-World War II Epidemiology, and the Vanishing Clinician's Eye," *American Journal of Public Health* 87, no. 11 (1997): 1824-35.

[xxxi] On employee fears of illness from contaminations over the decades at Hanford, see H. M. Parker, "Action Taken on Report on Visit to Site W by G. Failla," 10 July 1945, HW-7-1973, PRR; Hofmaster to Jackson, 24 July 1951, HM Jackson Papers (HMJ), box 28, folder 23; Stafford Warren, "Case of Leukemia in Mr. Donald H. Johnson," 7 February 1945, NAA, RG 4nn-326-8505, box 54, MD 700.2 "Enclosures; and K. R. Heid to W. F. Mills, 30 July 1979; and Michael Tiernan, 10 August 1979, RLHT595-0013-DEL, PRR.

[xxxii] Linda Nash, "Purity and Danger: Historical Reflections on the Regulation of Environmental Pollutants," *Environmental History* 13, no. 4 (October 1, 2008): 653-55.

[xxxiii] For a good discussion of the range of opinions on safe thresholds and reigning opinion, see Donna M. Goldstein and Magdalena Stawkowski, "James V. Neel and Yuri E. Dubrova: Cold War Debates and the Genetic Effects of Low-Dose Radiation," unpublished paper.

[xxxiv] See Kate Brown, *Plutopia,* 178-184.

[xxxv] Nash, Linda, "Finishing Nature: Harmonizing Bodies and Environments in Late-Nineteenth-Century California," *Environmental History* 8, no. 1 (January 1, 2003): 44. See also, Christopher Sellers, "Factory as Environment: Industrial Hygiene, Professional Collaboration and the Modern Sciences of Pollution," *Environmental History Review* 18, no. 1 (April 1, 1994): 55–83.

[xxxvi] Guidelines for public exposures were developed in the late fifties. See Interview with Lauriston Sale Taylor by Gilbert Whittemore, August 11, 1990, Niels Bohr Library and Archive, section II, http://www.aip.org/history/ohilist/5153_2.html.

[xxxvii] "Internal Dosimetry Results—Ringold," 30 January 1963, PNL 10337, DOE Public Reading Room, Richland, WA (PRR). In another study, the researchers estimated probable doses to neighboring children from drinking water and milk contaminated with iodine-131, but they did not test the actual children in question. R. F. Foster, "Evaluation of Radiological Conditions in the Vicinity of Hanford fro 1963, 24 February 1964 HW-80991, DOE Opennet. In another study, 58 children were tested: Swanberg, Jr. "Special Studies Conducted by Internal Dosimetry," 19 March 1963, PNL 9709, DOE Opennet.

[xxxviii] Novoselov, and Tolstikov, *Atomnyi sled,* 170.

[xxxix] "Experiments to test the validity of the Linear r-dose/mutation Rate Relation at Low Dosage," RG 4nn-326-87-6, Box 24, 'Summary Medical Research Program,' NAA.

[xl] Christopher Sellers, "Body, Place and the State: The Makings of an 'Environmentalist' Imaginary in the Post-World War II U.S." *Radical History Review* no. 74 (Spring 99 1999): 24-27.

[xli] Sarah S. Lochlann Jain, *Malignant How Cancer Becomes Us* (Berkeley: University of California Press, 2013), 80.

[xlii] Sanjiv Pandita, "Environment and Labour in China: Change is led from below," *ILWCH*, no. 85, fall 2014.

[xliii] David Richardson, Steve Wing, and Alice Stewart, "The Relevance of Occupational Epidemiology to Radiation Protection Standards," *New Solutions*, 9, no. 2 (1999): 133-51.

[xliv] Sander Greenland, "Underestimating effects: Why causation probabilities need to be replaced in regulation, policy, and the law," *Bulletin of Atomic Scientists*, 68/3, 76-83.

[xlv] In the Hanford Environmental Dose Reconstruction (HEDR) case, researchers set out to reconstruct the doses of people living downwind from the plant might have received over the decades. The study focused on the environment and overlooked the bodies of residents living in the downwind territories. See J. E. Till, J.E., "Environmental Dose Reconstruction," *Proceedings Thirty First Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP).* Washington, D.C., April 12–13, 1995, National Council on Radiation Protection, Bethesda, Maryland.

[xlvi] "Karta ekologicheskogo sostoianiia Cheliabinskoi oblasti," (Cheliabinsk, 1994); and A.E. Ivanova, V. G. Semyonova, N. S. Gavrilova, G. N. Evdokushkina, L. A. Gavrilov, "Mortality trends: Role of particular age groups and causes of death in their shaping," *Obshchestvenno zdorov'e i profilaktika zabolevanii,* 2004, 6: 3-9.

[xlvii] A new field of narrative medicine is emerging to incorporate biography and narrative in healing processes. Lorrie Klosterman,"Narrative Medicine Heals Bodies and Souls" *Utne Reade,* September-October 2009, 3. The field of medical anthropology has been exploring the question of the relationships between landscapes, health and bodies for some time. See, for example, João Guilherme Biehl, *Vita: Life in a Zone of Social Abandonment* (Berkeley: University of California Press, 2005); and Kristen Iversen, *Full Body Burden: Growing Up in the Nuclear Shadow of Rocky Flats*, 1st ed. (New York: Crown, 2012).