Radioactivity in the environment
The role of regulatory bodies

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Since the Chernobyl disaster, public opinion has demanded greater transparency in assessing the impact of nuclear accidents on people and the environment. To this end, both in France and abroad, various organizations are involved in monitoring the operation of nuclear power plants, in particular through radioactivity measurements.

Chernobyl and the emergence of the community measurements

For a long time, only specialists had access to the results of environmental radioactivity measurements. Following the Chernobyl disaster in 1986, which led to contamination to varying degrees of the whole of Europe, Europeans realized that they could all be potentially exposed to radioactive fallout. In France, the government sparked a serious crisis of confidence by denying the impact on French soil.

In response, scientists and non-scientists came together to create non-governmental laboratories to monitor radioactivity independently. Thus, the Munich Environmental Institute (Umweltinstitut München) [1], the Commission for Independent Research and Information on Radioactivity (CRIIRad) in Valence [2] and the Association for the Control of Radioactivity in western France (ACRO) in Caen [3] were created. Initially, they had to demonstrate to the authorities that their measurements were as reliable as the official ones. To do this, they had to set up a quality assurance system and carry out inter-laboratory tests. The two French non-governmental laboratories were only approved in 1997. Their monitoring services have been extended to include gamma spectrometry analyses, measurements of tritium levels in water, and measurement of radon in buildings. The Umweltinstitut, meanwhile, also investigates GMOs and electro-magnetic fields. This article focuses on ACRO, of which the author is president [4].

Waste

At the end of the 1990s a significant milestone was reached in the recognition of independent monitoring of radioactivity in the environment. This was through the work of the Groupe Radioécologie Nord-Cotentin (developed under the auspices of ASN and managed by IRSN, and in which ACRO participates). For the first time, some 50 experts from all walks of life worked together to try to respond to the concerns raised by an epidemiological study that had revealed an increase in the number of leukemia cases among young people within a 10-km radius of the La Hague reprocessing plant. Community-based sampling (including by ACRO) represented only a small part of the compiled results, but included samples or locations that had been little or never studied elsewhere. The groups' experts acquired new skills in radioecology, modelling, etc., which went beyond simply measuring radioactivity.

Through its direct involvement in monitoring, the public has transformed a purely technical subject into a political one. The result has been greater transparency and better monitoring of the impact of discharges. Since 2010, the National Measurement Network [5] (set up by the health and environment ministries) has been collecting the results of statutory measurements of radioactivity in the environment, and also those of other organizations, including ACRO, and these have all been made available to the public. This development is part of a more general process of democratization of those decisions which impact the environment, facilitated by the emergence of the Internet and marked by two key texts: the Aarhus Convention (1998) [6] and the Environmental Charter which was incorporated into the French Constitution in 2005. Public consultation on technical subjects becomes all the more meaningful when experts can provide a detailed analysis. For this reason, ACRO participates in several institutional working groups: this allows it to better understand the issues and to raise citizens' concerns.

All nuclear facilities, including storage centers, release radioactivity into the environment at varying levels. Incidents or accidents can result in much larger discharges. Globally, the highest radioactive releases in history were caused by the

Algae sampling carried out by ACRO.

atmospheric nuclear tests of the 1950s and 1960s. Many artificial radioelements resulting from these tests are still found in the environment, such as cesium-137, strontium-90, isotopes of plutonium, etc.

During normal operation, the Orano (ex-Areva) reprocessing plant at La Hague has the highest levels of environmental discharges of all the French facilities. For some radioelements, such as krypton-85 (a noble gas) or tritium, separation and disposal are complex. For others, such as iodine-129, which has a half-life of 16 million years, sea disposal is the preferred option. It can be detected in algae all along the coastline of the Channel and North Sea at levels, per kilogram of dry algae, ranging from a few becquerels[a] to a few dozen becquerels near the outflow of the La Hague plant. For tritium, about ten becquerels are measured per liter of seawater.

Fukushima and volunteer samplers

Over the past 30 years, the NGOs have had to adapt to remain relevant. ACRO responds to people's concerns by monitoring radioactivity in the environment through a network of volunteer samplers. This is intended to complement official environmental monitoring.

In 2011, when the "radioactive cloud" arrived from Fukushima and caused great concern, ACRO initiated nationwide fallout mapping based on plant samples. This confirmed that the impact of the accident was very small, but nevertheless detectable. This approach was complementary to that of the Institute of Radiological Protection and Nuclear Safety (IRSN), which was based on highly efficient measurement networks and modelling.

More recently, in 2016, on the occasion of the 30th anniversary of the Chernobyl disaster [7] (30 years is symbolic because it is the half-life of cesium-137), a complementary approach was taken again when mapping residual pollution: ACRO favored a grassroots approach by leaving the initiative to the samplers on the choice of samples and sampling locations, and by forging partnerships with local groups such as mushroom-picking associations. IRSN studied those areas where deposits had been shown to be highest.

Measurements taken by ACRO have shown that all soil samples are contaminated with cesium-137, due both to fallout from atmospheric nuclear tests and the Chernobyl disaster, at widely varying levels. This ranges from a few becquerels to 68,000 becquerels (per kilogram of dry soil) at the Col de Restefond in the French Alps. As far as foodstuffs are concerned, it is, unsurprisingly, mushrooms that remain the most contaminated, at highly variable levels of up to 4,000 becquerels per kilogram for 'sheep's foot' mushrooms taken from Luxembourg. Obviously, in the Ukraine and Belarus, or in the vicinity of the Fukushima power station, contamination levels are much higher and justify the maintenance of exclusion orders.

Following the disaster at the Fukushima power plant, Japan saw the emergence of community measurements [8]. It was the local inhabitants who mapped the contamination, sometimes with the help of local authorities. They soon identified hot spots that had escaped official surveillance. Hundreds of measuring stations were set up by producers, vendors and consumers to monitor food. The numerous controls imply that there is no longer any scandal and internal contamination of the inhabitants via food is very low, if not undetectable. This is very different from the situation in the land contaminated by the Chernobyl disaster, where the main contributor to the dose received is the consumption of contaminated food.

ACRO backed the creation of a laboratory in Japan, Chikurin-sha [9], by providing two gamma-ray spectrometry measurement systems and by training scientists. This was made possible due to a subscription and support from the Ile-de-France region. The laboratory has quickly established links with some thirty

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measuring stations equipped with less efficient but simpler to use equipment, which is appropriate in a post-accident situation (see box). Together, they have developed an online intercomparison system and database [10].

From the measuring crisis to crisis measures

Having a skilled and reputed laboratory, alongside a network of trained samplers, is essential for maintaining oversight and reacting quickly in the event of an incident. The most symbolic case dates back to 2001, following an incident at the La Hague reprocessing plant. As soon as the atmospheric release was reported, local residents were on site taking samples and it became apparent that the resulting release, dominated by the ruthenium/rhodium 106 pair, was in fact greater than the quantity reported. An atmospheric dispersion model showed that the operator had underestimated the quantity released by a factor of 1000. It was ACRO that discovered this error, which was due to a long-standing detection issue. More recently, they have identified plutonium pollution near the plant at levels of sufficient concern that the operator is now required to clean up the contaminated land.

In the event of a nuclear accident, the impact of radioactive releases is of a completely different magnitude. It may justify the long-term evacuation of more than 100,000 people, as was the case in Chernobyl and Fukushima. In addition, people living in contaminated areas must be able to monitor the radioactivity in order to adapt their daily lives. Access to measurements therefore becomes paramount. Independent laboratories and experts can complement the authorities and provide the public with solutions tailored to their problems.

The French authorities now recognize the value of community-based monitoring of radioactivity in the environment, even under normal circumstances. After a possible serious accident, they are counting on the population to take over part of the monitoring. IRSN, for its part, supported the creation of a system which uses Geiger counters coupled to interactive smartphone software and digital mapping to collate, share and use data.

Measuring radioactivity

Small field devices measure the ambient level of radiation, which includes natural radioactivity and possibly an artificial contribution. Some only consider gamma radiation and others gamma and beta radiation. They are especially useful in the event of a severe accident, with sufficiently high pollution levels that induce an increase in detectable ambient radiation compared to variations in natural background noise. They do not detect the impact of normal releases from nuclear facilities.

In order to distinguish artificial radioactivity from natural radioactivity in environmental samples, the radiation must be separated depending on its energy using a gamma spectrometer. Gamma radiation can be identified using different types of detector. The simplest, based on a NaI crystal at room temperature, have a fairly limited resolving power and a detection limit of about ten becquerels per kilogram. They are useful after a nuclear accident involving significant levels of a limited number of persistent radioelements. For best performance, a liquid nitrogen-cooled germanium semiconductor crystal is generally used. This type of detector, which is more expensive and complex to use, has sufficient resolution to distinguish many radioelements and a detection limit of less than one becquerel per kilogram. It is therefore appropriate for detecting the impact of routine releases. The identification of pure beta emitters, such as tritium, is more complicated because the energy of the electron is not unique. A chemical separation must therefore be carried out in order to be able to distinguish possible pollutants.

Although the Japanese authorities are still struggling to recognize the importance of these community measuring systems, it is undeniable that they have contributed to a better diagnosis of the impact of discharges. Accessing the data allows the people concerned to have a partial answer to their questions, but this is not enough. Japan, for example, lacks a strategy for compiling and analyzing data in order to extract additional information.

Community radioactivity measuring still has many days ahead of it and should be extended to other types of pollutants. The publication of the Houllier report [11] on participatory science and research in France showed the interest and richness of this approach. Whilst non-governmental organizations may have brought about the sharing of expertise as far as monitoring radioactivity in the environment, there is still scope for greater research collaborations in this field. ▮

a. Becquerel: number of radioactive disintegrations per second in a given quantity of material.

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