ecological aspects of radiation protection

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For the ecologists of the 1960s, the presence in the biosphere of fission products originating from nuclear explosions provided a wealth of opportunity for observation and experiment, for they were able to trace the paths of numerous radioactive substances in the atmosphere, immediate environment and eco-systems, and to determine the way in which these substances were metabolized in living organisms.

Moreover, nuclear techniques such as the use of radioactive tracers, autoradiography and neutron activation afforded a means of determining the mechanisms by which the biologically significant radionuclides take effect and the processes by which they are transferred.

Because of the comprehensive information that it can provide for analysis, radioecology has risen above its status as a pure science and has become an integral part in the planning of monitoring programmes for nuclear sites. Radioecology is thereby able to make an essential contribution to the attainment of one of the basic objectives of radiation protection, namely the elimination or control of the hazards that human beings and their environment are likely to be face through the peaceful applications of nuclear energy. The headway made in radioecological studies and research has been great; knowledge is being amassed by leaps and bounds despite the difficulties faced and the intricacy of the problems involved. As a consequence, radioactive contamination of the environment is certainly one of the best understood types of pollution, and probably one that it has so far been possible to anticipate and control under optimum conditions and with the most gratifying results.

But the growth of nuclear technology, considered essential for progress, will mean in the years to come a rapid increase in the number of nuclear power stations, the number and capacity of fuel reprocessing plants, and the amount of radioactive waste; consequently the potential sources of risk will be all the greater.

The problems that we have to face in the light of this expansion, particularly in the European countries, are not only economic – they are also ecological; the future of power programmes based on the use of nuclear stations may depend on finding solutions that are compatible with the protection of human health and of the environment.

The main tasks of radioecology, which has now become an indispensible tool in radiation protection, can be outlined as follows:

– To draw up an "ecological inventory" and analyse the eco-systems of a site or a region where nuclear activities are planned, thereby providing criteria with which to make an objective evaluation of the hazards inherent in such activities for human beings and their immediate environment;

– To provide permanent and systematic "ecological surveillance" of the site as an integral part of the radioactive contamination monitoring programme; and

– To make preparations, on an ecological level, for any action that might be needed in the event of an unscheduled or uncontrolled release of radiactivity.

Ecological inventory and analysis

The "ecological inventory and analysis" consists of a co-ordinated series of studies aimed at estimating the risk of irradiation of human beings and their environment which could conceivably result from the nuclear activity under consideration.

These studies should also help to establish the maximum quantity of radioactive material that may be released without any deleterious effect on human beings or their environment. More specifically, they should include theoretical analyses of the ecological consequences of the reference accidents envisaged in safety reports.

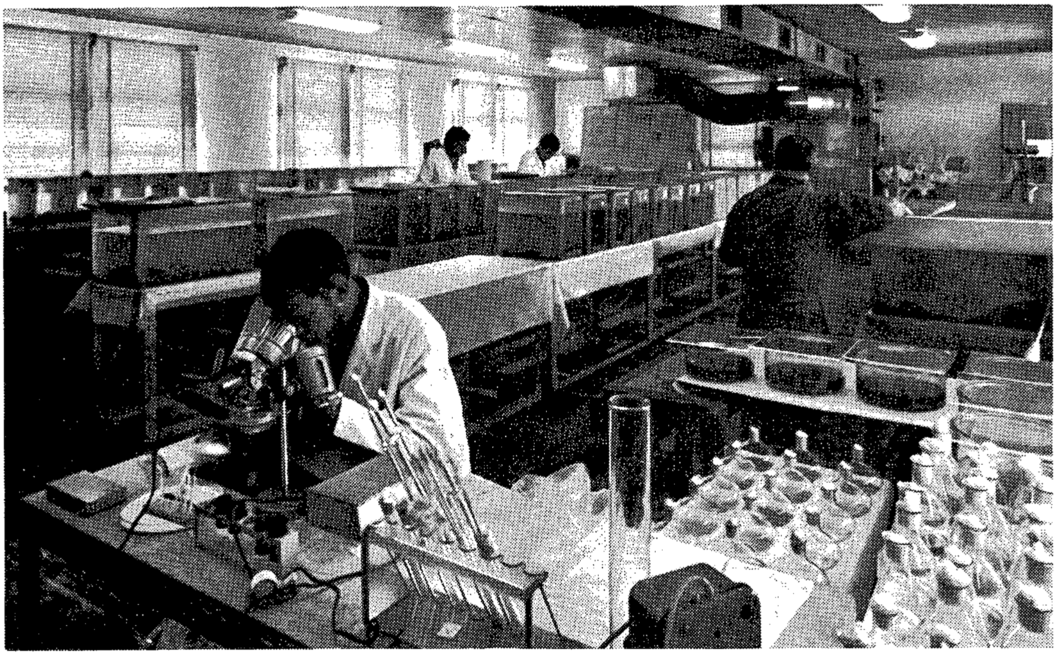
This inventory and analysis may be decisive in political and administrative decisions affecting the selection of sites, the issue of operators' licences, or the specification of conditions for construction and operation. Hence this phase is an important one, occurring relatively early in the planning and commissioning of a nuclear facility.

In the more industrialized countries, with their very dense populations, the sites available for nuclear facilities can be decided on well in advance; indeed it is usually possible to discern from the start which area or river bank, which lake-shore or sea coast will be used for the building of power stations or other major nuclear facilities in the coming decades. Hence it would be wise to begin right now with ecological studies based on the predicted expansion of nuclear activities, to determine, with reasonable approximation, the amount of radioactive material that can be accepted by various regions of the atmosphere, hydrographic basins, lakes or coastal areas that will be either directly or indirectly affected by nuclear projects.

A radioecological study of this kind should not be limited to one site or to the territory of one country; it must take a medium- or long-term view of the pollution danger and will often have to cover, in Europe at least, several countries. A programme of this kind should not be unduly difficult to carry out because the techniques and concepts of radiation protection and radioecology are by now fairly well standardized and clearly defined on an international level.

The methodology adopted in radioecology is based on the determination of various influential parameters, starting with the source emitting the ionizing radiation and ending with the receptor – human being, animal or plant – liable to experience its effects; these parameters govern, qualitatively and quantitatively, the possible transfer to human beings of the radioactivity released into the environment.

To introduce a certain simplicity into a complex type of research – which may even seem difficult out of all proportion owing to the number and diversity of the parameters involved – we apply the concepts of critical path of transfer and critical group of the population. Some radionuclides and some critical paths are more important or more meaningful than others,



The laboratory of marine radioecology, La Hague, France. Photo: Commissariat à l'énergie atomique

from the standpoint of radiation protection, and should be given preferential study. Examining them, we will also identify the so-called "critical" population groups which, by reason of their geographical location, dictory habits or age, may be assumed to be more exposed than other individuals, and represent populations sufficiently uniform to be studied collectively from the standpoint of their exposure to radiation [1].

An instance familiar to radiation protection specialists [2], which has since come to be regarded as a classic illustration of this approach, is the accidental release at the Windscale nuclear centre in the north of England.

An approach of this kind also permits us to study the capacity of a given environment for the acceptance of radioactivity, which could be defined as the quantity of radioactive matter, expressed in curies or fractions of curies per unit time, that an environment can accept continuously without an exposure to radiation eventually resulting that would be unacceptable from the standpoint of health or ecology. This capacity is based on the radiation dose limits as applied to the population group considered critical and is fixed by the national or international authorities on the basis of ICRP recommendations [3]. Depending on the complexity of the environments under consideration, use is made of either empirical and semi-empirical formulae, or else models which have been developed from analyses of systems.

The maximum capacity for acceptance of radioactivity should not be confused with the release levels that may be prescribed for a given facility. It must be recalled that the dose limits for the population recommended by ICRP are levels which must never in principle be exceeded; on the other hand they must certainly not be reached in every instance, since another fundamental principle of radiation protection is that the exposure of a population to radiation should be kept to a minimum. Hence every release of radioactive material must be kept to the minimum that is compatible with available technology and is economically acceptable. These levels are established by the competent authorities, who take into account the technical, economic, social and even psychological aspects of the matter. They may constitute a variable fraction of the radioactivity capacity limit.

Arrangement of "ecological surveillance" of a site

"Ecological analysis" also indicates the lines along which efforts should be directed in order to organize effective surveillance of the radioactive contamination of a given environment. The ecological conditions prevailing at a site must subjected to careful scrutiny right from the moment the pollutants, even in small quantity, start to be deposited here. Surveillance programmes require systematic monitoring of pollution levels and an evaluation of doses and dose commitment relating to members of the population.

Preliminary ecological studies afford a means of selecting elements and products (biological indicators, foodstuffs, etc.) and deciding the form of measurement suitable for both prompt and efficient control. British authors apply in this connection the concept of the "derived working limit" (DWL), which fixes environmental contamination limits (as a function of radioecological data) at levels below which there is no chance of any significant exposure of human beings to radiation.

At present radioecological studies are included in the monitoring programmes carried out near nuclear sites in all countries, but it is most likely that this research will take on a new dimension in view of the interest now being shown in safeguarding the environment. One cannot be sure that the safety of human beings will remain the only concern; the day may well be coming when ecologists, worried by the effects which radioactivity might have on living systems (even ones not directly linked to the human food chain), will consider that such effects require limits on the amount of radioactive material that can be released. In any event, one of the main topics of present-day ecological research is the biological effects of low-activity effluents.

Another problem of growing concern is how to control the thermal effects of nuclear as well as non-nuclear thermal power stations, which can influence the ecological equilibrium of rivers or lakes through the discharge of their coolant water. Heat load (thermal pollution) is now becoming one of the parameters to be considered in connection with radioactivity acceptance.

Unscheduled or uncontrolled releases

In the case of unscheduled or uncontrolled releases of radioactive material into the environment, ecological considerations play a prominent part in risk evaluation, in the planning of countermeasures, in judging the most suitable moment for implementing them, and in the determination of action levels or intervention thresholds. The latter will be all the easier to establish if appropriate analyses and ecological studies are carried out in good time and geared to the theoretical accidents envisaged by the planners of the project or by the competent authorities.

A final problem of some seriousness for the more industrialized countries is the search for suitable sites for final disposal of high-level radioactive wastes, particularly wastes from fuel reprocessing plants. Various solutions have been proposed and have been under study for some years. Among the projects under consideration is the use of salt mines. This can be regarded as an acceptable arrangement, provided all ecological and health requirements are satisfied.

Conclusion

Radioecology has a vital rôle to play in attaining the basic aims of radiation protection, especially now that comprehensive protection of the environment against pollution has become a matter of major concern not only to scientists but to national and international authorities as well. Absolute containment of the radioactive materials that are liable to be released by nuclear facilities is not possible. The growth of nuclear technology is assumed to go hand in

hand with a higher standard of living, and the use of nuclear plants for generating electricity represents a solution which is acceptable technically as well as from the standpoint of environmental protection.

On the technological level, we must employ the "most effective practical means" to reduce the size of waste releases so that they constitute no more than a fraction of the capacity that a given environment can accept. Evaluation is based on the concept of dose commitment or committed injury, which indicates the order of magnitude of all the effects of a pollutant on the receptor. The development of methods and the formulation of principles similar to those used in radioecology, but applied to non-radioactive pollutants, will not only help us to be more objective in comparing the hazards inherent in various forms of energy production, but also to cope more effectively with the impact of pollution on the environment.

Radioecology and radiological protection fit in exemplary fashion into the research and action programmes which modern society, anxious to safeguard health, protect the environment and improve the quality of life, considers it essential to promote in solutions to the problem of the environment – in keeping with the scientific spirit and acceptable in both the economic and human contexts – are to be found.

REFERENCES

[1] See Publication 7 of the International Commission on Radiological Protection, "Principles of environmental monitoring related to the handling of radioactive materials", Pergamon Press, Oxford (1965).

[2] In this example ruthenium-106 is the critical radionuclide. The critical path ends with consumption of laver bread, which is made with algae collected along the coast of the Irish Sea where the release took place. The critical group here is the Cornish population, which consumes large quantities of this food product.

[3] See Publication 9 of the International Commission on Radiological Protection, which recommends, among other things, a limit of 500 mrem per year for individual members of the population, and a limit of 5 rems in 30 years for the population as a whole, allowance being made for the genetic risk.

A technician prepares samples taken from freshwater fish for analysis of their uptake of radionuclides in a contaminated environment. This work is being done at the Cadarache research centre, France. Photo: Commissariat à l'énergie atomique