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## 6 From military surveillance to citizen counter-expertise: radioactivity monitoring in a nuclear world

*Nestor Herran*

In March 2015, a radioactivity monitoring station of the Swedish Defense Research Agency (FOI) detected a peak of the radioisotope iodine-131. The measures, confirmed by other stations in Finland, pointed to an accidental release somewhere in Russia. In January 2017, similar peaks were detected in several European countries, again pointing to a Russian source, and in February 2017, a US Air Force WC-135 Constant Phoenix plane equipped with radiation sensors was deployed to Norway to investigate a mysterious spike in radiation. Another peak, involving ruthenium-106, was revealed in late 2017, and the Russian Weather Bureau acknowledged that it came from the Mayak nuclear reprocessing and isotope production plant.

These incidents, like similar warnings around Fukushima, are a reminder of the relevance and ubiquity of environmental radioactivity monitoring networks throughout the modern world. Established by nation-states (such as the American RadNet) or international institutions (such as the European EURDEP or the International Monitoring System run by the Comprehensive Nuclear-Test-Ban Treaty Organization, CNTBTO), these infrastructures have an increasingly prominent place in the nuclear global landscape.

However, the history of these networks and their role in the configuration of the nuclear world is a quite underexplored topic. What were the motivations behind their establishment? Which actors and institutions played a relevant role in their creation and maintenance? How the measurements they provided were mobilised in debates on nuclear risks? In order to answer these questions, I examine their history since the establishment of the first monitoring programs in the late 1940s. This history reveals that their development has been driven by at least four different (and sometimes competing) agendas. The most fundamental one is typically military, associated with the implementation of military nuclear surveillance systems. Exemplified by the wide CNTBTO network, it continues to be central even after the end of the Cold War. In the mid- and late-1950s, a second agenda, related to the assessment of global nuclear risks, appeared amidst the controversy regarding nuclear tests

fallout. Intertwining military and civil institutions, this configuration contributed to the public visibility of radioactive fallout as well as its construction as a manageable problem. Following a similar logic, a third layer of monitoring networks was implemented starting in the 1960s alongside the extension of nuclear power stations. These both served to oversee potential problems and to preempt liability claims resulting from foreseeable accidental releases of radioactivity. These initially modest monitoring networks were expanded after the Chernobyl disaster in 1986 to appease public fear and distrust of nuclear technology. The parallel emergence of alternative, citizen-based monitoring networks, constitutes the fourth and last agenda, in direct tension with the previous one, which has aided to foster recent participative dynamics that promote transparency. Public participation emerged as key elements for the legitimation of the nuclear complex.

### **The military origin of environmental radioactivity monitoring**

Environmental radioactivity was known since the early twentieth century, but no systematic monitoring program was established until World War II, when the United States military decided to assess the state of German nuclear operations. In late 1943, General Leslie Groves, head of the Manhattan Engineering District and responsible for US nuclear intelligence operations, charged Luis Alvarez, a MIT-trained physicist, with the task of developing a system to detect nuclear activities by measuring radioactivity released into the environment (Ziegler and Jacobson, 1995). The method focused on the detection of xenon-133, a rare isotope released by the operation of nuclear reactors, by using detectors mounted in US and British A-26 aircraft. These monitoring activities, carried out in the fall of 1944, confirmed that Germany did not yet have an advanced nuclear program.

After the nuclear bombing of Hiroshima and Nagasaki, the US military developed other methods for monitoring nuclear blasts at a distance. Sonars, seismographs and Geiger Muller radiation counters were tested and compared as part of the Operation Fitzwilliam, carried during the Sandstone nuclear tests in the Marshall Islands in spring 1948. The results showed that the detection of environmental radioactivity was the most promising technique for long-range surveillance. Thereafter, the Central Intelligence Group (the institutional predecessor of the Central Intelligence Agency, or CIA) unified all monitoring activities under a single umbrella group called AFOAT-1 (Air Force Deputy Chief Staff of Operations, Atomic Energy Office, Section One), which took charge of monitoring all aspects of the US nuclear cycle, from uranium mining to stockpiling fissionable materials to nuclear testing. By combining its detection

capabilities with those of a similar network implemented by the United Kingdom, the system was able to detect the first Soviet nuclear test on August 29, 1949.<sup>1</sup>

In the 1950s, the US military improved the reliability of this monitoring network by checking its own nuclear tests in the Pacific using a diversity of methods: radiological analysis of air and precipitation aided in determining the composition of the bomb, the detection of electromagnetic pulses helped ascertain the time of explosion, analysis of sound waves was used to calculate the yield of the bomb, and seismic measurements determined the location of the test (Richelson, 2006: 113). Monitoring environmental radioactivity was also developed as part of systems aimed at the early detection of nuclear attacks, such as those implemented by the Federal Civil Defense Administration (FCDA) since 1951. In 1956, these systems were integrated into the Radiation Alert Network (RAN), a network of stations aimed at detecting nuclear attacks on the United States and providing alerts on radiation fallout.<sup>2</sup>

Knowledge gained in the early nuclear tests constructed fallout into a measurable object and a key element in military strategy. Nuclear strategists wondering about nuclear war scenarios asked themselves how many nuclear bombs could be used before the effects of fallout became an important health issue. In order to answer this question, the US military undertook the secret project dubbed Gabriel, whose first report, circulated in 1951, concluded that nuclear explosions released strontium-90, a radioisotope particularly dangerous to human life. Chemically similar to calcium, it is assimilated by the bones and becomes an *internal* source of damaging radiation. In the mid-1950s, the AEC expanded fallout studies under the direction of atomic chemist and AEC Commissioner Willard F. Libby. His project, codenamed Sunshine, collected samples of air, water, soil, milk and human bone in the United States and abroad, and can be considered as the first global survey of radioactive environmental contamination (Eisenbud, 1990; Masco in this volume).<sup>3</sup>

Early environmental radioactivity monitoring was carried under military secrecy, keeping fallout concerns out of public attention. However, the situation abruptly changed in 1954 with the development of thermonuclear bombs and the onset of the controversy that arose after the “Castle Bravo” nuclear test. Considered the very first global environmental controversy (McCormick, 1989), it emerged after the miscalculated test of a hydrogen bomb carried in March 1954 in the Marshall Islands, which spread nuclear fallout over hundreds of square kilometers. The population of nearby atolls received high radiation doses, as did the crew and cargo of a Japanese fishing boat called the Lucky Dragon No. 5. Public outcry in Japan was considerable, leading to the creation of a unified Japanese Council against Atomic and Hydrogen Bombs, which was able to gather more than 35 million signatures on petitions calling for a ban on nuclear weapons (Higuchi, 2018). The

pacifist movement seized the public concern about the tests, and non-aligned countries mobilised it as a stark example of Western powers' disregard for the health of human populations. India's first minister, Jawaharlal Nehru, was one of the most outspoken critics of nuclear tests. In April 1954, Nehru requested a "standstill agreement" on nuclear testing as a first step toward disarmament, pointing out that "Asia and her peoples appear to be always nearer these occurrences and experiments, and their fearsome consequences, actual and potential" (Jones, 2010: 202).<sup>4</sup> Confronted with the perspective of issue taken up by UNESCO's scientific committees, the United Nations General Assembly took action and, in December 1955, it approved the establishment of a research body of scientists and diplomats, the United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR).<sup>5</sup>

Counting among its membership representatives of 15 states, including the trio of nuclear powers (the United States, the Soviet Union, and the United Kingdom), UNSCEAR was the first international institution devoted to the regulation of nuclear affairs, predating the creation of the International Atomic Energy Agency (IAEA) (Fischer, 1997; Roehrlich, 2016). UNSCEAR also established the first open international effort for the monitoring of environmental radioactivity, which materialised in the first global map of fallout-produced Sr-90. Drawn as part of the first UNSCEAR report to the UN Assembly in 1958 (UNSCEAR, 1958), the map was based on data obtained from 350 stations worldwide, most of them part of the pre-existing American infrastructure, including the worldwide network of 122 stations put in place by the US Weather Bureau in 1955 to track the fallout from the Castle Bravo tests.<sup>6</sup>

The fallout controversy added a second, non-military layer of environmental monitoring programs, bringing environmental radioactivity monitoring into the daylight. Measurements of environmental radioactivity were incorporated into political debates over nuclear proliferation. In the United States, public anxiety over fallout led to the declassification of the data obtained in the Sunshine project in 1956, and the establishment of complementary Sr-90 surveys, such as the High Altitude Sampling Program (HASP), carried by the US Air Force (Friend, 1961).<sup>7</sup> Public distrust of the government also led to counter-expertise initiatives, the first examples of citizen-based monitoring of radioactivity. For example, the Consumers Union conducted a national study of Sr-90 concentrations in milk, which was published in the 1960s in the magazine *Consumer Records*, and the Greater St. Louis Citizens' Committee for Nuclear Information started a survey of Sr-90 in children's teeth (Lutts, 1985).

The fallout controversy contributed to the institutional displacement of environmental radioactivity monitoring from the military to the health domain: from 1959, the RAN network, established as part of the civil defense operation, was transferred to the jurisdiction of the US

Department of Health, Education, and Welfare. A decade later, in 1973, it merged with other measuring networks (the Air Surveillance Network, the Pasteurised Milk Network, the Interstate Carrier Drinking Water Network, and the Tritium Surveillance System) to form the Environmental Radiation Monitoring System (ERAMS). Counting with 68 monitoring stations and working under the responsibility of the Environmental Protection Agency (Aston, 2012), the ERAMS network was assimilated into the current RadNet network in 2005.

### **The rise of European radioactivity monitoring**

As in the United States, the first European initiatives for the monitoring of environmental radioactivity were related to the military. In 1958, the United Kingdom contributed 19 monitoring stations' data (from 6 stations in the British Islands and 13 overseas) to the previously discussed Anglo-American military surveillance network. Norwegian stations, such as those at Tromsø and Bodø, were also part of the US military monitoring network surveilling Soviet Union nuclear tests. When the fallout controversy erupted, Norway put to use an additional 12 stations run by the Norwegian Defense Research Establishment (FFI) to measure radioactivity in dust and precipitation through daily measurements of air and snow samples. These measurements were complemented by monthly measurements of sea water, fish, milk and foodstuffs, as well as occasional animal and human tissue tests, carried out by the Directorate of the Fisheries and the Institute of Marine Research in collaboration with Norwegian universities (Bergan, 2002; Skogen, 2003).

France, which counted with an advanced national nuclear program and was already developing its own atomic bomb, established by 1957 a network of 15 monitoring stations in continental France along with at least one more station in Tahiti. In 1958, this surveillance network was able to detect and determine the causes of the Sellafield accident and to survey British nuclear tests in the Pacific.<sup>8</sup> In southern Europe, Italy implemented a surveillance network of 17 measuring stations, five of them run by the meteorological service of the Italian Air Forces and three by the Nuclear Research Centre for the Armed Forces (CAMEN).<sup>9</sup> Sweden used 18 stations for the measurement of airborne radioactivity by the late 1950s, 13 of which were run by the Institute of Radiophysics (RFI) and 5 by the National Defense Research Institute (FOA). Both RFI and FOA also monitored radioactive material in dust, precipitation, soil, vegetation, milk, and foodstuffs. Germany, banned from most nuclear research until 1955, had ten monitoring stations run by the German Weather Service (DWD). This reliance on weather services instead of military stations also occurred in other countries with relatively small monitoring networks, such as Ireland (Irish Meteorological Service, 1957; Kelleher, 2017).<sup>10</sup>

As in the United States, fallout controversies led European countries to develop national monitoring initiatives, which were complemented and partially coordinated by the new nuclear international institutions emerging from the Atoms for Peace initiative. Between 1955 and 1960, a myriad of international expert committees related to radiation protection were established in response to growing concerns about the effects of radioactivity on human health (Boudia, 2008), which in some cases led to the development of monitoring networks or field programs to assess environmental radioactivity. In 1958, for example, the IAEA and the World Meteorological Organization (WMO) established the Global Network of Isotopes in Precipitation (GNIP) to monitor fallout from thermonuclear tests. From 1961 to the present, this network has gathered samples of precipitation and sent them to the IAEA's Isotope Hydrology Laboratory in Vienna to detect and monitor changes in the concentration of deuterium, oxygen-18, and tritium in rainfall. In the mid-1960s, these measurements revealed an important increase in tritium traced to the last American and Soviet atmospheric nuclear tests, conducted before the implementation of the Partial Test Ban Treaty (PTBT) in 1963 (Erikson, 1965).

At the same time, legislation and treaties were implemented at the national and international scale to regulate the use of nuclear technology, which also gave ground to monitoring initiatives. Euratom, signed in Rome on March 15, 1957, is a good example (Helmreich, 1991; Dumoulin et al., 1994; Krige, 2008; 2016). One of the first articles of this treaty indicated that signatory countries had to "establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied."<sup>11</sup> Indeed, it included provisions for the establishment of regular measuring of environmental radioactivity in European countries. In particular, Article 35 stated, "each member state shall establish the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil and to ensure compliance with the basic standards." This was accompanied by the indication that "the Commission shall have the right of access to such facilities; it may verify their operation and efficiency." Yet Article 36 required that member states "periodically communicate information on the checks referred to in Article 35 to the Commission so that it is kept informed of the level of radioactivity to which the public is exposed,"<sup>12</sup> implying that keeping the Commission informed by submitting regular radioactivity measurement data would obviate the need for more hands-on interventions.

The European Nuclear Energy Agency (ENEA) became one of the main vehicles for the implementation of the aforementioned directives.<sup>13</sup> Created by the Organization for European Economic Co-operation (OEEC) in February 1958, ENEA took one of its first actions in this sense by establishing a Health and Safety Committee (HSC) to develop recommendations for radiation protection against the hazards of ionising radiation that

member countries could apply in their own national legislation.<sup>14</sup> Working together with the International Commission on Radiological Protection (ICRP), the HSC thus implemented in 1959 standards for radiation protection norms in the OEEC countries (Marcus, 2008).

In relation to environmental radioactivity, the HSC's first actions were directed at compiling information about the OEEC member countries' ongoing monitoring. Einar Saeland, director of the ENEA, delegated this task to his compatriot Thorleif Hvinden in June 1958. Research director of the Norwegian Defense Research Institute (FFI) and an expert in the field of fallout deposition, Hvinden requested data from UNSCEAR, the IGY radiation monitoring program, and the Scientific Working Party of the NATO Civil Defense Committee, and he visited European countries, such as Sweden, Denmark, Holland, Germany, and Norway to examine their extant monitoring networks (Marcus, 1997). In his communications, Hvinden justified the collection of data "in view of the 'international' nature of radioactive contamination," which made it "desirable to have a common reporting system." The creation of this system, initially based on collaboration among existing facilities, would not only respond to the fear raised by nuclear testing, but also help the extension of nuclear energy in Europe, he wrote:

[It] is desirable to make routine measurements of natural and artificial radioactivity in air, precipitation, soil, plants, seawater, food, animals and humans, to learn about the level before nuclear activities start or accidents happen, to be able to take necessary protective steps if contamination due to activities or incidents should reach hazardous levels, and to be able to allay unreasoned apprehensions. A well-organized monitoring system will also be essential for the evaluation of economic claims in connection with nuclear activities in general or special accidents.<sup>15</sup>

In June 1959, Hvinden presented his report, "Measurements of Environmental Radioactivity in the OEEC Countries," to the HSC. In the introduction, he reiterated that implementation of nuclear technology naturally implies the "manipulation of considerable quantities of radioactive materials" in activities such as extraction, enrichment, reprocessing, disposal, production and transport, and this process would result in the regular exposure of workers and nearby populations to radiation "in the course of normal operations as well as in cases of accident." Thus, international radiation protection regulations were necessary "to keep the external radiation level and the concentration of radioactive material in air, in food and drink, below certain maximum permissible values" and required local authorities' constant surveillance and reporting of radiation levels at each nuclear reactor or nuclear installation. That radioactive pollution is mobile, and monitoring requires the coordinated exchange of information

between countries necessitated, in turn, the standardisation of methods of measurement and conversion factors. With such endeavors, the HSC could gather and provide international data “for [the] scientific evaluation of how radioactive materials reach men.”<sup>16</sup>

### Radioactivity monitoring and the nuclear industry

For the ENEA, environmental radioactivity monitoring had a third motivation. Beyond military surveillance and the management of nuclear test fallout concerns, the coordination of measures was supposed to be an essential element for the extension of the nuclear industry throughout Europe. However, the idea of establishing a European-wide network for the monitoring of environmental radioactivity lost momentum after the implementation of the PTBT and the extinction of the fallout controversy. This dip in enthusiasm can also be related to the signing in July 1960 of the Paris Convention on Third Party Liability in the Field of Nuclear Energy, which limited the liability of nuclear installation operators in case of accidental release of radioactivity. Monitoring of environmental radioactivity continued to be developed locally or nationally or under specific programs of international nuclear institutions.

At a global scale, the UNSCEAR continued to produce reports each four or five years after the mid-1960s,<sup>17</sup> and the GNIP program run by the IAEA to collect data on light radioisotopes in precipitation, but the focus gradually moved from fallout assessment to the establishment of data set for hydrological studies (Hamblin, 2009).<sup>18</sup> Indeed, after a first stage of expansion (from 155 stations in 1963 to 221 stations in 1965), the network dwindled: by 1987, it collected data from just 151 stations.<sup>19</sup> In Europe, the only systematic international monitoring program was led by the Euratom’s Joint Nuclear Research Center at Ispra (Italy), which measured radioisotopes strontium-89, strontium-90 and cesium-137 in air, rain, milk and fish. The Center produced yearly reports of local measurements from 1960, expanding in 1977 to include data from stations in the nine European Economic Community member states.<sup>20</sup> Another seven reports were issued, including data from around 25 stations in Western European countries, until the restructuring of the service after the Chernobyl accident in 1986. The list of stations and laboratories included in these surveys reveal the absence of a coordinated strategy among European countries, which relied on very diverse approaches to monitoring. Most states reported a diversity of institutions, from meteorological laboratories to military centers, nuclear establishments, and health and hygiene services, while others had dedicated services, such as the *Service Central de Protection Contre les Rayonnements Ionisants* (SCPRI), established by the French government in 1956.<sup>21</sup>

By the late 1970s, important advances in instrumentation, combined with the cessation of atmospheric nuclear tests (China performed its last

in October 1980) allowed for a significant reduction of atmospheric fallout activity worldwide.<sup>22</sup> As a result of this attenuation, the detection of accidental emissions became more precise. In the 1950s, nuclear accidents such as the Kyshtym disaster (1957) could go undetected—in that case, it would only be known in Western Europe after the revelations of a Soviet dissident in 1976 and confirmed by the careful reading between the lines of Soviet radioecology literature (Trabalka et al., 1980). By the early 1980s the situation had changed dramatically: new germanium detectors were able to detect radioactivity in the order of the micro-Becquerel per cubic meter and allowed the development of long-distance “early alert” systems associated. For example, a series of peaks in environmental radioactivity detected in northern Europe in 1983 spurred the creation of an informal system of data-exchange between scientists from Germany, Finland, Sweden, Norway and Denmark. Called the “ring of five,” this group has since provided a system of early alerts regarding radiological accidents.<sup>23</sup>

On April 27, 1986, the monitoring system at Forsmark, a Swedish nuclear station in the north of Stockholm, detected a sudden peak in radioactive fallout. It was one of the first indications in the West that Reactor 4 in Chernobyl’s nuclear complex had exploded.<sup>24</sup> The Chernobyl accident tested the reliability of European networks and their ability to communicate radioactive hazards to the public. In France, for example, the director of the SCPRI, Pierre Pellerin, was accused of minimising or denying the effects of the “Chernobyl radioactive cloud.” Noting the degree of difference among the discourses emanating from national monitoring systems after the accident, international organisations undertook to create centralised databases. In October 1986, the IAEA approved the Convention on Early Notification of a Nuclear Accident, which encouraged states to communicate nuclear accidents from which the “release of radioactive material occurs or is likely to occur and which has resulted or may result in an international trans-boundary release that could be of radiological safety significance for another State.”<sup>25</sup> Under this convention, each state must, as soon as possible, report to the IAEA the apparent or confirmed accident’s time, location, nature and other data essential for assessing the situation. Before the year’s close, Euratom adopted a resolution on community arrangements for the early exchange of information in the event of a radiological emergency (resolution 87/600, December 14, 1987). This included the obligation that member states “inform the Commission, at appropriate intervals, of the levels of radioactivity measured by their monitoring facilities in foodstuffs, feeding stuffs, drinking water and the environment.”<sup>26</sup> This was the basis for the 1988 creation of the Radioactivity Environmental Monitoring program by the European Commission (EC) at the Ispra Joint Research Centre. Aimed at collecting fallout measurements produced in countries of the European Community, this project constituted

the Radioactivity Environmental Monitoring data bank (REMdb), which included some radioactivity measurements in Eastern European countries from a similar database set up by IAEA.<sup>27</sup>

### A participative turn?

As happened during the nuclear fallout controversy, the Chernobyl crisis fostered a more critical attitude toward nuclear technology. In some countries, communication failures fueled public mistrust of data presented by the authorities, stimulating the emergence of counter-expertise initiatives. As I have mentioned, the French SCPRI's results and methodology were challenged, and citizens organised into groups like the CRIIRAD, the Commission for Independent Research and Information on Radioactivity (*Commission de Recherche et d'Information Indépendantes sur la Radioactivité*), which aimed to provide independent measurements of environmental radioactivity (Topçu, 2013). Established in 1989, the CRIIRAD set up independent monitoring groups across France and called for international coordination among similar groups (Topçu, 2013).<sup>28</sup> Since that time, the CRIIRAD's activities have evolved beyond the evaluation of the Chernobyl accident; it now gathers data on all aspects of the nuclear cycle, from the impact of uranium mining and milling in Africa (Hecht, 2012) to the monitoring of all types of nuclear installations, such as power stations, reprocessing plants, military plants, nuclear research centers and hospitals. However, its reliance on non-governmental funding circumscribes the scope of these initiatives to small-scale, local measurements.

In comparison, data dragnet behemoths such as the International Monitoring System (IMS) provide the public with abundant data on environmental radioactivity. Established in 1996 in the framework of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the IMS counts with 80 radionuclide stations among its 337 facilities, combining seismic, hydro-acoustic and infrasound technologies into a global alarm system aimed to detect "rogue" nuclear tests. Due to its global extent, it is not surprising that the CTBTO network became the main source of data about the global spread of radioactivity from the Fukushima nuclear accident on March 11, 2011. The first detections of radionuclides such as iodine-131 and cesium-137 came only one day after the accident, recorded at the Takasaki CTBTO monitoring station in Japan. Within three days, radioisotopes were detected in eastern Russia and on the west coast of the United States. One month later, the network was able to trace—in detail—the global spread of radioactivity from Fukushima.<sup>29</sup>

As had happened with the Chernobyl catastrophe, the Fukushima disaster brought nuclear controversy to new methods of public engagement in relation to environmental radioactivity. In addition to destroying the

reactors at the Fukushima nuclear station, the tsunami that followed the earthquake damaged 95% of the region's nuclear monitoring stations. The provisional monitoring stations installed by the government and commercial operators in the area (TEPCO) did not provide estimates of radioactivity releases until two weeks after the accident. In reaction, citizens took it upon themselves to volunteer to measure the radiation affecting their bodies. Groups of Japanese people built crowdfunded Geiger counters in a citizen-science project called Safecast, which recorded 45 million measurements using open-source detectors (the DIY model bGeigie Nano), publishing them in real-time through an open database under Creative Commons licensing for four years following the accident.<sup>30</sup> Armed with these data, activists confronted the Japanese government and challenged the official data, pointing out discrepancies of up to 30% between the citizen and government networks.<sup>31</sup> This case, as it happened with the early American citizen initiatives on fallout or the CRIIRAD counter-expertise, provide an ironic turn from the secretive, top-down character of early radioactivity monitoring. Its appropriation by groups of citizens constitutes a profoundly subversive action, as technologies of surveillance and monitoring activities traditionally accompanied and legitimated the concentration of power in big organisations.

However, as happened with controversies on the impact of nuclear accidents on human health, the validity and relevance of data collected by citizen initiatives has been questioned and confronted with the more massive and comprehensive reading produced by governmental institutions. It is maybe too soon to be certain whether citizen initiatives to monitor global radioactivity will pose a significant challenge to nuclear establishments. However, it is undeniable that citizen-science has contributed to the “participative-deliberative turn” of nuclear establishments (Sundqvist and Elam, 2010), which increasingly work to encourage public participation as a way to maneuver around public concerns regarding nuclear technology. In this sense, it will be no shock when future controversies over nuclear technology involve weighing the legitimacy of competing metrics and networks and the management of the data produced by official and unofficial watchdogs.

## Notes

- 1 The network included four dedicated BW-29 squadrons for air-sampling and stations along the Pacific, from Northern Alaska to the Philippines, and Atlantic coasts of the United States. The strategic importance of gathering intelligence about Soviet nuclear activities easily circumvented the limitations imposed by the 1946 McMahon Bill, which otherwise prevented the exchange of “American” nuclear information with foreign countries. See Goodman (2007: 43–46).
- 2 The extent of these early networks was not negligible. The federal government acquired instruments for these systems for a value of \$1.5 million in 1955,

- almost \$4 million in 1957 and more than \$20 million in 1962. Federal Emergency Management Agency (1986). *Radiological Instruments: An Essential Resource for National Preparedness*. Publication CPG 3-1. Available at: <https://www.hSDL.org/?view&did=456492> [Accessed June 15, 2021].
- 3 AEC (1956). *Worldwide Effects of Atomic Weapons: Project Sunshine*, August 6, 1953. Santa Monica, CA: Rand Corporation. Available at: <https://www.rand.org/content/dam/rand/pubs/reports/2008/R251.pdf> [Accessed June 15, 2021]. The monitoring of radioactive fallout was not only based on health concerns, but industrial ones, as it responded to complaints from the National Photographic Manufacturers Association and some producers of photographic films, whose production chains were affected by radioactive fallout.
  - 4 Trumbull, R. (1954). Nehru Proposes Atom “Standstill” Pending UN Curb. *New York Times*. April 3, 1954. Available at: <https://www.nytimes.com/1954/04/03/archives/nehru-proposes-atom-standstill-pending-u-n-curb-asks-powers-with.html> [Accessed June 15, 2021].
  - 5 On the role of UNSCEAR in delaying the implementation of a test ban, see Boudia (2007), Hamblin (2007), and Higuchi (2018). For a discussion on its connection to other international cooperation endeavors in radioprotection, see Hamblin (2006). For the networks, see Herran (2014).
  - 6 The US Weather Bureau network, established under the direction of meteorologist Lester Machta, coordinated measurements obtained from 39 stations in the continental United States and 14 overseas locations; 23 overseas stations operated by the Air Weather Service; 31 stations from the State Department; 3 operated by the Navy and the Coast Guard; and 2 by the Atomic Bomb Casualty Commission. The Canadian Meteorological Service and the Canadian Atomic Energy Commission cooperated, providing data from ten more stations (List, 1955), while the Military Sea Transport Service in the Pacific Ocean performed daily measurements based on gummed film stands.
  - 7 Between August 1957 and June 1960, this survey collected 3,700 air samples at more than 70,000 feet (around 20,000 meters) of altitude in a meridian-sampling corridor to measure stratospheric concentrations of fallout (particularly Sr-90) from nuclear tests. Data obtained allowed meteorologists to estimate the stratospheric residence times of fallout and model the mechanisms and rates of transfer within the stratosphere and from the stratosphere to the troposphere.
  - 8 *Division of international affairs, Memorandum of conversation. Discussion with Dr. Yves Rocard, French physicist*, February 26, 1958. NARA archives, box 490, folder 21.33.
  - 9 Of the remaining nine stations, seven were part of the Italian contribution to the International Geophysical Year, the National Committee for Nuclear Research, and Ferrania, a private photography company.
  - 10 The Irish Meteorological Service carried routine airborne measurements of radioactivity in precipitation and dust since 1957 in the stations of Dublin and in Valentia. Aiming at detecting fallout from nuclear weapons tests with GM counters, the system was nonetheless unable to detect radioactivity from the Windscale accident, as the increase of the levels of radioactivity detected in October 1957 were attributed to nuclear testing.
  - 11 Article 2b of the *Treaty Establishing the European Atomic Energy Community*, March 25, 1957. Other articles related to radiation protection are Articles 30–33 in Chapter 3, which dealt with radiation protection and safety standards, and Articles 34–38 in the same chapter, which concern environmental radioactivity.

- 12 *Treaty Establishing the European Atomic Energy Community*, March 25, 1957, Chapter 3, Articles 35 and 36. For an analysis of the practical implications of these articles, see Janssens (2004).
- 13 ENEA's main objective was to promote nuclear co-operation among OEEC countries and encourage the development and use of nuclear energy for peaceful purposes. Its founding members were the 17 OEEC countries: Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland, Turkey, and the United Kingdom. Canada and the United States were associate members. In 1972, the ENEA was renamed Nuclear Energy Agency (NEA) "to reflect its growing membership beyond Europe's boundaries." Available at: <https://www.oecd-nea.org/> [Accessed March 30, 2020].
- 14 It was not until June 1958 that the ENEA launched a second project: the building of a reactor in Halden (Norway), conceived as a space for training and exchange of information on reactor technology among different national nuclear programs. On the early history of the HSC, see Métivier (2007).
- 15 T. Hvinden to E. Saelund, *Memorandum. OEEC Monitoring Programme. Survey of Existing Radiation Monitoring Programmes in the OEEC Countries, with Recommendations on Coordinated OEEC Monitoring and Reporting System*. Historical Archives of the European Union, Florence. Work of the Sub-Committee of Health and Safety, NUC 79.
- 16 The Hvinden report also provides a detailed survey of existing radioactivity measuring stations in OEEC countries and measuring data from 1959. Fifteen national radioactivity monitoring networks and 144 stations are included, with France boasting the densest network, followed by Sweden, then Italy. The report includes tables with measurements of airborne radioactivity, settled dust, and precipitations and an annex with recommendations. *Measurement of Environmental Radioactivity in the OEEC Countries. Provisional Report Prepared by the Secretariat of the European Nuclear Energy Agency*. Historical Archives of the European Union, Florence. Work of the Sub-Committee of Health and Safety, NUC 79.
- 17 The UNSCEAR Reports were issued in 1958, 1962, 1964, 1966, 1969, 1972, 1977, and 1982, published as part of the official records of the United Nations. Since 1964, they included data on carbon-14.
- 18 The focus on hydrology is characteristic of the IAEA's increasing involvement in agricultural research as part of the so-called "green revolution."
- 19 The GNIP counted by 155 stations in the period 1953–1963; 221 in 1964–1965; 212 in 1966–1967; 177 in 1968–69; 164 in 1970–1983; and 151 in 1987. See the reports *Environmental Isotope Data*, number 1 to 9, published by the IAEA in 1969, 1970, 1971, 1973, 1975, 1979, 1983, 1986 and 1990, respectively.
- 20 Commission of the European Communities. (1977). *Results of Environmental Radioactivity Measurements in the Member States of the European Community for Air-Deposition-Water (1973-1974), Milk (1972-1973-1974)*. Luxembourg: Office for Official Publications of the European Communities.
- 21 In July 1994, le SCPRI was renamed *Office de protection contre les rayonnements ionisants* (OPRI), and in 2002 it merged with the *Institut de Protection de Sécurité Nucléaire* (IPSN) to become the current *Institut de Radioprotection et de Sécurité Nucléaire* (IRSN).
- 22 China and France continued to perform atmospheric nuclear tests until 1980 (50 tests between 1960 and 1974 by France and 22 tests between 1964 and 1980 by China), which is only a fraction of the more than 400 tests performed by the United States and the Soviet Union until 1962.

- 23 The informal status of the “ring of five” is stressed in public communications. However, the mailing list is notably maintained by the FOI.
- 24 According to Mould (2000), an American spy satellite in orbit over the Soviet Union also detected the explosion incidentally. Three days after the explosion, images of the Landsat 5 were also used to confirm the accident at the Chernobyl nuclear plant.
- 25 IAEA (1986). Convention of Early Notification of a Nuclear Accident. Available at: <https://www.iaea.org/sites/default/files/infcirc335.pdf> [Accessed May 31, 2021].
- 26 The resolution is available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31987D0600> [Accessed May 31, 2021].
- 27 The first collection of data was published in 1989 in two volumes: Raes, F., Graziani, G., Grossi, L., Marciano, L., Piers, D., Pedersen, B., Stanners, D., and Zarimpas, N. (1989). *Radioactivity Measurements in Europe after the Chernobyl Accident. Part 1: Air*. Luxemburg: Commission of the European Communities. Available at: <https://op.europa.eu/en/publication-detail/-/publication/ca9207fc-1490-4dbc-832d-35e206a9264f/language-en/format-PDF/source-search> [Accessed June 15, 2021]; Graziani, G., Raes, F., Stanners, D., Pierce, D., Holder, G. (1991). *Radioactivity Measurements in Europe after the Chernobyl Accident. Part 2: Fallout and Deposition*. Luxemburg: Commission of the European Communities. Available at: <https://op.europa.eu/en/publication-detail/-/publication/ebf6ce9a-89d2-4ca7-812b-c8a91234cb77> [Accessed June 15, 2021].
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- 29 Additionally, CTBTO seismological stations were able to detect the earthquake preceding the flooding of Fukushima and helped the Japanese authorities to issue tsunami warnings. A colloquium on the CTBTO role in early warning and monitoring in the Fukushima disaster was held in Vienna on March 9, 2012: *CTBTO Past and Future Contributions to Emergency Preparedness: Fukushima Case Study*, summary available at <https://www.ctbto.org/verification-regime/the-11-march-japan-disaster/one-year-after-fukushimathe-ctbtos-contributions/> [Accessed May 31, 2021].
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- 31 On Safecast results, see Brown et al. (2016). A comparison of Safecast and official contamination data is available in Hultquist and Cervone (2018). See also the Safecast blog (<https://blog.safecast.org>).

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