9 Fallout Memory Trajectories at Semipalatinsk

Reassembling the Post-Soviet Past

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Located in a river park in Semey, formerly Semipalatinsk, an enormous monument is dedicated to the victims of nuclear testing. Reaching higher than the trees, the memorial titled "Stronger than Death" on the banks of the river Irtysh features a gigantic tombstone in anthracite color, with the silhouette of the mushroom cloud of a nuclear explosion; beneath the atomic mushroom is the sculpture of a woman shielding a child (Figure 9.1). With nuclear tests being part of Semipalatinsk's formerly secret past and now public memory, residents of Semey city and surrounding settlements come here on weekends or for an afternoon stroll during summer, taking their pictures in front of the monument. Locals take their visitors to the memorial for sightseeing, along with Semey's museum of Dostoyevsky and the new suspension bridge across the river Irtysh built by a Japanese company in the 2000s, or the surrounding woods with the scent of pine trees and the historic burial sites in the wide-open steppe south of the city. Often this memorial is referred to as an achievement, given the weight and impact of the nuclear past as well as the overcoming of the economic crisis of the 1990s.

Built in 2001, the memorial "Stronger than Death" is an official, visible testimony to how the new Republic of Kazakhstan officially has positioned itself in relation to its Soviet nuclear past. The government commissioned two Kazakh artists to design it: Shota Valikhanov, a sculptor and architect who also supervised the creation of the independence monument on the Republic Square in Almaty (Alma-Ata during the Soviet time), and Zhandarbek Malibekov, the designer of the Kazakhstani national emblem. The memorial joins the new republic's state symbols, many of which evoke the Kazakh past as one of Eurasian steppe nomads. Some date back to the 6th–5th century BC, the century of the "Golden Man" ("*zolotoi chelovek*") found about 50 km east of Almaty in a Soviet archeological expedition in 1969–1970 and are today presented in a dedicated section of the Central Museum of Kazakhstan in Almaty. Foregrounding and linking "Kazakhness" back to the era of the Eastern Scythes is one example of how heritage representations in museums are crafting new accounts of deep Kazakh past.[1]

The politics of state building also reached into the ways in which the aftermath and legacies of Soviet nuclear testing was dealt with. Closing down

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Figure 9.1 Memorial "Stronger Than Death," Semey, Kazakhstan.

Source: Photograph by Susanne Bauer (2011).

nuclear testing at the Semipalatinsk test site was an important moment for post-Soviet state building which President Nazarbayev seized in a strategic effort and proudly presented as host of the OSCE meeting in Astana in December 2010.[2] To leave behind the Cold War logic of "mutually asserted destruction," the new independent Republic of Kazakhstan initiated a "Central Asian Nuclear-Weapon-Free Zone."[3] This was part of crafting a break with the Soviet past and nation building along with infrastructural changes, such as moving the capital from Almaty to then Tselinograd, renamed first Akmola and then Astana (capital in Kazakh) – today's Nur-Sultan – and the promotion of Kazakh as official language in all domains, while keeping Russian as a language of communication between different national groups within Kazakhstan. The government promoted the Kazakh language while labeling Kazakhstan's society as multiethnic and multireligious in the statutes of the new republic.

Most post-Soviet countries offered citizenship to all residents after the dissolution of the USSR independent of the entry of category "nationality" ("*natsional'nost'*") in their Soviet passports. Unlike other post-Soviet countries of central Asia, Kazakhstan kept distinguishing between "Kazakh" as a category for language and "*natsional'nost'*" – and "Kazakhstani" for citizenship.[4]

The Russian-focused Soviet standard curricula in history and philosophy were replaced by new textbooks; university graduates had to pass exams on Kazakh history and philosophy.[5] The Republic of Kazakhstan held on to the key categories of Soviet historiography, but exchanged most of its protagonists.[6] For instance the annual commemoration of the many Central Asian veterans on May 8–9 is an important unifying continuity of the Soviet past, while the history curricula in institutions and programs in science and education were completely reorganized. Major reorientations in research policies affected not only the humanities but also the environmental health sciences – especially in relation to the Soviet nuclear program and its Central Asian sites. Long-term health effects of nuclear test fallout and residual radionuclides became subject to major research programs under the auspices of different ministries of the Republic of Kazakhstan, including the Ministry of Health, the Ministry of Education and their regional branches.[7] For the neighboring Altai region, bordering the exposed areas to the northeast, the Russian Ministry of Emergency Situations set up a Federal Program "Semipalatinsk Test Site/Altai," which included the compilation of health data, dose reconstruction, and an exposure registry for the rural population of Altai region settlements, exposed to fallout from nuclear testing.[8]

In her account of Soviet census-taking in the early USSR, historian Francine Hirsch shows how scientific programs, the statistics and routines they generate, play a key role in shaping states, political technologies, and historical narratives. State-funded scientific programs also perform and constitute broader collective cultural memory and technologies of memorialization.[9] This chapter builds on studies of memorialization and Science and Technology Studies (STS) in order to broaden the concept of memorialization beyond its symbolic dimensions. In examining a specific set of scientific memory practices[10] in radiation risk studies, I trace the specific memorialization work done through biomedical risk assessments during the early post-Soviet years (1991–2010). While this approach builds on and joins recent scholarship in atomic heritage studies,[11] it foregrounds technoscience studies of biomedical practices. Theorizing residual radionuclides in the environment and human bodies, it takes inspiration in Hannah Landecker's notion of the "biology of history," in terms of "understanding both the materiality of history and the historicity of matter in theories and concepts of life today."[12]

I examine how, after the end of nuclear testing, risk assessment practices documented the nuclear past and its embodiments, especially with respect to transgenerational effects of fallout exposure. As techniques for tracing and scientific memory work, cytogenetics and population genetics had moved center stage in the atomic era, later on followed by standardized genomics-based techniques that came to constitute credible methods to document radiation effects in blood cells. By highlighting scientific practices as a particular mode of memory work, this chapter focuses on the production of radiation knowledge. I investigate how the post-Soviet reassembling[13] of legacies combined with new scientific developments shaped specific versions of risk assessment and nuclearity.[14] I will first address the role of the nuclear weapons program in post-Soviet Kazakhstan, followed by an examination of three scales of memory practices, which biomedical scientists have brought to work in order to document radiation effects. Thus, this chapter traces the ways in which environmental effects materialize at different scales and through biomedical concepts of life – chromosomal, transgenerational, and populational – as they are mobilized in the meticulous labor and memory practices in radiation science.

Post-Soviet Reassembling: Retrieval and Containment of the Cold War Nuclear

As part of the secret atomic program, Soviet authorities had decided to place the USSR's first nuclear weapons test site in the steppe area near Semipalatinsk, in the northeast of Kazakhstan. The area is situated south of the Altai region in today's Russian Federation, and not far from the border to the Xinjiang region of China.[15] In 1947 construction works for a closed nuclear city at the shores of the river Irtysh began, as a key step of the nuclear program at the dawn of the Cold War. At the command of Lavrentii Beria on August 29, 1949, the first Soviet nuclear bomb (22 kt TNT eq.) was detonated at the test site, under vast political pressure, during unfavorable weather conditions.[16] This first nuclear explosion in 1949 led to fallout reaching to settlements northeast of the test site and into parts of the Altai region, up to the city of Biisk, as aerial surveys showed.[17] Following the first Soviet nuclear test, military aircraft conducted measurements of the fallout and the radioactive cloud; in western countries, the detonation was detected on seismographic monitoring instruments. Under secrecy yet witnessed by largely ignored local communities,[18] nuclear weapons testing amounted to an official total of 456 nuclear detonations between 1949 and 1989, according to numbers published by Russian authorities.[19] Official sources counted 116 above ground nuclear explosions at the Semipalatinsk test site. This included the first Soviet hydrogen bomb on August 12, 1953, with a yield of 400 kt TNT eq., the most massive detonation conducted at Semipalatinsk. Atmospheric nuclear testing continued until 1963 and, as a result of the first moratorium of the Limited Nuclear Test Ban Treaty, nuclear testing proceeded with underground nuclear devices from 1965 through to 1989, before the test site was closed in 1991. Due to the sheer impossibility to take the complex formation of the exposure situation into account, Kazakhstani dosimetrists would begin their assessments by focusing on the most dose-contributing nuclear tests.

With Kazakh author Olzhas Sulemeinov as a prominent spokesperson and backed also by the movement Nevada-Semey, the issue of nuclear testing had played a role in the formation of opposition during the Gorbachev era, following the Zheltoksan (December) protests in Alma-Ata, which had been violently met by police and military.[20] Closing the Soviet nuclear test site was a highly symbolic and significant act that almost immediately followed the declaration of an independent Republic of Kazakhstan in December 1991.

With independence, USSR institutions were slowly fading from relevance, sometimes revived, given up, or rebuilt and transformed to fit the new Republic of Kazakhstan. As Alexei Yurchak noted, "everything was forever, until it was no more."[21] Visible and invisible infrastructures, institutions and everyday routines were disrupted. The administration of the new independent state changed the cityscape by renaming streets and making more space for Kazakh figures, such as 18th-century Kazakh warrior Kabanbai-batyr or famous 19th-century poet Abai Kubanbayev (Abai Qunanbaiuly), born in Semipalatinsk province. In contrast, Lenin statues were taken down and removed from central squares of the city – yet, they have been protected from complete disappearance and reassembled in a semicircle just behind the hotel Irtysh (Figure 9.2).

The city's name – Semipalatinsk – remained associated with Soviet nuclear weapons testing and hence also was up for revision. That Semipalatinsk was renamed Semey in 2007, was intended as a move toward sounding "somehow more light and friendly," and, without the association with the test site, more open for investors, as I am told. Over decades, nuclear testing indeed had not only been felt by the regular trembling of the earth, but also shaped the lives of scientific communities. One of my interlocutors, a physicist, pointed out that working under secrecy had become routine for scientific ground staff:

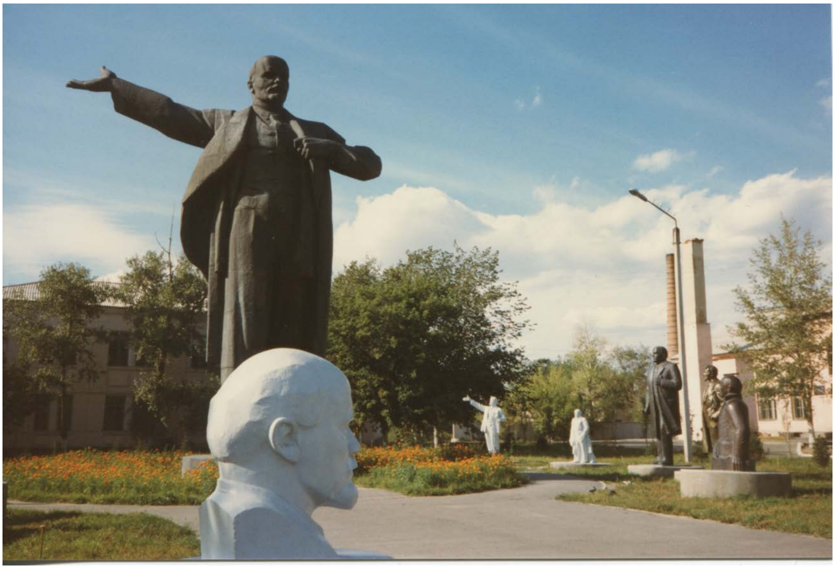

Figure 9.2 Semipalatinsk city's Lenin statues reassembled in a park near hotel Irtysh, after they were taken down in the city squares.

Source: Photograph by Susanne Bauer (1997).

"we were young, we were singing songs together during these shifts, it was a great collective and we firmly believed we worked for peace." What was perceived as normal and peace-building changed drastically over professional lifetimes.

During the early post-Soviet period, journalists described nuclear testing as "genetic genocide"[22] of the local Kazakh population, aligning fallout exposures with the long history of Russian imperialism and Moscow's Cold War technoscientific agenda in Central Asia. Indeed, modernization in pre-Soviet Kazakhstan, following 18th and 19th-century colonization, despite many uprisings began to destroy the seasonal livestock economies adapted to the steppe areas. While parts of the Kazakh elites in the 19th and early-20th century adopted Russian sciences,[23] medical modernization also came at the price of violent interventions into knowledge of the people as well as the nomadic livestock economies altogether. Cold War technoscience and post-Soviet transitions added further layers of violent disruption to livelihoods in northeast Kazakhstan.

Soviet modernity was not only about Lenin's saying that "communism is Soviet power plus electrification of the whole country"[24] but also about the establishment of a public health infrastructure – a promise that Sovietization held up to, albeit not without costs. During the Soviet era, medical modernization led to an increase in hospital beds and broad public health services, for instance through *fel'dshery*, i.e., the paramedical health staff introduced already with *zemstvo* medicine in the 19th century. During the post-Stalin years and throughout the 1960s, the USSR became internationally renowned for its comprehensive public health system, especially through the system of *fel'dshery* and public health nurses providing healthcare in addition to district hospitals in rural areas.[25]

With the post-Soviet dissolution of institutions, official policies in the new Republic of Kazakhstan began to reorient the collective memory. New narratives often recombined pre-Stalinist and pre-Soviet history of Kazakhstan, evoking the nomadic tradition of the steppe in novel ways and as a counterpart to Russian settler colonialism in Central Asia. Interestingly, the new historical narratives have also kept significant traditions from Soviet history, such as the importance of commemorating the Second World War and the many veterans from Kazakhstan. The episodes of hunger during the 1920s and the Kazakh Famine of 1930–1933, during with 1.5 million people, approximately a quarter of the population died, had been tragic part of the formation of the Kazakh SSR, but did not become a central narrative in the new Republic of Kazakhstan.[26] In short, the post-Soviet administration and nuclear research institutions worked on reassembling the past – much beyond the design of state symbols and memorials, or a makeover of slogans in public places – toward the orderings of a newly built nation state.

Scientific medicine and radiation research again underwent transformation in post-Soviet Kazakhstan. Scientific-technical infrastructures were substantially impacted as the USSR had dissolved – this included the loss of scientific archives, personnel as well as economic infrastructures to run and supply laboratories. Most archives of the science city of Kurchatov and especially those related to nuclear testing were transferred to the Russian Federation and some had been earmarked to be destroyed. As the relevant archives dealing with nuclear testing were ultimately turned over to military archives in the Russian Federation, researchers in Kazakhstan had to work with what the officials left behind before they moved back to Moscow. Legacies of Soviet nuclear infrastructure also comprised several sites of uranium mining, which in the USSR had been conducted in Central Asia for example in Stepnogorsk, Kazakhstan, by the Leninabad Mining, and Chemical Combine in Tajikistan as well as in Tyuya-Muyun and Mailuu-Suu in Kyrgyzstan.[27]

Central Asia has been described as "nuclear backyard" to Soviet Cold War sciences, both for its mineral resources and as the site for nuclear weapons development and testing. The atomic program and nuclear weapons industry needed human resources, which were recruited unequally across the USSR. Scientists were in part recruited from the western metropolitan centers of the Soviet Union – Moscow and St Petersburg – but also locally through the Medical and Polytechnic Universities, for instance in Southern Urals and the branches of the Academy of Sciences, for instance in the Soviet republics of Kazakhstan, Kyrgyzstan, or Tajikistan. In addition to the Academy of Sciences as the USSR's main research institution, there was a system of closed nuclear research centers under the auspices of SredMash in need of physicists, engineers, technicians, and physicians.[28] Centralized government policies prioritized those fields relevant to the Cold War nuclear sciences and these priorities shaped the institutions and the very organization of scientific research in the Soviet republics.

Closing the nuclear test site also meant to be left with the nuclear infrastructures at Kurchatov on the "polygon,"[29] which was later reorganized as Kazakhstan's "National Nuclear Center" that also held the mandate over radiation protection in efforts to develop the area through mining and other economic activities.[30] With the dissolution of the USSR, a new mode of transnational biomedical risk assessment entered the Semipalatinsk region, building on, inventorizing Soviet data and reevaluating fallout effects. In the early 1990s, institutional funding broke down, with employees having to move into parallel informal sectors as their employers were no longer able to pay salaries. For scientists in nuclear weapons research, conversion programs were set up to enable them to transition to the civil sector.[31] While science as a profession could no longer pay for a living, a whole generation of scientists found themselves interpellated to adopt new styles of business, such as pitching and selling one's research and data to funding agencies rather than delivering and receiving their share from a bureaucratic state which prioritized science. Frameworks of "transitioning," ad hoc "projectness" with international collaborators and donors now reorganized scientific practices, replacing the firm scientific infrastructures, state planning and reporting.

In the sections that follow, I bring to the fore the laborious memory practices in late Soviet and post-Soviet radiation risk assessment sciences, in particular those concerned with transgenerational effects. I proceed by examining two instances of this process of reassembling in risk assessment research that address the motive of "the mother and the child" in scientific accounts of risk assessment sciences. I describe how institutional scientific memory practices of atomic heritage grapple with the past of Soviet nuclear weapons testing, when it comes to studies of genetic and long-term effects of fallout exposures due to nuclear testing at Semipalatinsk.

Transgenerational Nuclear Memory: "Mother and Child," as Rendered in Population Genetics

Soon after the test site at Semipalatinsk was closed, politicians and government institutions began negotiating a compensation program, which was released as early as 1992.[32] Just after the test site was closed, the assessment of the immediate radiological situation and exposure effects were the main focus of risk assessment. The government of Kazakhstan invited international missions to take part in assessing the radiological situation and called the UN for help on assessing and containing the risks that remained from the nuclear installations and legacies of four decades of atomic weapons testing at Semipalatinsk.[33] Over the years, groups of Kazakhstani and international scholars have also addressed the long-term legacies of nuclear exposure, including transgenerational effects among the children and grandchildren of those exposed to nuclear fallout. As with epidemiological studies, these assessments were conducted as different observational studies analyzing data retrospectively as well as in a prospective way, by establishing health monitoring infrastructures that could register effects of radiation.

Reproductive health has been a key concern of Soviet modernization in medicine.[34] Not only motive of the official memorialization in public monuments, the "mother and the child" was literally built into Soviet institutions. During the late 1969s and 1970s, "Centers for the Health of Mother and Child" with mandates to advance obstetrics and reproductive health had been founded across the USSR. In the Soviet Republics of Central Asia, efforts to establish a modern healthcare infrastructure included reproductive health centers as well as cancer diagnostics and therapy. These two specializations of medical care were particularly entangled with the Soviet nuclear program and its research into diagnostic and therapeutic radiation medicine.

In Alma-Ata, a Center for Reproductive Health was founded in 1975 to carry out clinical services and consultations, including cytogenetics and other laboratory analyses as well as research in obstetrics and medical genetics. During the 1980s, there were close ties with the Moscow-based Institute for Medical Genetics of the USSR Academy of Medical Sciences, established as the leading USSR research center on cytogenetics after 1969. Cytogenetics as a field and practice within biology had a troubled history in the USSR.

Early Soviet visions for radically different future humans were disrupted through Stalin's politics, from biology – mainly based on versions of genetics linked to the increase of agricultural production following Lysenko's ideas, up to the complete ban on classic Mendelian genetics, which was featured as bourgeois and to be replaced by creative Darwinism, the Soviet version of genetics.[35] This was the exclusive policy for all biology institutes and departments at the Soviet Academy of Sciences, bringing classic genetics to a hold. This had consequences well into the 1960s, even after Lysenko was dismissed as head of the Institute of General Genetics. Nevertheless, there were a few niches where scientists continued to do research in classic genetics – and these were radiation biology and mutation research. This line of research dealt with environmental effects of radioactive and toxic agents and was key to parts of the research taking place in secret nuclear cities and military institutes. In research centers related to the nuclear program, radiation biology, the study of mutation induced by radiation exposure, was a key part of biophysics – yet, importantly, institutionally within physics and not biology.

It was only during the late 1960s that researchers were able to reestablish fields such as medical genetics under the Academy of Medical Sciences. The Institute of Medical Genetics had been founded in 1968, expanding its research areas from radiation immunology and studies of hereditary disease, including field studies, into Central Asia. Interestingly, the Institute of Medical Genetics' departmental structure in the early years following its establishment included radiation immunology and mutation studies.[36] This was a way of drawing in the research into genetic and somatic effects that was done during Soviet time, which under Lysenko could not take place in biology institutions, but only under the label radiation biology or mutations research. It was at this Moscow-based institute, where researchers from the Center for the Protection of the Health of Mother and Child completed research stays and defended their PhDs in population genetics.

Scientific memory work through medical genetics has been contested, especially given its entanglements with eugenics. Some of the metrics and indices used in post-Lysenko population genetics indeed evoke categories connected to a biopolitics of improvement of the biological "population body."[37] Indeed, Russia, like other European countries in the early-20th century, had developed their own socialist eugenics agendas. In the early Soviet era, these were connected to the making of the "New Soviet Human," a better version of humankind enabled by technoscientific means. The concept of convergence (*sblizhenie)* and, ultimately, merging (*slianie*) were the envisioned goals to be reached over time, if needed in different pathways.[38] The ethnic groups and nationalities making up the population of the Soviet Union were envisioned to merge into one socialist people, while they were assigned different pathways toward communism, corresponding with their cultures and languages, which social scientists had classified into a new system of categories during the early Soviet years. Anthropologists and ethnographers had played a key role in the first census and the use of the categories *narodnost'*, *natsional'nost', and natsiia* (terms for ethnic groups at different stages of development used by former imperial ethnographers) and by the mid-1950s the category ethnos, as "ethno-social formation" "distinguished by (…) historical and cultural traits."[39] During the early Soviet years, ethnographic knowledge was mobilized for politics in different ways – in and as the anticolonial yet also eugenic biopolitics of the early USSR. That biopolitical condition was again at stake and thus reworked during the post-Soviet transformation.

Interestingly, the scientists of the Almaty-based Republican Research Center for Protection of Mother and Child Health also collaborated on studies of ethnoterritorial groups, using molecular techniques of genomics, based on studies of DNA polymorphisms.[40] Here, population geneticists were closely connected to biological anthropology.[41] Researchers in the field also contributed to bodies of knowledge that intersected with questions about the origins of "Kazakhs" as a population group and their migration history. During the Soviet era, for example, biological anthropologist Orazhak Ismagulov, based in Alma-Ata, studied the ethnogenesis of the Kazakh people.[42] Ismagulov worked with serological methods as well as "dermatoglyphs."[43] These techniques, from physical anthropology, violently racialized human differences in colonial contexts of the early-20th century, yet they were perpetuated, albeit with different framings in the USSR. Coming to terms with "Kazakhness" and adopting a historiography based on modern science was one element that the new Republic assembled in the new state-building activities and their history policies.

The Almaty research center carried out work toward documenting health effects due to fallout from nuclear testing at Semipalatinsk. In particular, the center was involved in studying chromosome aberrations in different regions of northern Kazakhstan.[44] These studies compared incidence rates in different regions of Kazakhstan, for exposed and nonexposed areas. Trained in population genetics, the center's scientists brought their own approaches and methods into investigations of the Semipalatinsk region. Their studies focused mainly on hereditary disease and congenital malformations (*vrozhdenie poroki razvitiia*)[45] through demographic studies, rates of hereditary disease, as well as the full range of indexes established in the epistemologies of population genetics. While some of the studies carried out focused on clinical genetic counseling using family trees, others related migration patterns to the gene pool and genetic distance, or reproductive patterns in populations. This work used classic genetics in order to follow radiation effects in nuclear families, situating potential radiation effects in the studies of hereditary conditions. They focused on alterations in the germ line and until birth, integrating the study of radiation effects with biomedical knowledge on embryology and teratology.[46] Teratology in particular became a field that was relevant to the concerns over prenatal testing, perinatal care, genetic disease, and population health – fields that became tied in to nation building in specific ways.

At the same time, the government supported and developed the new projects. This included building a "National Genetic Registry" for the New Republic of

Kazakhstan as well as a "system of genetic monitoring."[47] The National Genetic Registry was introduced by 1998, following a "Law on Semipalatinsk" published in 1992.[48] A key goal of those monitoring practices was to study potentially radiation-induced "congenital malformations."[49] After 10 years of data collection in the National Genetic Registry, geneticist Berezina reported a significant increase of major and multiple congenital malformations pointing to the influence of environmental conditions.[50] These were most pronounced in the East Kazakhstan region, which included the Semipalatinsk fallout area as well as the chemical and nuclear production sites of Ust-Kamenogorsk. With such monitoring data, medical scientists envision effective public health responses, in terms of "dynamic response systems to the evolving of the genetic disease burden in human populations."[51] It was at the level of sciences and respective memory work that Kazakhstani scientists were called upon to contribute to constituting the future of a fully modern, independent state that now dealt with the Soviet past on its own.

Chromosomal Memory: Molecular Markers of Radiation Effects

Researchers in the labs of the Center for the Protection for Mother and Child Health used molecular biology and genetics – traditional methods like cytogenetics or newer techniques based on polymerase-chain-reaction (PCR), to assess exposure effects in several ways. More directly related to the area of research and clinical work at the Center was prenatal testing and the use of cytogenetics, i.e., the microscopic analysis of changes in chromatids and chromosomes, but also studies of health effects related to exposure to chemicals or radiation. The techniques established at the Center mostly for clinical prenatal testing – karyotyping – can also be used to study radiation effects, especially those of recent or ongoing exposure. Cytogenetics labs were, hence, key to the study of chromosomal aberrations caused by radiation.[52] Population geneticists at the Center for the Protection for Mother and Child Health in Almaty used cytogenetic tools to investigate genetic effects close to the Semipalatinsk nuclear test site. Relating and geographically mapping rates of congenital malformations, scientists strived to document radiation damage.[53] This presents a mode of radiation effects visualizing, projected on a geographic grid – mapping out a topography of chromosomal change.

In the Semipalatinsk region, a separate parallel research infrastructure had operated under secrecy and conducted research on radiation related diseases in the areas exposed to fallout from nuclear testing since the late 1950s. Additionally, the institutes on the Semipalatinsk polygon were in charge of nuclear technology as well as radiation protection and radiation monitoring.[54] Furthermore, the Russian program on research and compensation for those affected by fallout exposures due to the Semipalatinsk nuclear test site in the Altai region, also included some cytogenetic studies carried out by researchers based in Moscow and at the Center for Medical Radiation in

Obninsk.[55] Today's Scientific Institute for Radiation Medicine and Ecology in Semey is the successor institute of the code-named "brucellosis hospital": the "Dispensary no. 4." This unit was overseen by the Institute for Biophysics in Moscow and established for the purpose of studying radiation effects in the surroundings of the Semipalatinsk nuclear test site. Founded in 1959, it mainly followed up on the health status of exposed people in settlements exposed to fallout, focusing on particular in cancer incidence and mortality in the 1970s and 1980s. In addition to cross-sectional studies and cohort study, they also set up a program on cytogenetics. Analyzing blood samples of people living in exposed areas, radiation biologists compared the counts of chromosome aberrations, such as dicentrics and rings, using the method of karyotyping (the examination of chromosomes under the microscope) in the 1970s. Scientists examined these alterations in the sense of an effect marker, described as a clinical observation of radiation effects, comparing rates in the exposed areas with rates in areas outside known fallout.[56]

Controversies during the 1990s revolved around questions of dosimetry, a multidisciplinary research field that deals with the reconstruction of exposure. Scientists distinguish between radiation qualities and pathways: radiation qualities refers to alpha, beta, gamma radiation – each having different biological characteristics and effects on tissue and which radiation qualities are present depends on the radionuclide composition of fallout and residual radioactivity as well as on the decay chains. Pathways can be external radiation (whole body exposure) and internal exposure due to ingested or inhaled radionuclides. After radiation accidents, particular significance has been given, for instance, to radioiodine, which accumulates in the thyroid gland, but also to much longer-lived strontium-90 which, like radium, mimics calcium and collects in bones, where it remains for years, leading to irradiation of bone marrow. Methods for dose reconstruction – which examine and quantify radiation exposure – include physical, chemical, and biological techniques. Biodosimetry has become increasingly important in determining radiation dose after nuclear accidents. In epidemiological risk assessment projects, biodosimetrists used cytogenetic techniques to trace chromosomal alterations in human blood cells in order to quantify radiation dose at the individual level. Hence, this measurement setting became a biological memory device registering past exposure within the very human body.[57]

Given that there is sufficient stability of the aberrations over time – which for most markers are only a few months – these are used to confirm and even quantify radiation exposure. In these configurations, the human body is rendered not only as "at risk" due to fallout, but as a dosimetric memory in which radiation inscribes itself, similar to the dosimeter device carried by nuclear workers. Repurposed as memory work for "biodosimetry," chromosome aberrations became a human cellular that would be recognized as proof of exposure. Whether the marker is conceived of as a clinical marker of effect or whether it is a tool for dose estimation – seems to perhaps be a technical detail, but this small shift is relating fallout matters in a very different way.

Seen as "hallmarks of exposure to ionizing radiation,"[58] the presence of such markers is interpreted as indicators of whether there truly was a significant exposure. This locates the site of proof (and inscription device) within the exposed body rather than in the residuals in the environment or the knowledge about exposure of the past in an area of nuclear test fallout. It shifts the site of proof into exposed bodies and chromosomes of the blood cells in individuals, which positions the individual as the carrier of a somatic mutation and individualizes the burden of proof of documenting exposure. Results from some of these studies have fueled doubt about exposure and questioned compensation programs that already had become law.

Internationally cytogenetic techniques changed and moved on rapidly with PCR-based methods in genomics. Western scientists also used new techniques – glycophorine A (GPA) assays, minisatellite, and fluorescence in situ hybridization (FISH) that made visible more markers at Semipalatinsk to examine radiation-induced chromosome alterations.[59] Yet, acquiring the machinery and chemicals of genomics proved nearly impossible in the post-Soviet economic crisis for these institutions. Most research groups, during the early post-Soviet years, lacked funding to maintain the technological infrastructure, since the Soviet supply of equipment and access to common scientific publication channels and to researcher salaries were cut off. The post-Soviet crisis already had forced scientists into an improvised everyday research life that required them to take on secondary jobs, subsistence and care work within extended families, and occasional funded projects. Completing a project with funding from abroad became a job within the job, providing paid works in otherwise uncertain situations with salaries put on hold or delayed for months and handling precarious positions in an era where working in academia did no longer provide enough to cope with the economic crisis. With the formal salary infrastructures gone, the state once providing for them dissolved and with no new infrastructure yet, memory practices took place in an unofficial, informal project mode often negotiated ad hoc.

Bureaucratic Memory: Mining Vital Statistics of the Population

Like for all modern political entities, keeping population statistics was central to the making of a post-Soviet state.[60] With the end of the USSR's administration of the research systems in the Central Asian Republics, scientific funding structures dissolved and it proved difficult to sustain and realize long-term projects.[61] For epidemiological risk assessment, also the administrative infrastructure in other sectors were crucial to data access and the administrative memory of public health. Of particular importance to epidemiologists was the ZAGS system,[62] the vital statistics authorities of the USSR, which registered data on births and deaths.

Following modern epidemiology's generic definition, as "the study of distribution and determinants of disease in populations," radiation epidemiology is a scientific discipline that has been highly dependent on state infrastructures for standardized, long-term collection of data. Once the methods of counting are changed, the numbers are no longer comparable, requiring complex validation studies, modeling and translation work to render data combinable – and the more of these transformations are done, the more uncertainties are generated. Epidemiological studies ideally require standardized and unchanged data collection over a long time that is independent of exposure, so that there is no systematic error introduced in the data collection. This makes routine data recorded by the state, such causes of death records important data sources. Conducting an epidemiological study is a complex scientific memory practice, with data recording and measurement changing with improved diagnostics and therapeutics. Isolating the effect of radiation exposure at aggregate levels implies many assumptions, especially in the lower dose range and in retrospect when case ascertainment is different and often insecure. For instance, epidemiological studies of fallout-related leukemia at Semipalatinsk have proved difficult to carry out, with cases expected to have peaked 10 years after exposure – likely to be undiagnosed in the rural areas during the 1950s and 1960s, let alone what physicians outside the secret radiation research centers dared (not) to write into the medical death certificates.

Establishing a kind of "nuclear census" is a prerequisite to reconstruct exposures and retrieve disease to assess radiation risk. During the 1990s, both local and international research efforts focused on the establishment of registries, i.e., exposure and disease registries. Unless epidemiologists – as done in some prevalence studies – carried out an entirely new data collection from scratch, all studies had to work with data collected in the past. These epidemiological memory practices proved highly entangled with the political and administrative systems as well as with the enactment of Soviet modernity through public health. This was routine data, recorded by the USSR administration – in rural places it were the obligatory birth and death records as well as the *kolkhoz* books that functioned as registries for the exposed rural populations. Especially for the period of atmospheric nuclear testing 1949–1963, they were used as replacements for the lacking passport system for the rural USSR population.

Following up on concerns by health authorities and the UN resolution on Semipalatinsk of 1998, WHO commissioned a reproductive health study to be conducted in collaboration with institutes in Semipalatinsk, UK epidemiologists, and WHO researchers. Called upon by WHO to produce "a scientifically sound" epidemiological study, western scientists looked into and surveyed the possibilities and availability of records. Putting methods and exclusion of possible bias first, they decided to work with those long-term Soviet administrative data from vital statistics offices, for which completeness could be ascertained; the expectation was that they would be recorded exactly the same way independent of whether the area was exposed or not, thus avoiding bias in the data. This however restricted the outcomes that could be studied and the decision of what to study: were variables available for the entire time span of the retrospective studies and were they beyond suspicion of bias? A systematic error that would result from differences in recording between exposure groups or disease groups compared to those unexposed or healthy. For a study on reproductive health, this restricted the study to using records available for the entire population, i.e., birth certificates, marriage certificates, and death certificates.

Variables on these administrative documents ended up performative in the sense of what could be studied: causes of death data, for instance for childhood cancer between the 1950s and 1990s, were considered too heterogeneous in case ascertainment, with diagnostics established only for the later decades. Hence, the results of such a study would rather be reflecting the data recording and diagnostic practices than the effects of radiation exposure, or these two would be impossible to disentangle. Following the logic of epidemiological methods, these considerations determined what could be studied and what was left unstudied.

Prioritizing a scientifically sound study on reproductive health, as commissioned by WHO, scientists studied, for instance, sex ratios, an outcome shown to be related to radiation exposure.[63] Another study examined twinning rates which also could be studied based on administrative documents on marriages and births.[64] These were method-wise safe and sound studies, yet concerns over childhood leukemia and congenital malformations remained unaddressed in these studies, despite their scientific relevance and public concern. In that sense and in order to put sound science first, researchers found themselves trading public health relevance against methodologically clean studies.

Preoccupied with databases as memory infrastructures and metrics, scientists work with processes and politics of documentation. They grapple with the effects of exposure, in this case human-made exposure due to nuclear testing in the past but the effects of which linger in the present and are known to reach into the future. This is due to long half-lives of many radionuclides released in nuclear explosions, including cesium, strontium, and plutonium. While some exposures referred to (such as iodine in milk) were most pronounced in the months and years after atmospheric nuclear tests and thus an issue mostly for the generations young at time of atmospheric nuclear testing, the long-term effects of exposure, the internal exposures due to incorporated long-lived nuclides such as strontium accumulating in bones as well as the residual radionuclides in the ground that can be refracted and enter the food web, will remain for decades.[65]

Biomedical research into radiation effects studied the damage to people in affected territories. This, however, operated on epistemic conditions shaped by Cold War research infrastructures of risk assessment and risk factor epidemiology. They brought with them their own ways of knowing the health effects of radiation based on a certain set of study designs and concerns that often differed from those of local researchers and the concerns of clinicians. The memory work of Cold War risk assessment focused on deriving accurate relative risk estimates attributable to radiation alone. This contributed to a culture of research shaped by US scientific programs on the atomic bomb survivors in Japan. Here, researchers first and foremost looked at radiation as an isolated factor with different radiation qualities in order to contribute data to mathematical models. It assumed regularities (with threshold, no threshold, or linear shapes of the dose-effect curve) that would be described by purified mathematical functions, once proper study populations and databases were established. This idea of establishing and documenting damage by means of population studies of different exposure conditions would result in a purified data set, catering to the improvement of universalized risk estimates and dose-response curves.

Coda

This chapter has followed selected trajectories of how Soviet nuclear legacies have been assessed and reassembled, especially concerning long-term, transgenerational effects of fallout exposure. At Semipalatinsk, risk assessment sciences have been an integral part in memory practices and the ongoing post-Soviet reassembling of the past in order to envision futures for the new state. Focusing on scientific modes of documenting radiation effects shows the ongoing scaling and calibrating of risk assessment: there are transgenerational-individual, chromosomal-molecular as well as populational-aggregate scales and versions of risk research, each assembling different strands, disciplines, measurement devices, and scientists. Whether public science, open science, or secret science, scientific memory practices do ordering work, while brought to align with nation building or globalized regulatory regimes.

Different memory practices, material objects, scientific disciplines, and methods traditions participate in biomedical assessments of radiation effects at various scales: the transgenerational scale is tied to reproductive medicine, the chromosomal scale to microscopes, chemicals, and technical skills of visualizing invisible damage, and the population level to administrative procedures in vital statistics offices and bureaucratic data labor. There are somatic and genetic memory mechanisms at molecular levels, transgenerational effects as well as the documentation effects visible in epidemiological data at the aggregate level. All these constitute memory configurations as they were transformed in a long and gradual process of institutional change after the dissolution of the Soviet Union. One of those was the transformation of the Semipalatinsk polygon from a Soviet weapons test site into Kazakhstan's National Nuclear Center, now overseeing radiation protection as well as herding and mining activities on and near the site.

Closing the test site and promoting a Central Asian Nuclear-Weapons Free Zone were part of this nation-building process, which enabled a recognition of the suffering due to weapons tests and fallout affecting the people living close to and even within the nuclear test site borders. Nuclear legacies have been inscribed into the census and tracked through population counts, but also in individual exposed bodies in biodosimetry. After the first decade of research though, science policy shifted and began to strive toward bringing the post-Soviet chapter of handling the Semipalatinsk aftermath to a political close. At the same time, Kazakhstan embarked on new economic paths that comprised extractive economies, oil and gas, mining, metals, and in particular extensive uranium mining. As for Semipalatinsk, closing the radiation issue also implied redirecting research to studies of nuclear risk perception in terms of internalized mental health problems and as an issue of "radiophobia" in communities in regions near the test site. This turned attention away from the fallout's residuals in the environment, which could enter – literally via food webs and ingestion – into people's bodies and, in the case of incorporated radionuclides, result in chronic internal exposure.

When it comes to toxic or radioactive legacies in the environment post-Soviet kitchen conversations frequently arrive at "we are all mutants, after all." The long-term and genetic effects of radiation that would be transmitted to the next generation have been among the main public concerns. This motive is also alluded to in the monument "Stronger than Death" that epitomizes Cold War reproduction as core concern. Reproduction, childcare, and gender roles all have been shaped by a long history of state intervention, and the monument evokes and reproduces a particular burden on and myth of the mother and child, which haunted Soviet modernity. In contrast to the trope of the heroic mother in the shadow of the atomic mushroom cloud, conceiving oneself as a "radioactive mutant,"[66] as immune to radiation, or nuclear test survivor may enable or claim different forms of agency within the post-nuclear condition.

Kazakhstan's post-Soviet project of nation building has emerged as a multiscale endeavor that, in a biopolitical sense, reaches from state history policies, governance of the nuclear past, and politics of knowledge into citizens' subjectivities and embodiments. Studying the biologies of memory may open up for resistant and generative critical capacities in the Anthropocene that exceed victimization and, instead, join efforts of reimagining and intervening into Cold War epistemologies that continue to linger in the global nuclear aftermath.

Notes

1. Recent exhibitions of these archeological artifacts bear witness of the changed role assigned to these institutions by government. See Nursan Alimbai, *Tsentralnyi gosudarstvennyi muzei Respubliki Kazakhstan: kratkii istoricheskii ekskurs, strukturnye preobrazovaniia, problemy. Trudy Tsentralnogo Muzeia II* (Almaty: Gylym 2004), 11–18.
2. OSCE is the Acronym for the Organization for Security and Co-operation in Europe, founded as Conference on Security and Co-operation in Europe in 1975 in order to establish a dialogue to address security issues during the Cold War constellation. See Susanne Bauer, "Beyond the Nuclear Epicenter. Health Research, Knowledge Infrastructures and Secrecy at Semipalatinsk," *Cahiers du Monde Russe*, 60/no. 2–3, (2019): 493–516.

3. See for instance the statements at the OSCE summit of 2010, https://www.osce.org/event/summit_2010 and the UN Treaties documentation, https://www.un.org/nwfz/content/treaty-nuclear-weapon-free-zone-central-asia.
4. Olivier Roy, *The New Central Asia. Geopolitics and the Birth of Nations* (New York, NY: New York University Press, 2000): 177.
5. Scholarship on Kazakhstan was promoted and gained visibility through the creation of new sections in state libraries as well as the development of textbooks foregrounding a new canon of Kazakh philosophy, see for instance: O.A. Segizbaev, *Kazakhskaia Filosofiia XV-nachala XX veka*. (Almaty: Gylym, 1996).
6. Roy, *The New Central Asia*, xx.
7. For an overview on programs in Kazakhstan and the Altai region, see Susanne Bauer, *The Health Impact of Atmospheric Nuclear Testing. Cancer Epidemiology in Areas Adjacent to the Semipalatinsk Nuclear Test Site, Kazakhstan*. (Frankfurt am Main/New York, NY: Peter Lang Publishing Group, 2006); for the Kazakhstan program, see Susanne Bauer, Boris I. Gusev, Tatiana Belikhina, Timur Moldagaliev, Kazbek Apsalikov, "The Legacies of Soviet Nuclear Testing in Kazakhstan. Fallout, Public Health and Societal Issues," in Deborah Oughton and Sven-Ole Hansson (eds.), *Social and Ethical Aspects of Radiation Risk Management* (Amsterdam: Elsevier Science, 2013), 239–258.
8. For the scientific program in the Altai region, see Ya. N Shoikhet, V.I. Kiselev, V.M. Loborev, V.V. Sudakov, A.I. Algazin, V.F. Demin, and A.A. Lagutin. *The 29 August 1949 Nuclear Test. Radioactive Impact on the Altai Region Population*. (Barnaul: Scientific research Institute for Regional Medico-Ecological Problems, 1998) and Ya. N Shoikhet, V. I. Kiselev, A. I. Algazin, I. B. Kolyado, S. Bauer, and B. Grosche, "Fallout from nuclear tests: health effects in the Altai Region," *Radiation and Environmental Biophysics* 41 (2002): 69–74.
9. Pierre Nora and Lawrence D. Kritzman, *Realms of Memory: The Construction of the French Past* (New York, NY: Columbia University Press, 1998); Jan Assmann, "Communicative and Cultural Memory", in A. Erll and A. Nünning (eds.), *Cultural Memory Studies. An International and Interdisciplinary Handbook,* (Berlin, New York, NY: Walter de Gruyter, 2008), 109–118.; Maurice Halbwachs, *On collective memory* (Chicago, IL: The University of Chicago Press, 1992).
10. The notion of fallout memory practices takes up the concept from Geoffrey Bowker, *Memory Practices in the Sciences* (Cambridge, MA: MIT Press, 2006).
11. Anna Storm, Fredrik Krohn Andersson, Eglė Rindzevičiūtė. Urban nuclear reactors and the security theatre: the making of atomic heritage in Chicago, Moscow and Stockholm, in Heike Oevermann and Eszter Gantner (eds.), *Securing Urban Heritage: Agents, Access, and Securitization,* (London: Routledge, 2019), 111–129.
12. Hannah Landecker, Antibiotic Resistance and the Biology of History, *Body and Society* 22, 4 (2016): 19–52.
13. The concept of reassembling is foregrounded in order to empirically open up the ways these scientific memory practices align with politics. See Bruno Latour, *Reassembling the Social. An Introduction to Actor-Network Theory* (New York, NY: Oxford University Press, 2005).
14. Gabrielle Hecht, "Nuclear Ontologies," *Constellations,* 13, 3 (2006): 320–331.
15. The test site of China's nuclear weapons program at Lop Nor is situated in this region, comprising 22 atmospheric nuclear tests (1964–1980) and 22 underground tests (1970–1996), see B.B. Bennett, L.E. de Geer, D. Dour, "Nuclear Weapons Test Programmes of the Different Countries", in Sir Frederick Warner and René J.C. Kirchmann (eds.), *Nuclear Test Explosions. Environmental and Human Impacts* (Chichester, New York, NY: Wiley, 2000), 13–32.
16. Michael D. Gordin, *Red cloud at dawn. Truman, Stalin, and the end of the atomic monopoly* (New York, NY: Farrar Strauss and Giroux, 2009).

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20. For a recent summary of the formation of these opposition movements, Yemelianova, Galina M. "Muslims of Kazakhstan," in *Muslims of Central Asia: An Introduction* (Edinburgh: Edinburgh University Press, 2019), 105–128, 105.
21. Alexei Yurchak, *Everything was forever, until it was no more. The Last Soviet Generation* (Princeton, NJ: Princeton University Press, 2005).
22. See for instance https://centrasia.org/newsA.php?st=1061504640.
23. On Kazakh folk medicine, Russian orientalism, and Soviet modernization, see Paula A. Michaels, *Curative Powers. Medicine and Empire in Stalin's Central Asia* (Pittsburg, PA: University of Pittsburgh Press, 2005).
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26. Roy, The New Central Asia, 26; Niccolo Pianciola, "The Collectivization Famine in Kazakhstan, 1931–1933," *Harvard Ukrainian Studies*, 25, no. 3/4 (2001): 237–251; Sarah Cameron, *The Hungry Steppe: Famine, Violence, and the Making of Soviet Kazakhstan*, (Ithaca, NY, Cornell University Press 2018); see also Penter, this volume.
27. See Roche, this volume; Arkadii Kruglov, *The History of the Soviet Atomic Industry* (London: Taylor&Francis, 2002), 14.
28. See contributions by Stephan Guth and Laura Sembritzki (this volume).
29. Locals commonly use the Russian term "polygon" (for proving ground) to refer to the area of the Semipalatinsk nuclear test site.
30. See also Magdalena Stawkowski, "Everyday Radioactive Goods? Economic Development at Semipalatinsk, Kazakhstan," *Journal of Asian Studies*, 76, 2 (2017), 423–436.
31. See the Moscow-based International Science and Technology Center (ISTC) and its conversion programs, established in 1992, targeting former weapons scientists.
32. E.L. Iakubovskaia, V.I. Nagibin, V.P. Suslin, *Semipalatinskii iadernyi poligon—50 let* (The Semipalatinsk nuclear test site—50 years). (Novosibirsk: Sovetskaia Sibir', 1998); Bauer et al. "The Legacies of Soviet Nuclear Testing"; see also Penter, this volume.
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35. Nikolai Krementsov, *Stalinist Science* (Princeton, NJ: Princeton University Press, 1997); William deJong-Lambert, *The Cold War Politics of Genetic Research. An Introduction to the Lysenko Affair* (New York, NY: Springer, 2012).
36. See Susanne Bauer, "Mutations in Soviet public health science: Post-Lysenko medical genetics, 1969–1991", *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 47 no. 3 (2014): 163–172.
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39. Hirsch, *Empire of Nations*, 10, 196, 313–314.
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63. Previous studies showed that with increased radiation exposure, more females than males were born, an outcome the study could not find confirmed for the vital statistics data in Semipalatinsk. See also N.Y. Mudie, B.I. Gusev, L.M. Pivina, M.J. Schoemaker, O.N. Rijinkova, K.N. Apsalikov, and A.J. Swerdlow, "Sex ratio in the offspring of parents with chronic radiation exposure from nuclear testing in Kazakhstan," *Radiation Research* 168 (2007): 600–607.
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