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Safety clicks. The Geiger–Müller tube and radiation protection in Germany, 1928–1960

In 1956, the headline of a German newspaper read: "Are We Already Contaminated? Geiger Counters on Alpine Pastures."[1] The article described citizens enjoying themselves in the picturesque market place in Freiburg, drinking a glass of wine – which contained radioactive strontium: nuclear fallout had contaminated the environment and the food. The journalist then sought to calm the worries of the readers: "Death is not hiding in a glass of wine or a cup of milk."[2] In the face of day-to-day radiation hazards, it was necessary to re-assess the definition of safety, and in the course of this cultural development, radiation-measuring instruments gained particular importance. Although a range of different instruments such as ionisation chambers, photographic films or scintillation counters was used for radiation protection, for the general public it was the Geiger–Müller counter that symbolised the efforts to achieve radiation safety – it was even called the "watchdog of the atomic age."[3] For this reason, it is worth studying how that instrument's visible and audible representations of radioactivity achieved such significance.

The invention of the Geiger–Müller tube solved a challenging problem in science: the detection of particles and radiation that the human senses could not detect.[4] However, as this is a feature of all radiation-measuring instruments, it cannot sufficiently explain the Geiger counter's popularity. As an instrument that could make palpable radiations that fell beyond the ken of human senses, the Geiger counter came to represent health and safety in the face of unseen dangers. For both technical and socio-psychological reasons, the Geiger counter achieved a central role in the establishment and demonstration of safety measures. This paper relates the design of Geiger counters to distinct concepts for the preservation of public health and safety.

The focus of this study raises the more general question of how objects affect the creation of order in the social and cultural environment. Studies in material culture have pointed out the dialectical relationship between artefacts and social practice.[5] Accordingly, the design of Geiger–Müller counters resulted from scientists' reflections on radiation protection. Once produced, the instruments formed a powerful medium for structuring the practice of radiation protection: the devices defined *control procedures*, their material nature legitimised a *social order* related to radiation control, and the appearance of the instruments carried a *symbolic meaning* representing radiation safety.

Figure 1. Exhibition of a Geiger–Müller counter at the Nuclear Research Centre Karlsruhe.

Why is the main emphasis of this study on concepts of radiation protection and not on their practical enforcement? Scientists and government officials involved in the organisation of radiation safety also discussed the design of measuring instruments. Their expertise crucially informed instrument manufacturing. The design of these instruments therefore expresses safety concepts that were not immediately linked to actual measuring practices.

In this paper, I will first briefly comment on the mode of operation of the Geiger–Müller tube and the history of nuclear research in Germany. The following paragraphs deal with the history of radiation-measuring instruments that have been constructed for a range of different atomic hazards: radiation exposure in the workplace,[6] nuclear fallout in the environment, and nuclear war. Variations in the design and use of measuring instruments reflected strategies to deal with different nuclear hazards that affected increasing sections of the population and involved supposedly less-qualified people in radiation measurements. Finally, I will reflect on the public debate about the so-called "Volks-Geiger counter," in which the instruments themselves became a representation of radiation safety.

The time span of this study is set by the invention of the Geiger–Müller tube in 1928, and the implementation of atomic legislation in the early 1960s. The post-war period deals only with radiation protection in West Germany.

The Geiger–Müller Counter

So far, I have spoken about the so-called Geiger counter as if it existed as a clearly defined object. However, the Geiger–Müller tube offers, rather, a generic *method* of counting. It is not a single specific *artefact*. According to its formal definition, the Geiger–Müller tube is merely a radiation detector working on a specific kind of gas amplification, with the possibility of a wide range of designs and types. Installations comprising such detectors, an amplifier and registration devices, have been colloquially called "Geiger counters" (Figure 1).

The Geiger–Müller tube converts ionising radiation into electric pulses. These pulses are then transformed by electronic amplifiers: pulse shaping, pulse generation and clipping are methods used to produce uniform pulses. The amplifiers thereby process the incoming information and generate clear and unambiguous signals. Finally, the configuration of the Geiger counter shapes the ways in which it is possible to perceive radiation: the clicks of a loudspeaker, the numbers on automatic counters, and also the movement of an indicator have become representations of radiation.

A wide range of instruments utilise the counting method of Geiger and Müller. These devices differ fundamentally in size and shape, materials, and function. By 1960, radiation-measuring instruments allowed a direct reading of the number of counts, indication of pulses per minute and of the dose rate, and measurement of different levels of radiation – all with only one instrument and the construction of optical and acoustic warning systems. Differences in the design of the instruments depended on various measurement factors. However, the appearance of these objects cannot be explained simply by reference to different functions; the different instrument designs also reflect different concepts of radiation control.

The Geiger–Müller Tube Before the Second World War

Many features of the Geiger–Müller tube used in the 1950s for radiation protection were developed in the 1930s. Hans Geiger and his research assistant, Walther Müller, invented the electrical method of counting radioactive particles that is now known as the "Geiger–Müller tube" in 1928. In contrast to the optical method of counting tiny flashes on a scintillation screen, electrical methods relied on the electrical effects of particles. Geiger's interest in the electrical counting of radiation dated from his early experiments in Ernest Rutherford's laboratory in Manchester in 1908. After his move to the radioactivity laboratory of the "Physikalisch-Technische Reichsanstalt" in Berlin in 1911, Geiger continued with further experiments on the measurement of individual particles which resulted in a new type of electrical detector, the Geiger point counter. In spite of an obvious lack of clarity about the reliability and practical utility of the counter, the detector came to be used in a number of significant experiments in the early 1920s. In 1925, Geiger left Berlin in order to become Professor of Physics at Kiel University. Müller was one of his first

PhD students there. He performed the experiments that finally led to the invention of the Geiger–Müller tube.[7]

It was the presumed sensitivity of the apparatus that caught the attention of the physics community. In their first publications, Geiger and Müller emphasised the capability of the tube to indicate even the weakest radiation. In comparing methods of measurement, "sensitivity" was defined in practice as the ability to measure a small amount of radiation in a short period of time. The practical time management of radiation investigations was a strong motivation for the use and further technical development of the Geiger–Müller tube.[8]

Geiger skilfully managed the presentation of the new apparatus. A number of physicists visited his laboratory in Kiel and observed the counter in action. Niels Bohr himself is said to have played around with it, as happy as a small child. Geiger and Müller also attended a number of conferences, where they demonstrated the working of the counting tube. Installing a loudspeaker, they impressed their colleagues with the clicks of the new apparatus. They conveyed the sensation of an immediate perception of radiation accessible hitherto only by the means of complex and lengthy experiments.[9] The Geiger–Müller tube thus became an instrument, not only for the *measurement* of radiation, but also for *public demonstration*, even though that was, as yet, to a very select audience.

Jeff Hughes has shown that the further practical development of the Geiger–Müller counter was crucially linked to the emerging "wireless" (radio) industry of the 1920s. These links transformed the practice and organisation of atomic physics, the techniques of which had been called into question in the course of serious controversies about the certainty of radioactivity measurements. Electronic amplifiers made the use of loudspeakers and mechanical counters possible. The new electronic technologies allowed the *automatic* registration of radiation, and thereby reduced the active involvement of physicists, who had previously been essential in the process of measurement. The automatic counting of ionising particles became common practice in scientific laboratories – although it remained a delicate task to overcome practical difficulties in the construction and operation of the counting devices.[10]

In the 1930s, the instrument proved useful in investigations of cosmic rays, neutron physics and work related to the German "uranium machine." Instruments and common experimental practices had been crucial to the emergence of a nuclear physics community.[11] However, the uses of the Geiger–Müller tube were not confined to the boundaries of physics laboratories. Since 1934, Boris Rajewsky had been examining several cases of human contamination in the radium industry; he was Director of the Institute of the Physical Foundations of Medicine at Frankfurt University.[12] In 1937, his institute became the "Kaiser-Wilhelm-Institut" of Biophysics, where Rajewsky established a centre for the investigation of radiation injuries. The ability to measure radiation in the human body was crucial for the diagnosis and therapy of "radium poisoning" or "radium infection" – the contemporary terms for the intake of radioactive elements, and the Geiger–Müller tube became a predominant device in Rajewsky's investigations. He was seriously concerned by the duration of existing medical examinations, in which weakened patients were exposed to time-consuming measurements of small quantities of radioactive substances deposited in their bodies. Because of the sensitivity of the counting tube, he hoped to be able to reduce the time required for the measurements.[13]

The transfer of the Geiger–Müller tube from physics laboratories to medical centres required changes in the operation of the instrument. The design of the control panel and the registration of the signals were adjusted for the convenience of the physicians, as they were unfamiliar with the technicalities of the instrument. In order to introduce the Geiger–Müller counter into medical practice, Rajewsky even drew an analogy to one of the most common medical instruments – he called the detector, fixed to a flexible tube, a "radiation stethoscope." Like the stethoscope, it allowed an examination of the organs and the diagnosis of localised physical defects.[14] Whereas other ways of measuring radiation in the human body indicated only whole-body activity, the Geiger–Müller tube allowed local measurement of radioactivity.[15] Rajewsky used the Geiger–Müller tube not only for medical examinations, but also in the search for uranium ores. In the early 1940s, he developed these instruments on the basis of previous applications in geological fieldwork.[16]

In the late 1930s, the first German *commercial* Geiger counters entered the market. These were designed for radiation protection in hospitals. Radium tubes were frequently lost or misplaced in hospitals, not only leading to economic losses, but also posing a danger to the health of patients and employees. Geiger–Müller tubes could find lost radium. The commercial counters were easily portable, being equipped with a battery or mains connection and stored in a box. Whereas physicists working in laboratories had struggled to achieve quantitative interpretations of their data, the commercial instruments offered impressive ways of representing detections: clicking loudspeakers, mechanical counters and flashing lights. If we can believe the advertisements, one had only to flick a switch – and the counter was ready for use.[17]

By the end of the Second World War, Geiger counters had been used for physical research, medical examinations and also for radiation measurements in buildings and in the environment. In the 1950s, these implementations were linked, in order to guarantee radiation safety.

Nuclear Research and Industries in Post-War Germany

After the Second World War, German physicists were occupied with the re-organisation of scientific research and teaching. Struggling with the material devastations of the War, at the same time they also attempted to overcome the intellectual isolation that had resulted from the National-Socialist regime. In the course of "Operation Paperclip," physicists worked in the USA and thereby became familiar with what they saw as the enormous advancements of American science.[18] The encounters of German physicists with post-war nuclear physics in the USA and Great Britain left a deep impression; they met a level of scientific co-operation and of government involvement that was not yet known at home. The feeling that Germany had fallen behind in the field of atomic research and industries constituted a continuing justification for further research and industrial development in Germany.[19] The development of measuring instruments, the enforcement of safety regulations and the handling of public relations relied on examples from the USA, France and Britain.

Until 1955, atomic research in Germany was restricted by Allied control. The construction of nuclear reactors, isotope separation plants and large accelerators was forbidden. However, from 1948, Britain's Atomic Energy Research Establishment delivered isotopes to the Federal Republic of Germany for medical applications and non-military research. In addition, public funding provided by the Ministry of the Interior for civil defence supported nuclear research. This allowed circumvention of some legal restrictions. Allied control of nuclear research ended when the Federal Republic of Germany gained sovereignty in 1955; the Ministry of Atomic Energy co-ordinated efforts in the new field of scientific and industrial development. In the following years, the nuclear industries grew rapidly. The Federal Government and the states established three nuclear research centres in Karlsruhe, Jülich and Geesthacht near Hamburg. Universities in Munich, Frankfurt and Berlin built research reactors. The first nuclear power station near Kahl went into operation in 1961.[20]

The euphoric belief in atomic energy brought radioactivity into the centre of politics. The political and economic significance ascribed to nuclear research and industry dramatically changed the public role of atomic scientists. They increasingly moved from the laboratory bench to the conference table in Bonn. Nuclear scientists of the pre-war period became members of government advisory commissions.[21] Many former colleagues of Hans Geiger and their students crucially influenced regulatory policies. Their expertise in the measuring technologies for physical, medical and geological investigations became relevant to the problem of radiation protection. Instruments and practices that had been developed in the context of physical or medical research in the 1930s and 1940s were transferred to radiation protection and civil defence in the 1950s.[22] As early as 1950, the Ministry of the Interior convened an advisory committee for civil defence in the event of a nuclear war. Physicists and radiologists discussed ways of protecting the population and the emergency services from the threat of radioactivity. In 1955, the government established the "Deutsche Atomkommission" (German Atomic Commission) – the main advisory body for nuclear research and industries. In 1957, the "Sonderausschuß Radioaktivität," responsible for radiation monitoring in West Germany, started work. The commissions established sub-committees for radiation-measuring instruments. The state became actively involved in instrument manufacturing. The committees co-ordinated technological developments, distributed information on the trade and determined instrument specifications required for civil defence.[23] The scientists represented in the commissions managed the crucial link between instrument design and specific concepts of radiation protection.

Germany imported mainly American-made radiation-measuring instruments until domestic manufacturers managed to construct practical instruments. In the early 1950s, a large number of companies entered the field of nuclear instrumentation. They were drawn from the electrotechnical industry, for example Siemens (Karlsruhe); the radiographic industry, for example "Laboratorium Prof. Dr. Berthold" (Wildbad); or the radio industry, for example "Frieseke & Hoepfner" (Erlangen), to name but a few influential companies. In 1959, a government directory listed 53 manufacturers of nuclear instruments in Germany.[24] Separation of the development of instruments from the practice of experimental physics effectively evolved in Germany in the early 1950s. The companies became an independent factor in nuclear politics. At the same time, it was necessary to co-ordinate industrial production, nuclear research and government regulations. A government advisory committee dealt exclusively with the design of radiation-measuring instruments. The committee's chairman, Wolfgang Gentner, from 1949 Professor of Physics in Freiburg and later in Heidelberg, established a large collection of foreign instruments that influenced the specifications for the design of instruments in West Germany.[25] In addition, the nuclear research centres equipped electronic laboratories for the development of instruments and the standardisation of nuclear instrumentation. However, in contrast to some American research centres, they did not produce large series of equipment, but restricted their efforts to industrial advice.[26] The manufacturers themselves established close links with the nuclear research centres; their presence became most obvious in courses on the practice of radiation measurement that provided opportunities for future users to become accustomed to the instruments.

In the 1950s, the atomic nucleus caught the attention of many different groups: physicists, politicians in the Federal Government and the federal states, instrument manufacturers, employees in nuclear industries, the military, the emergency services and the so-called lay public. The atom appeared to be the universal answer to all problems of public and private life. It brought the promise of health and wealth as well as a solution for the problems of transportation and energy.[27] At the same time, nuclear hazards fundamentally changed both working conditions and private life. Regulations concerning radiation protection were set in place in order to maintain an awareness of safety. It is not my task here to evaluate the effectiveness of different approaches to radiation protection; instead, I will outline general arguments that appeared as plausible means of establishing a definition of safety in the presence of radiation hazards. The various approaches to the realisation of safety differed in the specific responsibilities they attributed to scientific experts, state authorities, protection crews, sections of the population affected, and measuring instruments.

Radiation in the Workplace

In post-war Germany, radiation endangered an increasing number of employees. Since the first deliveries of isotopes in 1948, the handling of radioactive substances had become part of the day-to-day experiences of scientists and employees in medicine, industry and agriculture. According to numbers produced by the unions, more than 70,000 workers were exposed to radioactivity in 1957.[28] Before the Second World War, the risk of exposure had been regulated within the professions concerned; after the Second World War, a changing public perception of radiation and the increase in the number of people handling radioactivity led to state regulation. In addition, the US authorities insisted on the imposition of legal regulations before Germany could count on the delivery of American nuclear fuels.[29] Public promotion of the nuclear industries was paralleled by legislation and support for instrument-manufacturing industry. From 1956, the scientists and civil servants of the German Atomic Commission discussed regulations on radiation protection; in 1957, the Federal Government began to prepare a decree on radiation protection that was finally promulgated in 1960. It is important to emphasise that, while politicians generally acknowledged the need for tough regulations, this did not imply that they had fundamental doubts about the benefits of nuclear energy – they saw the regulations as means of promoting the new technology. They argued that the lack of regulations at the beginning of the Industrial Revolution had led to pollution; they therefore insisted on investing in safety measures right at the beginning of the Nuclear Age. It is not sufficient to dismiss these considerations as mere "safety rhetoric." Although the radiation protection decree remained controversial, it provided guidelines for "safe" working conditions that could be adhered to. In public, physicists frequently claimed that workplace safety in the nuclear industries was superior to that in the chemical industry, for example. They justified their claims by referring to tighter regulations and more sensitive radiation detectors.[30] Thus, instruments concerned with radiation formed an indispensible contribution to the image of safe nuclear industries.

Regulations at a local level supplemented, and sometimes even pre-dated, state legislation that was implemented in 1960. In the late 1950s, nuclear research centres established special measurement departments to enforce safety regulations. They enjoyed particular independence from management and were authorised to intervene in experiments if radiation safety was endangered. Objects for radiation protection also filled isotope laboratories. Shields and containers protected radioactive materials, and special tools made it possible for researchers to work at a distance from the source of radiation. Such measures had already been the cornerstone of regulations before the Second World War.[31] In addition, measuring instruments

Figure 2. Advertisement for a contamination monitor [Mitteilungsblätter Strahlungsmeßgeräte (Frieseke & Hoepfner, Erlangen), *1 (1960): 10].*

surrounded employees in radiation laboratories. Measurements in the workplace became regular practice. Film badges and dosimeters registered the doses of radiation to which workers were exposed, and portable contamination monitors enabled the detection of local contamination. In order to measure confined radioactive sources without exposing the employees to full radiation, Geiger–Müller tubes were fixed to poles. These devices combined two principles of radiation protection: taking measurements, and keeping a distance from the potential source of radiation. The separation of detector and control panel is a manifestation of the basic principle of radiation protection: keep your distance![32]

Regulations instructed the employees how to behave in the hazardous environment: eating, drinking and smoking were forbidden. The workplace had to be clean and tidy. In case of contamination, it was the duty of employees to clean the areas thoroughly. The progress of decontamination had to be checked with radiation-measuring instruments.[33]

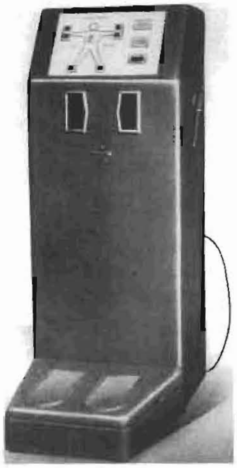

Figure 3. Advertisement for a hand and foot monitor [Mitteilungsblätter Strahlungsmeßgeräte (Frieseke & Hoepfner, Erlangen), *3 (1960): 14]*.

Instructions demanding care and order were an integral part of all regulations concerned with radiation protection. "Hoover"-shaped Geiger counters might have been a reminder of the cleanliness required (*see* Figure 2). Care and order not only reduced health hazards, but also prevented the malfunction of instruments as a result of contamination. Instructions on cleanliness and discipline at work put the onus of responsibility on the workers. Authorities in the nuclear industry identified carelessness, thoughtlessness and negligence as the prime causes of injuries.[34] Measuring instruments not only detected radiation, but also ensured care and order – the instruments became indicators of the character of the workers.

Concepts of radiation protection relied not only on the employees' personal responsibility, but also on work organisation and workplace layout. Protection regulations defined areas in which exposure to radiation might exceed a certain limit as "control areas." Early proposals for the West German radiation protection act used the term "danger zone;" atomic ministry experts rejected this and introduced the terms "control area" and "warning area."[35] This terminology was chosen in order to calm the worries of the employees, but it does also reflect the conviction that technological control made it possible to avoid dangers. "Danger" was not perceived as an inherent quality of these workplaces, but rather as a unique event in the case of accidents. Technical control reduced the possibility of accidents; technical warning allowed the workers to escape danger.

Before leaving control areas, employees were obliged to check for contamination. The location of personnel monitors became a characteristic of zones with high radiation risks. The instruments dictated the structure of the nuclear workplace. The layout of research centres afforded a clear distinction between safe and hazardous areas.[36] Radiation monitors detected the contamination of workers' hands, shoes and bodies (*see* Figure 3). Alarms indicated excessive counts. Further alarms ensured that the person whose contamination was being measured remained for the prescribed time of measurement.[37] A "Doorpost Gamma Radiation Monitor" was able to detect the movement of a reasonably strong radioactive source through a doorway; it comprised two Geiger–Müller counters on either side of the doorway. These counters registered any dramatic increase over the background level of radiation and could thus identify a contaminated worker as a radiation source and sound the alarm.

Regulations concerned with radiation protection rested on the concept of a "tolerance dose." Biophysicists and politicians at the highest level agreed that the tolerance dose was no more than a disguise for the practice of changing scientific conventions without sufficient experimental evidence. The Minister of Atomic Energy, Siegfried Balke, even called the tolerance dose a threshold to calm the public and workers concerned.[38] The tolerance dose defined a reference threshold for safe working conditions; it was a practical way of establishing "safety" that went beyond individual evaluation and experience. Radiation-measuring instruments sustained occupational safety – they proved that radiation was within the officially defined limit. The alarms on these devices can be seen as a manifestation of this method of dealing with health hazards by defining thresholds.[39]

Workplace safety was closely related to the organisation of the research centres. As a result of this, prevention of accidents was the responsibility of the leadership. The Minister of Atomic Energy emphasised in 1957 that every injury proved mismanagement and a lack of leadership. Radiation-measuring instruments not only controlled discipline at work, but also placed responsibility for the safety of the employees with the management.[40]

The instruments described so far were part of the system of radiation protection in large nuclear research centres and reactors. In general, industrial users of isotopes did not have these instruments at their disposal, therefore the federal states of West Germany established radiation-measuring crews. The factory inspectorate or the employment ministry equipped radiation-measuring cars that travelled around, making the prescribed measurements.[41]

Concepts of workshop safety relied on regulations that provided standards for "safe" working conditions. Authorised crews supervised work that involved radioactive substances. The enforcement of safety regulations depended on measuring instruments that structured both the work organisation of the management *and* the work practice of the individual employees.

Fallout and Radiation Safety

Nuclear research centres appeared to be sources of danger, not only to their employees, but also for people living near reactors. Safety, therefore, was not only an issue within the nuclear workplace, but had also to be established outside in the local environment. Physicists managing reactor projects calmed the concerns of the state governments by explaining the automatic radiation surveillance of reactors. They argued that radiation leaks were extremely improbable, but, even if a leak occurred, the Geiger counter would indicate it immediately. Health physics departments surveyed the areas surrounding nuclear research centres; stationary instruments monitored radiation in water, in the atmosphere and in soil. These radiation measurements allowed for the monitoring of the as-yet-unknown behaviour of reactors.[42]

The health physics department of the Nuclear Research Centre in Karlsruhe had a van at their disposal. It was equipped with a large measuring instrument, a recorder, a scintillation counter, a small portable counter, and chemical devices for the preparation of plants and water before measurements. The radiation monitors for such investigations consisted of several modules (*see* Figure 4). The manufacturing industry offered a range of counting tubes, pulse amplifiers and registration devices. Such a modular construction system made possible the adaptation of measuring instruments to meet the specific needs of the laboratories.[43]

It was the task of these instruments to prove the *absence* of radiation released by nuclear reactors. At the same time, these radiation measurements demonstrated the *presence* of radiation in the atmosphere resulting from nuclear fallout after atomic bomb testing. In 1953, Otto Haxel (Heidelberg University) and Wolfgang Gentner (Freiburg University) and their colleagues had already begun measuring radioactivity in the atmosphere and in rain. These measurements were an important source of information about nuclear-weapons testing for the West German Government. The physics department of Freiburg University became the Central Office for radioactive fallout; it published regular reports, starting in 1956. The measurements revealed a drastic increase in radiation, which was publicly perceived as a danger to the health of the population. The measurements, which were originally intended as a source of information on the risks involved in a nuclear war, became evidence of a possible threat even in peacetime.[44]

The German Government ordered the permanent registration of radiation. Between 1955 and 1960, an expanding network of instruments made the national surveillance of radiation possible. A number of state institutions at regional and national levels, several university departments and private institutes monitored radiation in the atmosphere, in water and in food. This multitude of measurements was an ideal basis for disagreement. Controversies about radiation measurements were a frequent source of conflict between scientists of various disciplines and state authorities. The headline of a Munich tabloid read: "Controversy on Contaminated Water Brought New Surprise: Even Our Milk is in Danger. Two Authorities in Dispute."[45] Several strategies were available to deal with and reduce these uncertainties: the unification of methods, the centralisation of measurements and the development of standardised measuring techniques. Scientists called for state intervention to standardise the methods.[46] In addition, government officials proposed to authorise only those state institutions equipped to undertake the surveillance of radiation, while university departments were to be concerned with developing new measuring technologies. The argument was that radiation monitoring was a task of the state and therefore should be controlled by the state; the authorisation of state institutions to measure radiation was an attempt to provide uncontroversial data. The Federal Government consequently supported a network of measuring stations all over the country. Water supply companies and meteorological services were the first to measure radiation in the atmosphere and in waste water both systematically and continuously. In 1955, the German Weather Service was given responsibility for monitoring the atmosphere, to supplement the activities of the institutions that were already in charge of radiation measurements in water, food and in the soil. The permanent registration of radiation was seen as a means to avert hazards to human life.

These institutes were occupied with routine measurements that had previously been the task of physicists who, from the beginnings of their careers, had been accustomed to making measurements of radiation, and who consequently frequently emphasised their skills in evaluating the quality of measurements. The expansion of responsibility for routine measurements increased the number of less-qualified people being involved in the determination of radiation. Meteorologists, biologists and other scientists employed in institutions instructed to monitor radiation struggled with the unfamiliar task. As a result, new requirements emerged for the measuring technologies. In order to overcome the restrictions presented by the working hours of assistants reading the instruments, the devices were equipped with automatic recorders. The construction of devices with long-term reliability became a new challenge for the instrument manufacturing industry; scientists frequently complained about instruments that worked properly for only a couple of weeks. At first, the German Weather Service was equipped with automatically registering instruments from Switzerland. They used Swiss instruments because German counters counted unreliably and thereby required supervision by trained people; the Swiss instruments, in contrast, were "foolproof."[47] While academic scientists relied on their individual expertise when they judged the proper working of measuring devices, reliably working instruments were seen as a guarantee of competent measurements performed by non-specialists.

Figure 4. Large radiation monitor FH 49 of Frieseke & Hoepfner (Erlangen) in the radiation biology department of the Nuclear Research Centre Karlsruhe, 1958.

The need for qualified judgement when assessing the potential hazard of radiation was an obstacle for non-experts. Instruments automatically indicated an increase in radiation beyond a certain threshold. However, the determination of total radiation was not sufficient for the assessment of health hazards. Radiologists took into account radiation only from those elements with half-lives sufficiently long to be of significance; measuring devices automated the complex laboratory processes involved in these evaluations. Standardised measuring technologies reduced the need for expert judgement that tended to be a source of disagreement.[48]

In the 1950s, the government had thus reacted to the awareness of radiation hazards in the atmosphere and on the ground, in water and in food, with the establishment of a network of measuring offices. This extension of routine measurements brought about changes in the design of measuring instruments. Long-term reliability, further automation and standardisation of data evaluation became requirements for measuring devices. The network of measuring offices and instruments monitoring radiation in the environment afforded proof of the provision of care by the government and thereby established "safety" in everyday life.

The Geiger Counter and Civil Defence

While radiation in the workplace and nuclear fallout became part of everyday life, radioactive contamination caused by a nuclear war preoccupied the imaginations of politicians and rescue teams. The possible exposure of a large number of people to high levels of radiation required strategies for the protection of the entire population. As a result of this extension of the scope of protection measures, it became necessary to involve non-scientists in radiation measurements. For this reason, the question of expertise gained particular significance. The nature of the instruments reflected this problem, and was closely related to civil defence organisation. In 1953, the Ministry of the Interior considered supplying the entire population with small dosimeters that registered individual doses of radiation. These instruments – film badges or ball-pen ionisation chambers – allowed control of atomic hazards with reference to individual radiation exposure. The scientists on the committee for radiation instruments considered in detail the problem of whether the instruments should have an open display. Every user would have had access to immediate information on his or her exposure to radiation; open access to the data was seen as a potential source of panic. For that reason, the consultant scientists favoured devices *documenting* the dose; *evaluation* of the measurements should be a responsibility restricted to centralised radiation offices.[49] In this way, it was possible to limit access to the information that could be deduced from the instruments.

For practical and financial reasons, the committee decided to equip only emergency services personnel with individual dosimeters, and not the entire population. Instead of requiring *individual* exposure to be monitored,

Figure 5. Air-raid drill with radiation measuring instrument in 1959 [Bundesluftschutzverband Köln (ed.), Lehrbuch für leitende Helfer und Luftschutzlehrer im Bundesluftschutzverband. *Vol. 1.* Selbsthilfe im Zivilen Luftschutz. *(Cologne, 1959), p. 27].*

the committee approved the surveillance of *areas* affected by a nuclear attack. The Geiger–Müller counter was particularly suitable for this task; the choice of the instrument was based on a specific concept of radiation protection in civil defence: the control of contaminated areas (in contrast to the alternative concept of monitoring the individual dose). The instruments became a characteristic of those specialised teams in charge of maintaining the health and safety of the population should a nuclear war occur. It was the job of measuring crews to mark radioactive areas and determine the permissible duration of stay. These applications required tough, portable instruments that were water resistant and, above all, easy to operate. Figure 5 shows a portable instrument for the detection of radiation: the counting tube and the amplifier were fitted in a bar, and the pulses were registered acoustically using earphones. One did not need much training to take the measurements; however, in order to assess the hazards, one had to gain some practical experience in interpreting the clicks in the earphone: it was a matter of personal evaluation and judgement to infer radiation threats from the acoustic signals.[50]

Such rough-and-ready measurements of radiation based on the personal experience of the measuring crews were generally unsatisfactory. Strategies of civil defence relied on quantitative values that prescribed further action. The duration of permissible stay in a contaminated area, for example, depended on calculations that took into consideration the tolerance dose and the activity in the region. Quantitative measurements required specially qualified crews. The scientists on the committee on radiation protection still believed the scientific terms such as "dose" or "dose rate" to be too complex for members of the emergency services. For this reason, they considered producing instruments that immediately indicated the time of permissible stay: in ambiguous situations – when the protection crews were confronted with the conflicting values of self-protection versus the protection of others and of inanimate objects – the instruments allowed fast decisions as to restriction of access to contaminated areas.

Members of emergency services were expected to make decisions on rescue attempts affecting health and survival of citizens in the face of nuclear contamination. The commission on civil defence aimed at a reduction of individual evaluation and judgement. They defined the amount of radiation to which members of protection crews were permitted to be exposed. They allowed, not only for the possibility of health defects, but also for the problem of decreasing human efficiency as a result of exposure to radiation. They struggled with the dilemma that every rescue attempt in a contaminated area presented a radiation hazard for the protection crew. State institutions settled these problems by creating rules and making decrees.[51] The design of instruments for civil defence was adapted to these regulations, in order to provide a clear basis for further action. Their range of sensitivity and the design of the instrumental scales depended on previously determined threshold values. Concealing the complex negotiations surrounding the matter of the so-called tolerance dose, the instruments provided clear-cut data in accordance with prescribed regulations.

In addition to portable radiation-measuring instruments, central radiation laboratories were equipped with instruments for the measurement of radiation in water, air, dust and food. In contrast to the instruments mentioned above, the use of these devices and the complex evaluation of the data they generated required special training.[52] The Ministry of the Interior suggested equipping a mobile measuring station with large radiation-measuring instruments; the civil servants favoured mobile stations because stationary instruments could be endangered in the event of a nuclear attack. In addition, the German Red Cross kept two measuring vans for use in disasters caused by accidents in nuclear reactors. These various measuring vans allowed the surveillance of radiation to be made independently of stationary laboratories.[53]

The press frequently published reports about super-bombs and impending nuclear war. These articles portrayed the population as defencelessly exposed to the invisible and deadly dust that could be detected only with a Geiger counter.[54] In such situations, the public was told, they should trust radiation crews tracing radioactive contamination with Geiger counters. Measuring radiation was presented as a means of controlling it. Although the emergency services used a variety of different instruments, in public, the Geiger counter became the the device that characterised rescue teams controlling radiation.

Safety in case of a nuclear war relied on specialised crews mastering measuring instruments. These objects brought about a hierarchical structure within the civil defence services that was linked to the application of different classes of radiation-measuring instruments: the lay public did not have any instruments; members of protection crews were equipped with small dosimeters, several radiation detectors and dose-rate meters; and finally, specialised officers managed the most sensitive and advanced instruments. This hierarchy in civil defence also emerged from the means of decision making. The kind of information available to the various groups depended both on the instruments and on the conclusions that could be drawn from the measurements. Some devices suggested formal, strictly rule-governed decisions with hardly any scope for judgement, while others provided data amenable only to expert evaluation and judgement.

The Volks-Geiger Counter

The expanding network of measuring instruments proved the ubiquity of radiation. In addition, in the early years of the Cold War, nuclear war was a permanent threat. The different sources of nuclear hazards blurred in the perception of politicians and the press. This had enormous consequences for the meanings that were ascribed to radiation-measuring instruments.

Figure 6. Public Information meeting organised by the Nuclear Research Centre Karlsruhe, 1957.

It is interesting to examine the effect of the Geiger counter on the relationship between the public, scientists and civil servants. First, it is necessary to spend some time considering how politicians perceived the public's reaction to radiation in their day-to-day life. Since the early 1950s, the German tabloids regularly reported on fallout and the contamination of the environment and of food. In the view of most politicians and scientists, these reports distorted the proper purpose of scientific articles on this issue and caused unnecessary public concern. Civil servants of the Atomic Ministry frequently labelled the reactions of the public as a "radiation psychosis."[55] A government adviser identified the public's difficulty in *perceiving* radiation as being the origin of the "magic," "irrational," "emotional" fears of the population. He demanded that the public had to be convinced that radiation was not an unknown, unpredictable, magic power, but a natural force that could be controlled by scientific experts.[56] It is important to emphasise that it was in the government's interest to inform the population regularly concerning radiation. The government saw the need to "accustom the German population to radiation hazards." This information had to be accompanied by confirmation that the government had taken measures for the public's protection.[57]

The health physics department of the Nuclear Research Centre in Karlsruhe complained about the increasing public doubts caused by the black-and-white portrayal of press reports on nuclear-weapons tests.[58] Confronted with opposition from villages in the neighbourhood of the planned reactor near Karlsruhe, the Nuclear Research Centre organised meetings at which the public was informed about how the reactor worked. The Geiger counter shown in Figure 6 was one of the few original instruments they brought with them. This instrument represented the entire network of measuring installations that spanned the research centre and the surrounding area. Furthermore, the radiation-measuring department demanded that measurements should be undertaken publicly, so that the people were able to convince themselves of the safety of the reactor. The van with the instruments driving through the villages around the reactor not only measured the radioactivity in the entire neighbourhood, but also demonstrated, by the visible presence of the counting tube on the roof, the ubiquity of the safety network and its operation (*see* Figure 7). It was the achievement of the Geiger counter that it registered a potential danger – and thereby created safety.[59]

Figure 7. Measuring minibus of the Nuclear Research Centre Karlsruhe, 1957.

Why shouldn't everybody be able to own a Geiger counter? Since the late 1950s, many manufacturers of radiation-measuring instruments considered the production of a so-called "Volksgeigerzähler" – a people's counter. The discourse about instruments controlling radiation was embodied in the new artefact of the Volks-Geiger counter. The instrument fitted into strategies for personal radiation protection that had already been discussed in relation to the field of civil defence. In contrast to the personal dosimeters mentioned above, the Volks-Geiger counter relied on the idea of a responsible citizen mastering information regarding the contamination of the environment and of food. At the beginning of the 1960s, many manufacturers of measuring instruments anticipated a growing market for these instruments. Some even considered marketing small radiation monitors via the popular mail-order firm, Neckermann.

Emergency services had already been equipped with small, portable Geiger–Müller counters. At the beginning of the 1960s, the federal states supplied several offices with small, portable instruments.[60] However, the production of Volks-Geiger counters went far beyond the concepts embodied in these instruments for disaster control: they satisfied both the demand of government officials organising civil defence and the desire of the public to gain access to information about radiation in their day-to-day life. The government supported this idea of broadening the range of users of radiation-measuring instruments.

Similar devices were produced by a manufacturer of cameras, AGFA; the instrument could be kept in a camera box, and the earphones were stored in a camera-case lens-pocket.[61] A prime requirement for such counters was that they should be affordable: they were priced in the range DM100–150. The Ministry of the Interior welcomed their development. Of particular interest were counters installed in transistor radios – government officials hoped such a combination would increase the popularity of the measuring instruments.[62]

The Volks-Geiger counter was seen as an instrument that would give the lay public the ability to control radiation hazards in food and in the environment – a task that had previously been restricted to scientists. The press reported eagerly on new developments: the headline of a paper in Augsburg read: "First Lively Dance Music – Then the Geiger Counter Clicks. Pocket-sized Radio is Radiation Measuring Instrument."[63] The national press also praised the invention of Volks-Geiger counters. The *Frankfurter Allgemeine Zeitung* reported: "Radiation Measurements Made Easy."[64] The article claimed that the counter could be used like a radio, without any expert knowledge.

Scientific experts firmly rejected the concept of the Volks-Geiger counter, insisting on the complex laboratory equipment needed to assess the health hazards of radioactive contamination. They judged the simple testing of food to be insufficient for the evaluation of potential threats. Health physicists at the Nuclear Research Centre in Karlsruhe emphasised: "The individual is unable to judge the real hazard of contamination. Even the

Volks-Geiger counter can't change that."[65] The scientists in charge of radiation protection were well aware of the constraints of their job; they knew of the complexity and ambiguity of radiation measurements; they understood that the assessment of health hazards and the definition of radiation safety depended on conventions maintained by institutions that regulated decision-making processes. Scientists thus defended their role as experts in radiation matters, referring to the *social nature* of their judgements – social in the sense that the evaluation of hazards depended on institutional agreements, which were without complete scientific evidence and open to permanent revision. In contrast, the press and government officials promoting the use of Volks-Geiger counters perceived the problem of safety as clear-cut, considering that it could be settled using a simple instrument. From this point of view, radiation safety was reduced to the *technological problem* of registering radiation: individuals were in charge of controlling, and thereby maintaining, safety.

It might be worth emphasising that there were no regulations as to how to act in case of increased radiation. Scientists of the German Atomic Commission were unhappy that the population had no information about protection measures. Riezler, the chairman of the Protection Commission, and Otto Haxel, scientist at Heidelberg University, supported this point with very drastic arguments referring to the nuclear incident in 1954, when some fishermen on Bikini Atoll were caught in nuclear fallout. That entire affair had received extensive press coverage in Germany, as it was the first time that the global effects of radiation and its global threat became public. Haxel argued that the serious illness of the Bikini fishermen was caused by their ignorance of any protection measures – they had eaten contaminated fish. He claimed that similar incidents could happen in Germany if the population was not informed of protection measures that they could take.[66] The Volks-Geiger counter did not solve this problem; it served only to prove the presence of radiation in food and in the environment.

The instruments were not a success on the market. The Ministry of the Interior gave up its proposals to distribute them for the purpose of civil defence because of the high costs involved; the manufacturers complained about slow sales; atomic scientists questioned the use of the instruments on principle. However, their production is testimony to the belief in the power of instruments to provide a safety control for everybody.

Conclusion

In order to assess the significance of the Geiger counter in the twentieth century, it is essential to understand its use for public regulation and control. A range of institutions involving government officials, scientists, instrument manufacturers and the emergency services "settled" the problem of radiation safety – they provided practical guidelines and arguments that allowed them to speak of safety in the presence of radiation hazards. Nuclear war, radiation in the workplace and radioactive fallout required different safety measures. In each case, measuring instruments reflected the debates on specific features of radiation protection. It was a question of *social order* to designate those who were in charge of radiation control. The design of the instruments became a crucial factor in the organisation of protection measures. The qualifications necessary for making measurements, and the information obtainable, depended on the instruments. Instruments such as large radiation monitors (Figure 5) embodied the concept of qualified-expert systems with exclusive access to data. In contrast, the Volks-Geiger counter represented the ideal of responsible citizens with free access to information.

Radiation-measuring instruments made the application of safety regulations possible. The devices were adapted for day-to-day measurements and thus dictated *control procedures*. The determination of threshold values marking the boundary between safety and danger was of crucial significance for radiation control. Contemporary physicists and radiologists emphasised that the definitions of "threshold values," of "admissible exposure to radiation" and of "radiation safety" relied on changing scientific conventions. In common with atomic radiation itself, these conventions could not be experienced in day-to-day life. However, the definition of threshold values transformed the problem of safety into the technical problem of determining the level of radiation.

The Geiger–Müller counter was not only an important instrument for radiation control. By reference to the Geiger counter, it was possible to represent the entire network of instruments and institutions controlling radiation. However, the *symbolic meaning* of the instruments went beyond a visible exemplification of authorities enforcing safety standards. In 1956, a newspaper emphasised that no-one denied the danger of radioactivity. However, "as soon as it is possible to grasp a danger, its dangerous face disappears."[67] The Geiger counter's impressive representation of radiation publicly demonstrated the capacity to control radioactivity. In the 1950s, it was a widely held belief that the *detection* of radiation was a means to create *safety*. By the late 1960s, this attitude had changed – and measurements came to be representative of danger, rather than to be perceived as creating safety.

Notes

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2. "In einem Glas Wein oder einer Tasse Milch steckt nicht der Tod," *Hamburger Abendblatt*, September 21, 1956.
3. Hans A. Künkel, *Atomschutzfibel. Die deutsche Wissenschaft urteilt* (Göttingen, 1950), p. 37; "Geigerzähler auf der Alm" (n. 1 above).
4. D. Alan Bromley, "Evolution and Use of Nuclear Detectors and Systems," *Nuclear Instruments and Methods* 162 (1979): 1.
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9. Rheingans (n. 7 above), p. 42; see also the correspondence between Müller and his parents 1928–1929, the letter about Bohr's visit to Kiel is dated June 20, 1929, Deutsches Museum, Archiv, NL 24–7/30. On Geiger's popularity as a public lecturer, see Edgar Swinne, *Hans Geiger. Spuren aus einem Leben für die Physik* (Berlin, 1988), pp. 84–85.
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21. Spencer R. Weart, *Scientists in Power* (Cambridge, Mass., 1979).
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23. On the history of the "Deutsche Atomkommission" see Radkau (n. 20 above), pp. 137–48.
24. "Alphaberisches Firmen- und Warengruppenverzeichnis," January 1, 1959, Bundesarchiv Koblenz B 138/256.
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31. See, for example, *Strahlentherapie* 32 (1929): 606–11; *Strahlentherapie* 43 (1932): 796–800. As an example of post-war regulations see "Regeln für den Strahlenschutz" [SiB 57/2, Forschungszentrum Karlsruhe. Technik und Umwelt. Hauptabteilung Sicherheit].
32. See, for example, an instrument in the collections of the Deutsches Museum: "Graetz–Dosisleistungsmesser X-50 mit Sonde," Deutsches Museum, Inv. No. 89/466.
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34. Paper from Schulren in "Arbeitskreis IV/2 der Deutschen Atomkommission," minutes dated February 22, 1957, Bundesarchiv Koblenz B 138/3413.599.
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38. Rajewsky, "Total-Body Radioactivity" (n. 15 above), pp. 18–19. Paper of Straimer in "Fachkommission IV der Deutschen Atomkommission," constituent session, September 13, 1956, Bundesarchiv Koblenz B 138/566. Paper of Atomic Minister Balke, presented in Düsseldorf on November 15, 1957, Generallandesarchiv Karlsruhe 69–150; see also Radkau (n. 20 above), pp. 350–52.
39. Radkau (n. 20 above), pp. 350–52, argued that the tolerance dose did not become a target of American opposition to the nuclear industries until the late 1960s, while the issue has never become a major cause for conflict in Germany. Peter Lundgreen has drawn my attention to the significance of threshold values for the handling of radiation risks.
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41. Directory of authorities for radiation measurements, Bundesarchiv Koblenz B 138/372.
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50. Robert G. Jaeger, *Strahlennachweis- und -meßgeräte [Schriftenreihe über den zivilen Luftschutz Heft 6]* (Koblenz, 1956), p. 28.
51. See, for example, recommendations of Otto Haxel in "Ausschuß 3 der Schutzkommission der DFG," minutes dated October 23, 1952, Bundesarchiv Koblenz B 106/17176. Mary Douglas has provided a framework for the analysis of institutions in charge of risk management. The institutional regulation of hazards is of crucial importance for radiation protection in civil defence, in the workplace and in day-to-day life. For the general argument, see Mary Douglas, *How Institutions Think* (London, 1987) and *Risk Acceptability According to the Social Sciences* (London, 1986).
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