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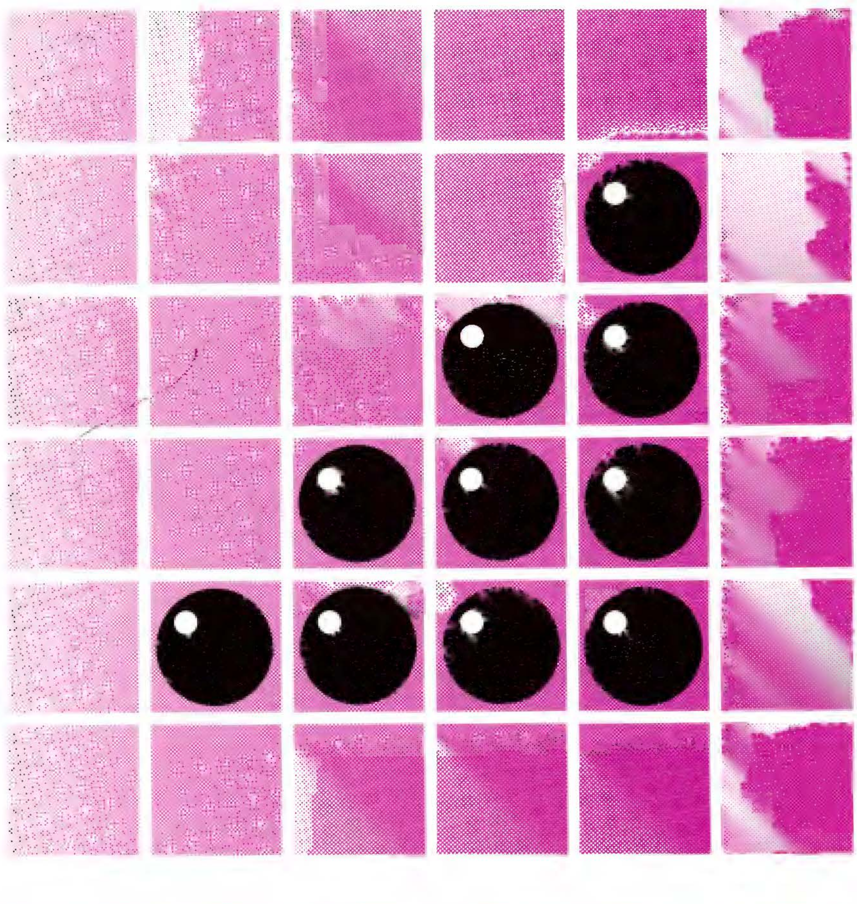
NUCLEAR SAFETY IN THE EUROPEAN COMMUNITY



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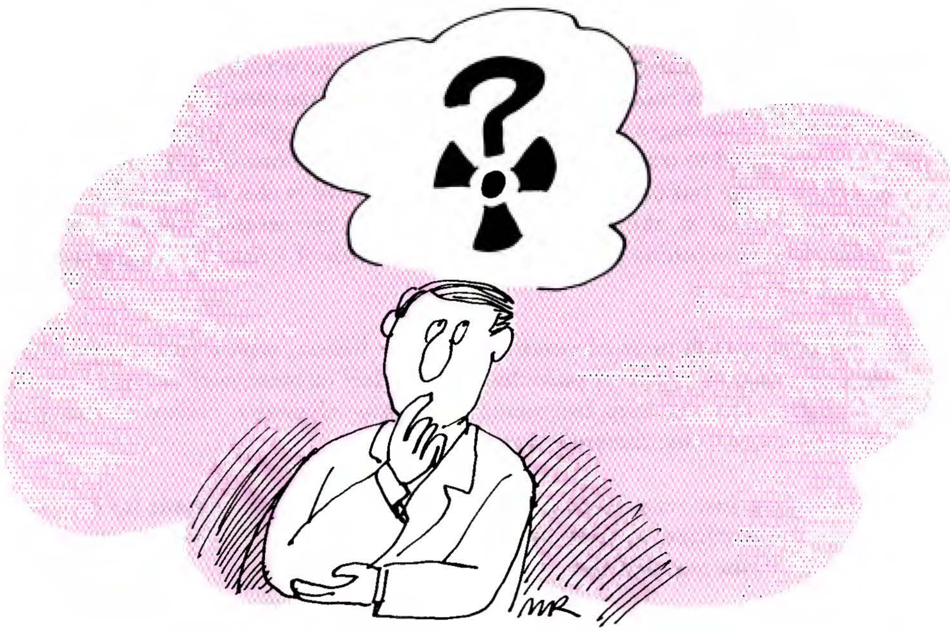

Nuclear safety is one of the goals of the Treaty signed in Rome in 1957, establishing the European Atomic Energy Community (Euratom). It requires the Member States to ensure that the peaceful uses of nuclear energy have no adverse effects on man or the environment.

This brochure describes the European Community's efforts to achieve this objective.

Measures designed to confine the uses of nuclear energy to peaceful purposes and to prevent its application for violent or illegal ends are not covered in this brochure, however. Though unquestionably no less important than protecting man and the environment, such measures are of an entirely different nature and require a correspondingly different approach.

Nuclear energy

With one exception, each atom of every chemical element has a nucleus made up of a certain combination of two types of particles, protons and neutrons, [1] held together by a 'binding energy'. The exception is ordinary hydrogen, whose nucleus consists of a single proton.

Reactions taking place in the nucleus may release some part of this binding energy.

The nuclei of some elements, known as radioactive elements, change their composition spontaneously by the process of 'disintegration', in which they release one or more particles and emit radiation. In this way, radioactive elements undergo mutation in one or several stages into stable elements. For example, a series of 16 disintegrations is required to transform uranium into lead. The rate of disintegration differs widely from one radioactive element to another and is characterized by the element's 'half-life', that is, the time it takes for half of the atoms present to disintegrate. This may be anything from less than a millionth of a second to thousands of millions of years.

Another kind of transformation occurs in nuclear fission, where the heavy nuclei, consisting of a large number of particles, of a 'fissile' element such as uranium are split artificially. The resulting fragments are lighter elements, called 'fission products', which are as a rule themselves radioactive.

A third type of nuclear reaction is the 'fusion' of two light nuclei made up of a very small number of particles, to produce a single, heavier nucleus. This reaction takes place naturally in the sun and the stars.

Man is able to trigger such a reaction to produce the explosion of a hydrogen bomb. Experiments are under way to harness nuclear fusion to provide a useable form of energy.

The energy released by nuclear reactions appears in two forms: heat and radiation.

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[1] Some of the terms commonly used in the nuclear field are defined in the Glossary, at the end of the brochure.

Radioactivity

Nuclear reactions produce various types of radiation: the main ones being alpha, beta and gamma radiation, found in different proportions depending on the circumstances.

The first two come under the general category of corpuscular, or particle, radiation. Alpha radiation is an emission of particles made up of two protons and two neutrons, that is, a helium nucleus. It has a low penetrating power and is therefore easily stopped and has effect only over very short distances. Beta radiation consists of electrons with somewhat greater penetrating power and range than alpha particles. The neutrons produced as a result of nuclear fission or fusion reactions come under this category.

Gamma radiation is a form of electromagnetic radiation, in which energy quanta or 'photons' move in accordance with the laws of wave mechanics and, in a vacuum, with the speed of light. The various types of electromagnetic radiation are distinguished by their wave length. Gamma rays have a very short wavelength and, since the one is inversely proportional to the other, a very high frequency and considerable penetrating power. Physically, they are similar to high-energy X-rays, the difference lying in their origin, in that X-rays are not produced by nuclear reactions.

The various types of radiation have different intensities and energies according to the reaction and the nucleus from which they originate.

In addition to the radiation resulting directly from a nuclear reaction there is an induced or secondary form of radioactivity resulting from the capture of radiation or particles — especially neutrons — by certain substances which are thereby 'activated' and themselves become sources of radiation, particularly of beta and gamma rays.

Another important characteristic of nuclear radiation is that it is 'ionizing', that is, it gives rise directly or indirectly to the formation of ions — atoms or groups of atoms with an electrical charge — in the irradiated material.

The ionization of the atoms or molecules in the cell tissue of living organisms exposed to radiation has biological effects.

Uses of radioactivity and nuclear reactions

The range of uses nowadays is considerable: radiation is used for widely differing purposes in medicine, manufacturing industry, agriculture and research, while the heat released in nuclear reactions is most commonly used for generating electricity.

Using radiation

Radiation is used in medicine in a variety of ways as a tool of examination and also as an aid to diagnosis; for example, radiography and radioscopy and tests and analyses using radioactive molecules as markers or tracers. Radiation is also used for therapeutic purposes, such as to destroy cancer cells.

Industry uses radiation in many different ways, including the inspection of metal components by gammagraphy, measurement and control systems, the initiation or acceleration of certain chemical reactions, facilitating operating procedures and the sterilization of various products.

Ionizing radiation is also used to sterilize and preserve certain foodstuffs and to kill germs and parasites.

Most of these applications are also employed, along with more specific uses, in research.

The radiation used comes from the radioactive isotopes of various elements: cobalt, phosphorus, iodine, gold, etc. Isotopes are different forms of the same element, with differences in the numbers of neutrons in their nuclei: they all have the same chemical properties but their physical behaviour, especially from the nuclear point of view, differs; thus some isotopes of a given element are radioactive whereas others are stable. The radioactive isotopes used in the fields mentioned above are by and large artificially created specifically for a given purpose.

Generating electricity from nuclear energy

The heat released in nuclear reactions — fission or fusion — can theoretically be used directly, for example in industrial plant or district heating systems.

At present, however, its practical use is almost entirely limited to generating electricity in power stations equipped with nuclear fission reactors, which are used in the same way as the steam boilers in conventional power stations fired with fossil fuels: they create steam which drives the electrical generators.

Nowadays, the most common types of nuclear reactor are fuelled by slightly enriched uranium. Enrichment consists of raising the proportion of the uranium isotope whose nuclei are best suited for fission but are present in too low a concentration.

This isotope is characterized by its mass number 235; the other isotope present having the mass number 238. Fuel elements containing the low enriched uranium are arranged in the reactor core; they are encased to prevent the dispersion of substances, especially fission products, during operation.

Fission is induced by a neutron penetrating the nucleus of uranium-235. The neutron triggers a chain reaction which is maintained by the neutrons produced by each nuclear fission reaction. The process is held in a state of equilibrium by means of control rods. Since these rods are made of neutron-absorbing material, they are also capable of stopping the process.

In the type of reactors most commonly used today, the heat generated by the reaction is removed from the core by ordinary or 'light' water, as distinct from 'heavy' water whose hydrogen nuclei are made up of one proton and one neutron. This light water serves at the same time as a 'moderator', whose function is to slow down the neutrons and thereby render them more likely to cause fission of the uranium-235 nuclei.

After a certain time in operation, the fuel elements become exhausted or 'spent' and they are removed from the reactor and replaced with fresh elements. As a rule, they are then reprocessed to recover the remaining uranium, still partially enriched with uranium-235, and also the plutonium which has been produced by neutrons captured in the nuclei of uranium-238. Some isotopes of this artificial element plutonium are themselves fissile, although under different conditions to uranium. Reactors designed specifically to use plutonium are currently being perfected.

Nuclear power plants are now in operation in a number of countries, including several European Community Member States. Others are under construction or planned. The proportion of electricity produced by nuclear energy has grown in recent years and, in view of its economic advantages, will continue to grow in the future. The economic advantages are becoming greater as the prices of oil and fossil fuels rise. Also, and this is particularly relevant for the European Community, nuclear energy increases the security of energy supplies, since energy sources are diversified and dependence on oil imports is reduced.

While nuclear energy already supplies one fifth of all the electricity consumed in the Community, this proportion is appreciably higher in those Member States which have embarked upon substantial nuclear power programmes, such as Belgium, Germany, France and the United Kingdom.

A number of new industrial activities have emerged based on the successive operations that comprise the nuclear fuel cycle: extraction and processing of uranium ore, production of enriched uranium, manufacture of fuel elements, operation of reactors, reprocessing spent fuel, and the treatment and management of wastes. All of these involve the handling of radioactive substances of low or high activity, depending on whether they precede or follow the reactor in the nuclear fuel cycle.

Products transported from one installation to another are also radioactive as are the wastes produced in each step of the cycle, especially the fission products separated out in reprocessing the irradiated fuel. Finally there is the radioactivity always found in power stations that have reached the end of their operational or economic lifetime and have to be decommissioned and dismantled.

Radioactivity therefore presents the nuclear industry with a number of problems, associated with the need to ensure the protection of workers, the general public and the environment.

Effects of radioactivity

The evolution of life on earth from the first living cells to the emergence of modern man has taken place in a natural environment incorporating a certain degree of ambient ionizing radiation. This radiation comes from cosmic rays, deposits of radioactive ores, and radioelements in nature in general and in living tissue particularly. In the course of his evolution, man has adapted to this natural background radiation.

At the beginning of this century, artificial radiation was produced by X-rays and this in turn led to the discovery of the potential hazards with the first reported cases of erythema, a skin inflammation which can lead to malignancy.

The subsequent extraction, scientific handling and industrial and therapeutic use of radioactive elements, especially radium, exposed some of the research scientists and workers to radiation doses whose effects were rendered all the more formidable by the fact that at that time the dangers were barely suspected.

Shortly before the Second World War, science revealed to mankind a number of ways of using the energy released by nuclear fission.

The first applications were military: the atom bombs which fell on Hiroshima and Nagasaki in 1945, the A-bombs and H-bombs which various countries exploded and still explode in tests and the atomic weapons being manufactured and stockpiled by the nuclear powers. The radioactive substances released into the atmosphere as a result of nuclear weapons testing, as well as the industrial activities associated with the manufacture of bombs, have led to an increase in the level of radiation in the environment.

Fortunately, since the end of the Second World War, the peaceful uses of nuclear energy listed above have gained more and more in importance.

A number of man-made sources have been added to the natural background radiation, causing an increase in the level of radiation to which man is permanently exposed.

Living organisms have, admittedly, been exposed to ionizing radiation for aeons, but it has only been since the discovery of radioactivity and developments that have raised the natural radiation level that any attempts have been made to look into the biological effects.

Our knowledge of these effects has grown significantly. We now know that ionization is responsible for the effects observed but, as to how it produces these effects, we still frequently have to fall back on pure hypothesis.

One obvious but none the less important characteristic is that radiation can neither be seen nor heard; its detection therefore requires special instruments.

There are two distinct categories of possible effects of ionizing radiation. Some of these effects are said to be 'stochastic', or influenced by chance, since in their case the laws of determinism do not apply absolutely; in other words, no rigid causal relationship can be established between exposure to radiation and some possible effect. Other radiations are 'non-stochastic'. They may for example cause a cataract to form on the lens of the eye, in which case the effect appears only after a fairly high dose of radiation but once this threshold is reached, the damage increases in proportion to the intensity of radiation received.

In the case of stochastic effects, particularly as regards malignant tumours and hereditary cancers, it has not yet proved possible to identify such a threshold. On the other hand, neither, the degree of severity of these effects, if they should occur, nor the time they take to manifest themselves seem to depend on the level of radiation dose.

Knowledge of the effects of small doses of radiation can therefore only be obtained by statistical methods, which presumes observation of a large number of cases. Studies of population groups exposed to different levels of natural radiation has not permitted any conclusion, positive or negative, to be drawn about dose-effect relationships.

Of course survivors of the Hiroshima and Nagasaki explosions have been and still are being studied and the results compared with those for control groups. But this is a special case: a single, instantaneous but intense exposure to radiation. Other groups of people, irradiated for therapeutic purposes, have also been examined, but again, the doses involved were huge and there are relatively few such groups.

While there are more cases of cancer and leukaemia in these groups than in appropriate control groups, with our present state of knowledge it is impossible to say with certainty, given a particular person and a given dose of radiation, whether a cancer will develop, and if it should, whether it results from the exposure to radiation or from some other cause. It is, in effect, impossible to discriminate between artificial radiation and other competing causal factors, such as natural background radiactivity, air pollution, chemical pollution and individual situations.

There is a further distinction in the biological effects of radiation, according to whether they attack the cells of the reproductive organs or of other organs or tissues. The first type are called 'genetic' effects, since they cause hereditary damage involving mutations. The second type, 'somatic' effects, can cause cancer or leukaemia.

The body is made up of many different types of cells, which have differing sensitivities to ionizing radiation. The sensitivity is higher in rapidly dividing cells. The cells of the muscles or of the central nervous system reproduce slowly and are relatively resistant to radiological effects. The blood-forming organs and the reproductive organs, however, form new cells continuously and are therefore much more sensitive to radiation.

Radiation-damaged cells have a certain capacity for spontaneous repair, although we do not yet know how this works. Nor do we know whether the organism or specific organs can develop a tolerance to radiation. There has as yet been no scientific proof of the results of studies indicating that small doses of ionizing radiation have beneficial effects in living organisms, producing for example greater resistance to disease and faster healing.

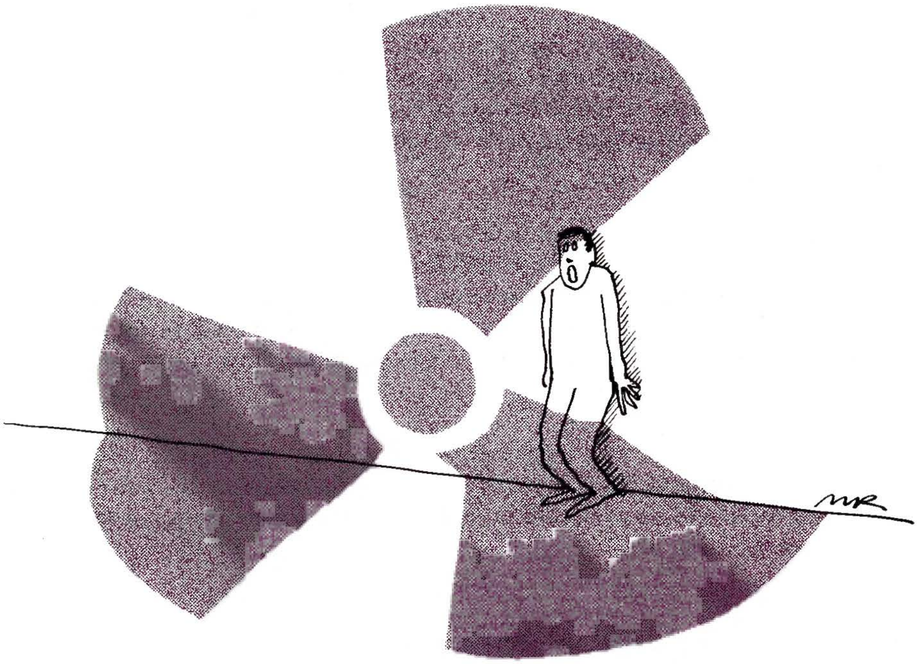
It is also worth recalling that at one time the radioactivity of certain table waters was held up as one of their qualities and that even today some thermal spring resorts still boast of the radioactivity of their waters in their publicity.

The problem of risks

The increase in radioactivity and the greater number of opportunities of being exposed to radiation as a result of the expansion of all kinds of nuclear activities require precautions to be taken to reduce the risk to those who may be exposed to radiation in their work and to ensure the safety of the general public and of the environment.

Dangers to workers

All workers in industry, the medical services, research centres or elsewhere who handle substances or equipment emitting ionizing or other harmful forms of radiation are at risk.



The danger of occupational disease or of an accident at work is, of course, not restricted to nuclear activities. In industry alone, it is obvious that hazards are to be found in all sectors in varying degrees. In energy, coal mining has a particularly high risk of accident and occupational disease.

Almost every type of work carries risks of disease or accident for the workers involved. These risks can never be entirely eliminated. This poses a problem that is both philosophical and moral.

In principle, every illness and injury, every permanent disability and even more so every premature death is unjustifiable and to be avoided.

In our society, however, it is quite acceptable for someone to sacrifice his life to save others — the obvious examples being wars or other disasters, where such sacrifice is even glorified. Equally, nobody would seriously consider stopping people from voluntarily risking their lives in leisure pursuits such as climbing or yachting, or in sports. On the other hand, it seems less acceptable for professionals, such as tightrope walkers, bullfighters, racing drivers and the like to risk their lives to earn a living by providing a spectacle.

The problem presents itself in a different manner in the case of activities contributing to the economy. On the one hand, the ethics of our society do not accept that the production of goods and services for the mass of the population should involve physical harm for those directly involved in the production. On the other hand, the general public does not appear prepared to forgo the goods and services whose suppliers are at risk.

The only solution, therefore, is to take suitable action to limit as far as possible the occurrence of occupational accidents and diseases. These precautions can take various forms. The worker himself can be equipped with protective helmet, goggles, special clothing and so on. Machinery and equipment can be improved to make it less dangerous to operate. Certain particularly dangerous production processes can be curtailed or stopped altogether.

In nuclear activities there are all the usual accident risks — falling objects, fire and so on — but what distinguishes this sector is the presence and nature of ionizing radiation. Workers have to be protected from the hazards arising from radiation and its special characteristics.

Hazards to the general public and the environment

Such hazards are not peculiar to the nuclear industry. Most human activities involve risks for man and his environment. Accidents like major oil spills and the release of dioxin at the Seveso chemical plant in Italy are not easily forgotten. The normal operation of many industrial plants also brings with it damage to the environment and to the biosphere and, in the long term, threatens the very existence of mankind. Smoke and dust from industry, exhaust gases from vehicles, agricultural pesticides, etc. give rise to such effects as air pollution, acid rain, dying forests, acidification of lakes and other surface waters, and so on. The list of pollution and its harmful effects is long.

A large part of this pollution can be attributed to energy production. To give only a few examples: power stations fired by fossil fuels — coal, lignite, fuel oil, etc. — release considerable quantities of harmful gases and solid particles into the atmosphere; the combustion of coal also gives rise to small emissions of uranium and its radioactive derivatives (radium, radon, etc.). All these emissions have damaging effects both on the environment and on public health.

The use of energy likewise has its risks: gas explosions and asphyxiation caused by gas, electrocution and so on — not to mention air pollution in the home.

As for accidents, it is remarkable that a renewable and reputedly inoffensive energy source has so far caused the greatest damage. The bursting of dams built to contain water to power hydroelectric stations is in no way exceptional and a sad record is held by the 1979 breach of the Gujerat dam in India, which caused the death of 15 000 people.

As regards the risks of radiation, some of the exposure to which the public is subjected does not come from the nuclear industry at all. The radioactive substances emitted with other pollutants from conventional power stations has already been mentioned above. Certain building materials also emit radiation or give off radioactive substances, especially radon. This exposure, together with that from natural background radiation and from nuclear activities, is cumulative in its potential effects.

One of the nuclear activities involved is radiodiagnosis, a highly significant source of exposure to the patients involved, but whose usefulness is never challenged. Since examinations of this kind are being carried out increasingly frequently, rules have been devised to limit them to an essential minimum, to minimize the doses involved and to ensure that examinations are carried out by qualified medical staff.

Of the risks arising directly from nuclear activities and in particular from the nuclear industry, one can be ruled out entirely: there is nothing in the design of a nuclear reactor or in the nature of the fuel it uses that could ever cause it to explode like an atom bomb. The fuel used in nuclear reactors is enriched to between 3 and 5% whereas a nuclear explosion requires uranium of about 90% enrichment.

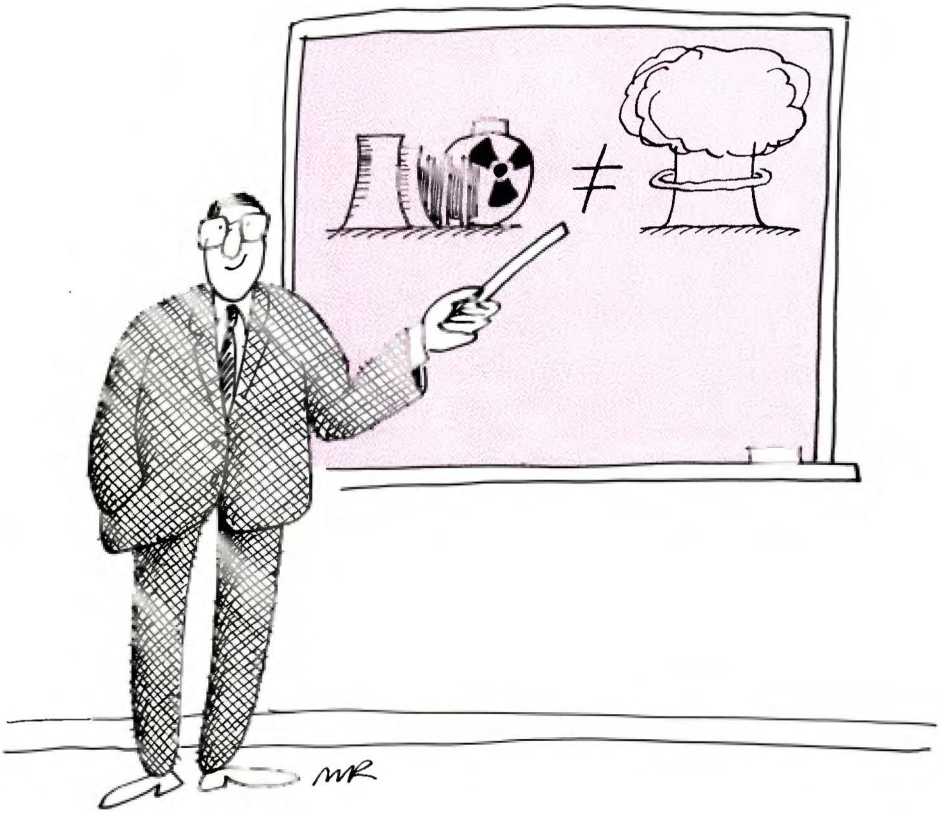
The effluents produced in normal operation of nuclear power plants, that enter the atmosphere and surface waters contain only very small amounts of radioactive materials.

The radiation dose emanating from these wastes corresponds to about 1% of that from natural background radiation.

No matter how strict the precautions might be, an equipment failure or human error — or a combination of both — cannot be completely ruled out and provision is made to limit the consequences.

The transport of radioactive materials as of a number of other products also carries risks which need to be kept within certain limits.

Radioactive wastes produced by nuclear activities have to be disposed of in such a way as to ensure that they remain harmless to man and the environment over the long term. In view of the very long radioactive half-lives of certain nuclear wastes, special techniques are necessary for their processing, management and final storage. Other wastes and products from conventional industry such as arsenic and dioxin, cause comparable disposal problems.



Finally, strict rules have to be laid down to determine what is to happen to nuclear installations that have been taken out of services.

The role of the European Community

The desire to create safety conditions to eliminate hazards to life and public health is expressed in the preamble to the 1957 Treaty of Rome, in which the European Atomic Energy Community (Euratom) Member States declared their intention to create the conditions necessary for the development of a powerful nuclear industry.

The very nature of the safety problems involved, even more than the legal regulations, justifies the responsibilities that the Community institutions have assumed in the nuclear field.

The Community's nuclear industry must not, any more than any other economic activity, be the object of discrimination on a national basis. Ensuring safety brings with it obligations and financial burdens for the companies concerned. It is therefore appropriate that the safety restrictions governing the construction and operation of nuclear installations should conform to the maximum possible extent to common guidelines.

Emissions of radioactive substances do not stop at national boundaries any more than do other forms of air or water pollution. The problem is all the more acute since in an electricity grid it is technically justifiable to build a number of power stations — especially nuclear power stations — near borders and on watercourses that cross borders.

It is the task of the European institutions, particularly the Commission, to establish and apply a common safety policy in order to protect the health of the public and of the workers involved.

This policy comprises two separate areas.

The first chiefly concerns the nuclear industry. Here efforts are being made to improve the design of installations and the various stages of operation, in order to keep the risk of exposure to radiation to a minimum and to prevent as far as possible the escape of radioactive substances and contamination of the air, soil and surface and ground waters. These efforts to ensure adequate technical safety thereby increase the safety of workers and the public and help conserve the environment.

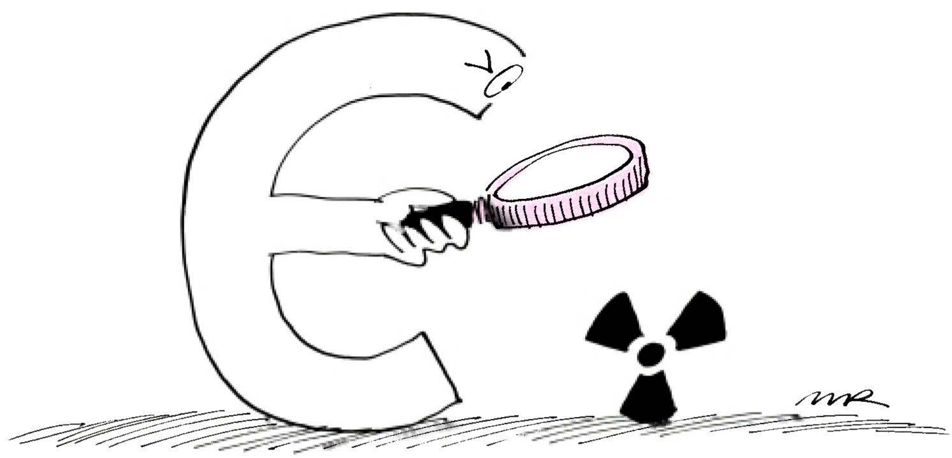
The second area concerns radiation protection. This is not confined to nuclear energy but extends to all activities where ionizing radiation is present. Protective measures are taken in the operation of installations to minimize the risk of exposure of workers and the public at large to radiation which cannot be eliminated completely, and the contamination of air, soil and water. The duration of exposure to radiation is limited, close approach to radioactive emitters is avoided, shields or protective barriers are interposed to absorb the maximum amount of incident radiation. contamination of the environment is monitored and radiation doses received by the public are evaluated.

These measures also cover malfunctioning of installations. The consequences and effects of the exposure of man to radiation and a systematic response to these problems are the subject of the Community's Radiation Protection Research Programme.

Different regulations apply to the protection of workers and the general public against radiation, but all are based on common principles.

One of these principles is particularly important: the linear extrapolation of the dose-effect relationship observed for major exposure to low level exposure. This means that as a general rule, the risks are regarded as strictly proportional to the doses received, even for doses less than those received from natural background radioactivity. Although this is a hypothesis that has yet to be proved, it is accepted since it offers a maximum safety margin.

Community policy on nuclear safety comprises in the main support for research and the implementation of regulatory measures. Research is aimed at a better understanding of the effects of ionizing radiation, how and in what way it takes effect and what protective means can be devised. The results of research work are made available to all interested parties in the Community. Regulatory measures are based directly on the latest research findings so that the safety of the public and the protection of the environment can be ensured and steadily upgraded.



A. Safety in the nuclear industry

All industrial activities are subject to special limitations arising from the techniques applied; these limitations become even more restrictive as time goes by, as closer concern is taken about living conditions now and in the future and therefore with conservation of the environment.

The specific limitations affecting the nuclear industry are due to the presence of radioactivity and heat. In a reactor, for example, the chain reaction can be stopped in a moment but heat sources remain in the core and this heat has to be conducted away long after shutdown. This combination of radioactivity and heat also has to be taken into account in the transport of radioactive materials and in the disposal and storage of radioactive wastes.

To counter these specific problems, the European Community concentrates on the promotion of research and technological development, on stepping up the exchange of information between the groups concerned and on bringing national requirements and criteria closer to the principles on which appropriate solutions can be adopted.

(a) Safety of nuclear equipment

The increased use of nuclear energy makes it necessary to have safe and reliable installations that are as little prone to breakdown and accident as possible. This requirement is not exclusive to the nuclear industry, it is essential to the efficient and economic operation of any industrial equipment, and to avoid risks to workers and the general public.

Nuclear reactors and other nuclear equipment must, however, not only be safe in normal operation but also in all potential emergencies: earth tremors, accidents in adjacent conventional equipment (such as an explosion in a chemical factory), floods, air crashes, and so on.

In order to ensure an adequate degree of safety in all these situations highly reliable techniques and equipment have to be used, the most advanced safety devices have to be built in and nuclear installations have to be located at sites where there is only a low risk of natural or man-made disasters.

With regard to technical safety in normal operation, nuclear installations are largely constructed with conventional building materials — concrete, steel, etc. — and for the most part use traditional fittings: pipes, pumps, pressure vessels, etc. Ensuring nuclear safety therefore depends to a large extent on the quality of the conventional materials used. In the nuclear sector, very high quality standards are set compared with the rules laid down at national level for the more traditional industries.

One additional feature of the nuclear sector is the way in which the safety assessments that all installations, especially nuclear power stations, have to undergo, are carried out.

Apart from the normal requirements of safe and sensible design and construction and operation in accordance with strict quality standards and technological practices, special safety systems are necessary to prevent or minimize the damage resulting from equipment breakdowns or errors in operation that can occur during the lifetime of a power plant, despite the preventative measures incorporated in the design.

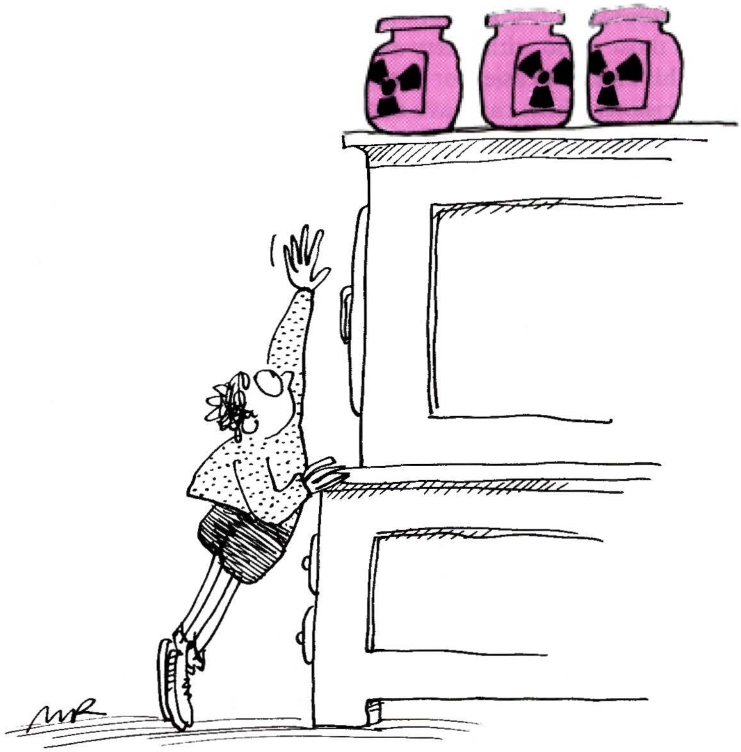
Additional safety devices are provided to protect the public against the consequences of more serious accidents. To complement these precautions, contingency plans have to be worked out both for the installation itself and for the surrounding area.

A number of barriers are installed designed to prevent the diffusion of radioactive substances: matrix and cladding of the fuel elements in the reactor core, pressure jackets and isolation of the primary coolant circuit. It is vital to ensure that these barriers remain undamaged both in normal working conditions and in the event of a fault or accident.

Application of these basic principles and the concrete solutions derived from them have so far provided the public with quite satisfactory protection.

Nuclear safety policy is, however, above all dynamic: the aim must always be to attain optimum safety conditions, taking account of experience, technical progress, operating conditions and operating cost.

To this end the Commission is carrying out research work in the Joint Research Centre, financing specific studies in the laboratories of the Member States and endeavouring to coordinate Member States' research programmes. It also has links with the research activities of other countries, especially the United States. In addition the Commission is conducting an exchange of opinions and experience among interested circles in the Community and analyzing the methods, codes and standards of nuclear safety applied by the individual countries. In this way it can be shown



where national regulations coincide and where they differ, and the principles to be observed and specific objectives to be pursued can be established by common accord.

The trend of recent developments has been towards the setting of both qualitative and quantitative objectives for nuclear safety. The Commission is trying to coordinate the work of the Member States in this regard and is in permanent contact with other countries, again especially with the United States.

Acceptance of these goals, which need to be continually updated to take account of new experience and technical know-how, would be another step towards standardization of national regulations within the European Community.

Licensing and monitoring of the operation of nuclear power plants are the responsibility of the national governments alone. Nevertheless, a decision taken by one Member State on a project in its own territory can have repercussions on other Member States. Consequently, the Community has an important task to perform.

The approximation of regulations and methods that the Commission is aiming at includes those to do with safety assessments and the granting of licences for installations. This makes it easier for Member States to act in concert if one of their number takes decisions which can have consequences for one or more other States.

The Community's activities in the field of equipment safety have hitherto been geared primarily towards 'thermal' fission reactors, that is, reactors in which the neutrons which maintain the chain reaction in the uranium are slowed by a 'moderator' — water, heavy water or graphite. These reactor types, especially those using ordinary, or light, water, are to be found in most nuclear power stations operating in the European Community.

The Community has, however, also looked into the safety of breeder reactors and into the fuel cycle of the plutonium used to fuel them. The chain reaction maintained by 'fast' neutrons — not slowed by a moderator — creates in the uranium also present in the reactor more plutonium than is used in the process.

Breeders thus permit much more extensive use of the nuclear fuel, and in the coming years, power stations are more likely to employ this type of reactor.

The Commission has also begun to investigate safety aspects of reactors of the future, in which it may one day be possible to achieve thermonuclear fusion of light atoms. The Commission is looking at safety in parallel with its efforts to develop this technology, which shows great promise for the next century.

The safety of nuclear plant and particularly of reactors is the most important part of the Community's technological research and development effort. This is especially true for research into energy from nuclear fission. The trend is likely to continue: in the draft research programme for 1984-87, more than half the total budget is allocated to nuclear fission and reactor safety projects.

Research carried out so far in this field has covered:

(i) safe design of the individual reactor components;

(ii) improving their reliability, paying more attention to the choice of materials, quality assurance and application and monitoring methods;

(iii) earliest possible detection of defects likely to cause accidents;

(iv) behaviour of reactors in the event of defects in specific components.

This is to be the general pattern of research in the coming years as well, the aim being to perfect the design of control and monitoring systems and to improve the quality of components and systems, thereby raising the level of operating reliability and safety. A better knowledge of safety margins will also no doubt help to improve profitability.

The 1984-87 research programme on reactor safety will continue to contribute to the activities of the Member States in this important field. A substantial part of the research work will be devoted to accident prevention, especially to study of the behaviour of nuclear plant operating staff in various situations and to 'man-machine interaction'. Another important element will be component integrity, particularly that of the primary coolant circuit, the reactor pressure vessel and the reactor core, and their behaviour in various situations differing to a greater or lesser extent from normal operation.

The increased use of nuclear energy for power generation in the Community — which leads the world in this field — has not yet resulted in a single serious accident. There have been only a few minor accidents and a small number of other incidents that were reported because of their material effects, but which had no consequences for public health or for the environment. The possibility of an accident cannot, however, be entirely ruled out. The accident at the Three Mile Island nuclear power plant near Harrisburg in the United States occurred as a result of a succession of equipment failures with unexpected consequences and human error.

Nevertheless, this technically serious accident caused no radiological harm to the public or to the environment. It did, however, give those responsible for nuclear safety cause to examine the priorities of research, since it underlined the importance of the human factor in the operation of a complex industrial plant and the need for well-established emergency plans.

The safety policy for nuclear equipment that the Community has pursued and will continue to pursue together with the Member States, has steadily reduced the risk of an accident. Small though this risk may be, it can never be eliminated altogether, and the Community is therefore endeavouring to keep the potential consequences of any accident to a minimum.

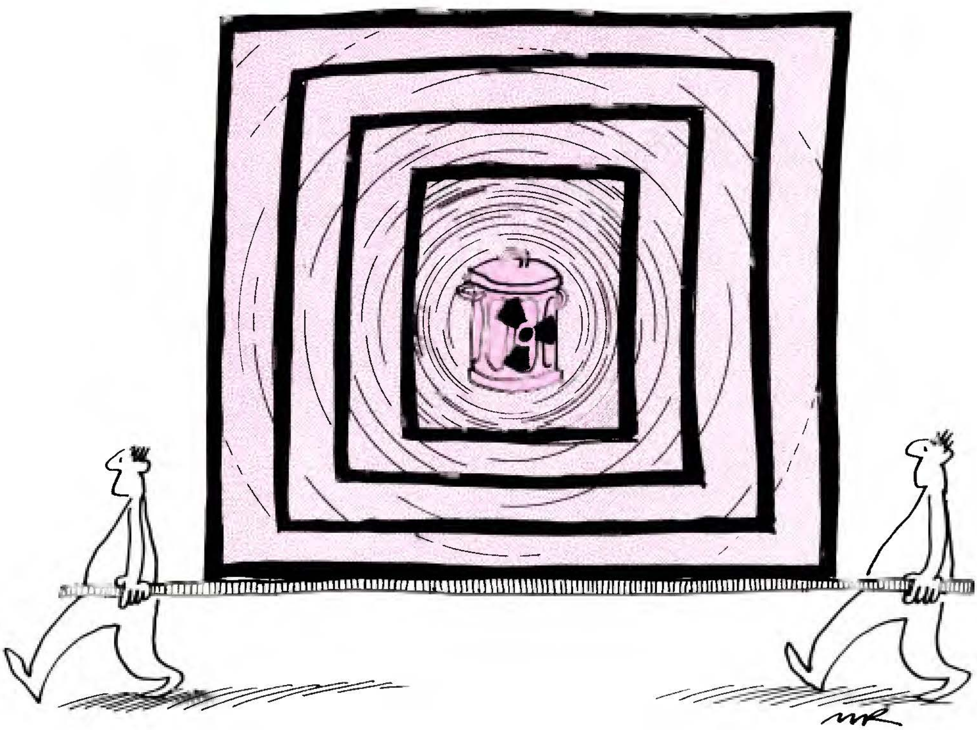
(b) Safety in the transport of radioactive substances

In the European Community a substantial proportion of transport crosses national frontiers: this is only one of the reasons that the Commission is looking into this problem. Since 1959, the International Atomic Energy Agency (IAEA) in Vienna has drawn up recommendations for the transportation of both slightly radioactive substances and highly radioactive emitters. These IAEA recommendations — the 'Order concerning the Transport of Radioactive Substances' — form the basis of all national and international regulations in this field. The Commission cooperates with the IAEA and other international organizations concerned with transport in an effort to approximate the national laws of the Community Member States.

Fissile materials which have not yet spent any time in reactors are only slightly radioactive. Certain precautions do have to be taken in their transportation — in particular to prevent theft — but these do not present serious problems. Fuel that has been used in a nuclear fission reaction is a different matter, however. It demands more thorough safety monitoring since, in addition to energy fission produces elements or isotopes which give the spent fuel a high level of radioactivity.

This makes it vital to ensure appropriate safety conditions during the shipment of irradiated fuels between the nuclear plant and the reprocessing plant, where the still usable fissile materials are separated from the fission products. This phase is part of the fuel cycle and its unhindered execution is important for the further use of the nuclear energy.

The IAEA has recommended very strict regulations. These largely cover the packages and containers on which the safe transport of highly active substances most depends. The packages have to specially designed to keep the level of ionizing radiation as low as possible under normal transport conditions and to preclude any risk of a release of radioactive substances even in the event of a serious accident in transit.



The containers have to be designed to prevent any possibility of a 'criticality risk', that is the triggering of a chain reaction in the cargo. They must also be resistant to the heat still being emitted by the irradiated fuel elements and able to conduct part of this heat away. The containers are therefore complex, heavy and expensive devices.

Apart from the need for appropriate packaging, the transport of radioactive substances raises additional problems, whose solution becomes all the more urgent as the level of traffic increases. The Community's efforts to reach an economic solution to these problems includes harmonization of the licensing procedures and transport formalities and the establishment of emergency services capable of coping not merely with simple mechanical defects but with a serious nuclear accident during transport by air, water, road or rail. Furthermore all those who have to handle radioactive packages need to be given appropriate training in hygiene and safety. Finally, the Member States of the European Community must coordinate their positions on all these points with the organizations dealing with international transport.

There have been no accidents in the Community during the transport of radioactiv substances — which is increasing in line with the rise in nuclear energy use — that have caused an exposure of operating staff or the general public to radiation.

(c) Safety of radioactive wastes

All human activities generate waste; the distinguishing feature of activities making use of nuclear reactions or their products, however, be they in medicine, industry, agriculture or research, is that they produce radioactive wastes. This characteristic can be explained by the fact that these wastes directly contain radioactive natural or artificial elements and, furthermore, all sorts of substances that have become contaminated by particles of such radioactive elements or activated by the absorbed neutrons.

Radioactive wastes therefore comprise a large number of substances which emit different types of radiation: alpha, beta or gamma rays. These wastes come from nuclear power stations and various installations involved in the respective fuel cycle, as well as from laboratories and research centres, factories and workshops and hospitals.

The relative importance of these sources varies from one country to another: all countries use radioactive elements all the time for research, industrial processes or medical purposes, whereas not all countries yet generate electricity from nuclear power.

Industrial and medical applications generally produce low-active wastes. The wastes from nuclear research centres are comparable in nature with those derived from nuclear power generation.

The latter which contain the largest proportion of the total radioactivity of the wastes, fall into different categories. The activities which come before nuclear power stations in the fuel cycle generate low-active wastes in both the extraction and dressing of the ores and in uranium enrichment and the manufacture of the fuel elements. Operation of the reactors of nuclear power stations produces low and intermediate level wastes and spent fuel elements that have to be taken out at regular intervals. The part of the nuclear cycle downstream of the reactor gives rise to low, intermediate and high level wastes.

These come mainly from plants involved in chemical reprocessing of the spent fuels. Still usable fissile materials (uranium and plutonium) are recovered in these plants, and various radioactive elements, fission products and transuranic elements produced in nuclear fission are also recovered as by-products.

In the course of their operation, nuclear installations also produce liquid and gaseous effluents which have to be disposed of into surface waters and the atmosphere in accordance with radiation protection regulations and under appropriate supervision (see Chapter C, page 43 *et seq.*).

One feature of radioactive wastes is their radioactive life: in the case of some elements or isotopes this is of very short or short duration, radioactivity ceasing after a period of a few hours to a few weeks. In practice, these elements scarcely present a problem. They include, for example, certain radioactive elements contained in the spent fuel rods whose radioactivity almost completely disappears during the 'decay period' in a special pit on the reactor site, i.e., before transport or reprocessing.

In the wastes for reprocessing there are radioactive elements with half-lives of years or decades, even centuries, and others have long or very long radioactive lives, lasting thousands or even tens of thousands of years.

However, there is a law of nature which ensures that radioactive elements with high specific activity decay relatively quickly, so that after no more than a few hundred years their activity is very low. This is the case with most of the fission products that are beta or gamma emitters. On the other hand the elements which retain their radioactivity over very long periods have relatively low specific activity.

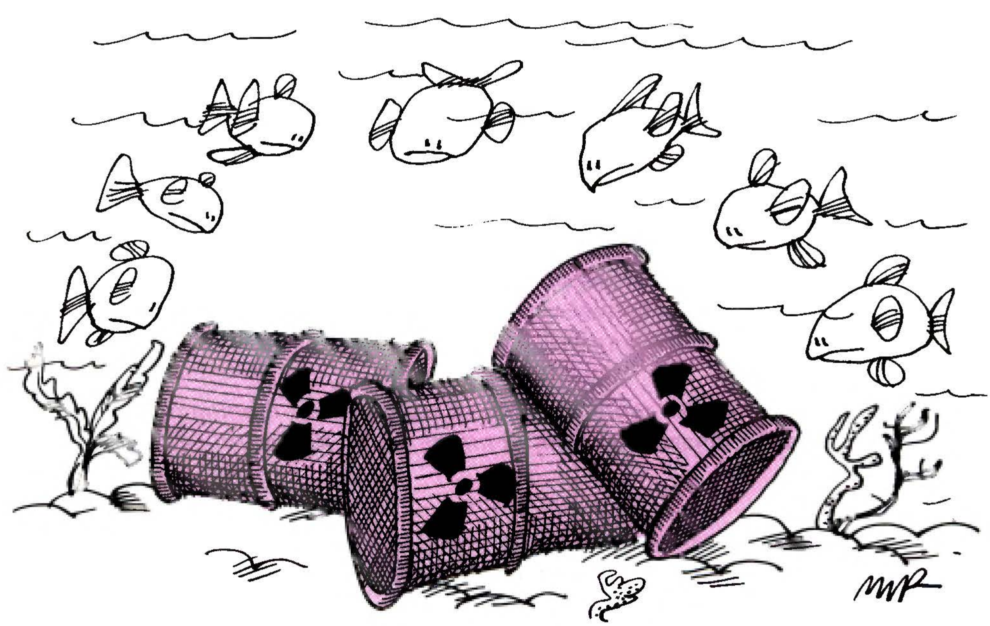
These are alpha emitters, which belong to the family of actinides, and fissile materials that have not been recoverable in their entirety in the reprocessing of the spent fuels.

The sizeable production of radioactive wastes requires appropriate management to protect present and future generations and their environment — at least for as long as the radioactive substances in the wastes have not reached harmless radiation levels by a process of natural decay.

The two basic tasks of nuclear waste management are selecting the conditioning method — the form into which they are to be put — and deciding on the nature of their ultimate disposal. These problems naturally increase as nuclear energy production expands and the volume of waste generated increases.

In some Community countries R&D efforts to find the most appropriate solutions have been under way since the early 1950s. The extension of national programmes and projects and the wide range of possible options have gradually made it clear that the techniques and methods used have to be carefully selected and optimized.

Cooperation at Community level was called for. In 1973, the Council of Ministers established the fundamental responsibility of the Community for protecting the environment and in particular for coping with nuclear and non-nuclear wastes. The Community then embarked on research that takes two different forms: firstly, the Community runs five-year action programmes, which it partially finances and which it coordinates in the framework of a shared-cost project with various national labo-



ratories in the Member States, and secondly, it undertakes its own research work at the Joint Research Centre, especially at the Ispra establishment in Italy. In addition, work is undertaken as part of programmes run by non-Community countries, such as the United States and Canada in the context of bi-lateral cooperation agreements.

Low-level waste has up to now generally been disposed of by encapsulating it in concrete or bitumen packed into drums, some of which are then dumped in the deep ocean in the framework of measures taken and monitored by the OECD's Nuclear Energy Agency. The rest are stored either in abandoned mines or in specially constructed dump sites.

Waste of intermediate activity is either solid, in which case it is encapsulated in concrete or bitumen, or liquid, in which case it is concentrated and treated in the same way as high level waste.

Low and intermediate activity waste currently accounts for almost 95% by volume of the waste being conditioned in the Community and it will continue to predominate in the future, still amounting to around 85% in the year 2000.

Until a few years ago the only sources of high level waste were a few research centres or experimental installations. It was concentrated and then stored at the production sites in liquid form without further conditioning in steel containers that are resistant to corrosion for at least 20 years; monitoring and continuous maintenance was to ensure that there were no leakages. This, of course, was only an interim solution, and recently a start was made with developing and applying conditioning methods in which liquid and gaseous wastes are solidified, for example into glass blocks which offer good guarantees of strength over a long period.

The solutions adopted and applied are of the utmost public interest. The need to coordinate all the efforts being undertaken throughout Europe is obvious, if only for reasons of efficiency. Reprocessing plants for irradiated fuels — the main source of radioactive wastes — do not confine their operations to their own countries but process fuels from other countries as well.

Radioactive wastes present problems both of technological development and of a legal, administrative, financial and social nature which all have to be solved in the same context.

With the nuclear power boom in the Community and the consequent production of considerable quantities of wastes, a common European approach had to be decided upon.

In February 1980 the Council of Ministers adopted a Commission proposal laying down a plan of action for the management and storage of radioactive waste. This plan covers the period from 1980 to 1992; it includes the current 1980-84 research programme and will similarly include the subsequent programmes dealing with the problem.

There are numerous research projects currently under way most of them following on from earlier research work; these projects are geared to a few key areas of concern.

One of these key areas is that of the chemical, physical or physico-chemical separation of waste with short or intermediate life from wastes that have long or very long half-lives. The separation of actinides is also being studied with a view to their re-use in nuclear reactors or their degradation into the other categories of wastes.

Efforts are also being made to diminish the problem of radioactive wastes by reducing their volume.

There is also research into reprocessing and conditioning of waste. In the case of low and intermediate level waste, the prime object is to find the best processes and place more economic, more efficient and more reliable methods at the disposal of users. For wastes with long half-lives and high activity the basic technologies for reprocessing and conditioning do, admittedly, already exist, but processes still need to be developed and improved; the most effective of these then have to be selected in order to ensure optimum disposal.

Storage of conditioned wastes is planned in geological formations, such as clay or salt beds or in the granite rock found in many parts of the Community. Another possibility for the future is burial under the sea bed. Technical feasibility studies and investigations of the potential consequences for man and the environment are presently under way in a number of countries.

Theoretical research work and on-the-spot examinations are necessary to test the effectiveness of barriers between the radioactivity and the surroundings, to check the amount of heat released by the wastes and to establish with certainty the stability of the geological formations selected.

The Community's 12 year action plan guarantees the necessary joint Community action in these areas. It also ensures that the action undertaken is correctly targeted and will result in an integrated system for treating and storing radioactive waste that will safeguard man and the environment in the short, medium and long term.

(d) Safety in decommissioning and dismantling nuclear plants

As with all industrial installations, nuclear plants have one day to be taken out of service.

The shutdowns carried out so far have largely concerned research or test facilities, such as reactors of a type that has subsequently been abandoned. No large nuclear power station has yet been decommissioned.

The time will come, however, when power stations and other installations in service now will have to be shut down, either because some of their components are showing wear that can no longer be repaired by normal maintenance or because they have been overtaken by technology and they are no longer economically viable compared with newer facilities.

In the case of power stations, the admittedly relatively limited experience gathered so far suggests that they may on the whole have a longer technical lifetime than had at first been predicted. With the rapid onward march of technology, however, there is a danger of equipment fast becoming obsolete and having to be replaced prematurely even though it is still in good condition.

The increased use of nuclear energy thus requires appropriate solutions to the unavoidable problem of having to shut down nuclear plant. Solutions have to be found before more and more actual cases where decommissioning is required arise.

Studies are being carried out in the Community on large light water reactors with capacities between 900 and 13 000 MWe, since this type of reactor is typical of current nuclear programmes; they are sufficiently standardized to permit generalization of the solutions found.

Shutdown can be carried out in a number of different ways. First, the plant can be kept in a state in which it presents no further risk to man or the environment. This is possible without having to dismantle the equipment, and the tightness of the containment is maintained. Access to the plant is prevented and the site is placed under surveillance. Second, the superstructure can be demolished and the foundations and other concrete basement structures left *in situ*. Third, the entire plant can be removed together with its foundations, in which case the site can be re-used for other purposes without restriction.

In accordance with a Council Resolution of 1977 recommending an environment policy and action programme the Commission has continued earlier research work on the decommissioning of nuclear power stations in the framework of five-year programmes in which a number of research contracts are coordinated and financed on a shared-cost basis. This gives effective support to the activities of the Member

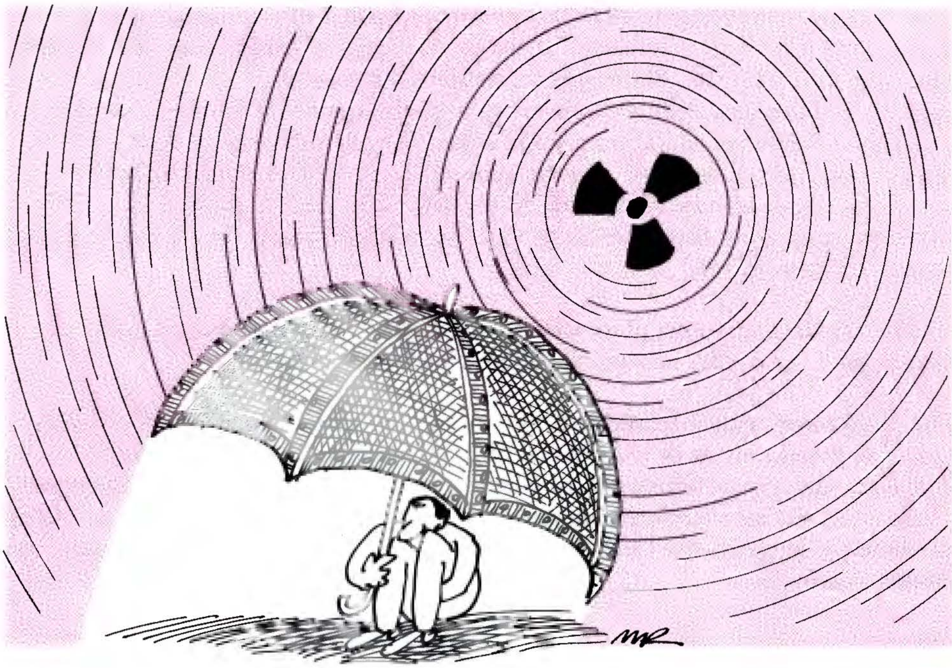
States aimed at establishing the basic principles governing shutdown of the power plants. The problems involved are those of rehabilitation of sites and recovery of the materials used by the nuclear installations — bearing in mind the strict standards applied in operating these installations.

In concrete terms this means that efforts are being made to devise effective decontamination techniques which leave behind as little radioactive waste as possible; in addition there is an attempt under way to work out satisfactory techniques for dismantling the leakproof metal components and reinforced concrete structures while at the same time ensuring adequate protection of workers against radiation. The research work extends beyond this to include the conditioning of specific radioactive wastes which occur during dismantling. At the same time forecasting techniques are being developed to permit a dismantling policy which takes account of the limitations imposed by radiation exposure, cost and disposal or storage of the radioactive waste. Finally, an attempt is being made to sketch out the changes that will be necessary in the design and operation of future installations with a view to easier decommissioning.

The Commission would also like to promote large-scale exchange of information on the decommissioning projects being carried out in the Member States. The experience gained in shutting down a power plant will be very valuable when other installations are decommissioned in the future. Briefing sessions have taken place on shutdowns that have already been carried out and on dismantling projects currently being planned in the Community, and further meetings are scheduled.

This coordinated action offers the best guarantee that satisfactory methods for decommissioning and dismantling nuclear installations that have reached the end of their service life will be available in good time.

B. Protecting the health of workers



Protecting the health of workers who may be exposed to ionizing radiations requires, on the one hand, prevention of exposure in the first place, and on the other assessment of an exposure that may have taken place and the provision of appropriate medical supervision.

(a) The basic standards for radiation protection

As early as 2 February 1959 — scarcely a year after the Euratom Treaty entered into force — a system was created for protecting the public in the Community. The basic standards for radiation protection which were laid down at that time in a Council

Directive have since been repeatedly revised and amended — in 1962, 1966, 1976 and, most recently, in 1980 — in order to take account of increased scientific and technical knowledge on radiation protection and of the development of the relevant concepts, as well as of the practical experience that had been gained in the application of the Directives.

The drafting of the basic standards is linked to as many safety guarantees as possible. In drawing up its proposals the Commission takes as its basis the recommendations regularly issued by the International Commission on Radiation Protection (ICRP). This body, set up in 1928 by the International Radiological Congress, numbers among its members scientists of world standing; its competence and independence are unchallenged. The proposals of the Commission of the European Communities are submitted for an opinion to a group appointed by the Scientific and Technical Committee of Euratom from among the scientific experts in the Member States. The Commission then asks the Economic and Social Committee for its opinion on the basic standards drafted; in the ESC both the employers' associations which have to apply these standards and the workers whom they are intended to protect are represented.

Finally, consultation takes place with the European Parliament before the Council, dealing with the dossier as a whole, adopts the basic standards.

The abovementioned regulations for safety at work and health protection and the radiation dose limits to be maintained for individual groups are not intended to be applied directly to the citizens of the Member States but through their governments. These directives are therefore binding on the Member States as regards the results to be obtained, but leave the form and the resources to be used to the discretion of the national authorities.

Incorporation in national laws of the principles and values contained in the basic standards has taken place in a flexible manner and with due consideration to the differences in the legal or administrative structures of the Member States and in the attitutde of their citizens; it has led to harmonization in the field of radiation protection, eliminating any discrimination between workers and employers on grounds of nationality or place of work.

(b) Field of application of the basic standards

The field of application of the basic standards is not limited to large-scale nuclear plant but covers all activities of production, treatment, handling, utilization, possession, storage, transport and disposal of natural and artificial radioactive substances and all other activities involving a risk resulting from exposure to ionizing radiations.

If activities fall within the scope of the standards they must as a rule be reported. Provision is made for exemptions from this requirement if the radiation is very weak or if the equipment in question has been licensed by the responsible authority. On the other hand, and subject to similar exemptions, these activities require prior authorization from the country concerned.

(c) Dose limitation

The directives laying down the basic standards provide for limitation of dose in the case of controlled exposure to radiation. For such limitation the following general principles apply:

(a) Any activity involving an exposure to radiation must be justified by the benefit the activity brings. Adherence to this principle means that any unnecessary exposure is prevented. The principle is difficult to apply and requires the acceptance of a number of criteria.

(b) Any exposure to radiation must be kept as low as reasonably feasible. The judgment as to what is reasonably feasible takes socio-economic factors into account.

Application of these two principles is very complicated, above all because of the problems of evaluation. For this reason the Commission is endeavouring to arrive at as exact a knowledge as possible of how they are put into practice, and to this end it has established regular contacts with the relevant trade unions. On the basis of the knowledge thus gained changes can then be made in the provisions of the basic standards which will improve application of the principles and raise efficiency. It is obvious that as scientific knowledge deepens and radiation protection techniques become more advanced it will be possible to make the evaluation criteria more precise and thus to minimize subjectiveness and arbitrariness in applying these principles.

This has been confirmed by experience: these two elements, namely practical experience and scientific and technical progress, have made it possible, as has already been mentioned, to amend the basic standards four times in order to ensure better protection.

(c) Apart from in exceptional cases the total of absorbed doses received and committed doses must not exceed certain limits which are set down for workers, apprentices and students exposed to radiation.

'Absorbed doses' are doses absorbed by the body of a person exposed to radiation, whereas 'committed doses' are the radiation values which are absorbed by an organ or tissue and which originate from one or more radioactive particles ingested, inhaled or taken into the body in some other manner.

Workers exposed to radiation are persons who are exposed through their work to radiation which can cause annual doses in excess of one-tenth of the annual dose limits set for workers. The dose limit for whole-body exposure of workers exposed to radiation is currently set at 50 mSv[1] per year. It should be mentioned here that in the case of workers exposed to radiation the requirements of industrial safety have led to a distinction being made between category A — workers liable to receive a dose higher than three-tenths of the limit dose — and category B — workers not liable to receive such a dose.

Other rules have been laid down as well:

(i) Higher dose limits are applied if only a single part of the body is affected. For stochastic effects a weighting factor corresponding to the whole body has been applied to the dose absorbed by each organ or tissue, the total of all factors being 1. Each weighting factor expresses the proportion of risk represented by the irradiation of the organ or tissue in question compared with irradiation with the same intensity spread uniformly over the whole body. This system of equivalent effective dose is intended fully to ensure workers' safety, irrespective of whether the radiation is uniformly distributed over the whole body or whether it only affects particular organs or tissues.

(ii) Workers under the age of 18 must not be assigned to a workplace where they can be regarded as workers exposed to radiation, i. e., they must not be exposed to a radiation dose of more than 5 mSv/year.

(iii) For apprentices and students 16 to 18 years old who might be exposed to radiation as a result of their studies, the dose limit is three-tenths of that laid down for workers exposed to radiation. This rule is intended to reconcile the demands of an adequate academic and vocational training with the dictates of appropriate health protection.

(iv) There are special rules to protect women of childbearing age and yet more stringent ones for pregnant women. In order to avoid genetic effects, these women must work in conditions corresponding to category B.

These rules apply to exposures which occur in the course of everyday work under normal conditions. The 'basic standards' directive also makes provision for planned special exposures to radiation and accidental exposures. The first of these occur, for example, when maintenance, repair or decontamination work has to be carried out. Work of this kind may be authorized only in justified exceptional cases when alternative techniques involving less exposure cannot be applied. Account is also taken of the age and health of the worker in question, who of necessity must fall

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[1] mSv stands for millisievert, the SI unit of radiation dose equivalent, and corresponds to 100 mrem ('rad equivalent man'). See also the glossary at the end of this brochure. It should also be noted that 1 mSv/year roughly corresponds to the average dose obtained from exposure to the natural background radiation at the Earth's surface.

within category A, for which the aptitude criteria and medical supervision are more comprehensive. Workers who have been exposed to heavy doses of radiation as a result of an accident, workers who have exceeded the dose limits over the preceding 12 months and women of childebearing age must not be subjected to any planned special exposures to radiation. Workers who do come into consideration for such special exposures must be given appropriate information about the risks involved and the precautions to be taken during the operation.

As regards emergency exposures — to which only volunteers may be subjected — and accidental esposures, it is not possible to make a general ruling. The only possibility is as far as possible to provide medical supervision and to make a special record of the doses received.

(d) Protection at work

Workplaces where there is a risk of radiation exposure are divided into three categories:

(i) areas where doses do not exceed one-tenth of the annual dose limits (i. e., 5 mSv); for these areas it is not necessary to make special arrangements for radiation protection;

(ii) areas where doses are liable to be between one-tenth and three-tenths of the limit value (i. e., between 5 and 15 mSv): these are the so-called 'supervised areas';

(iii) areas where doses are liable to exceed three-tenths of the limit value (i. e., 15 mSv): these areas are called 'controlled areas'.

In the two last-mentioned areas, where the access has to be marked and entry made subject to controls, special arrangements have to be made for radiation protection in accordance with the type of plant, the radiation sources and the risks. In these areas attention is drawn to the radiation sources and the associated dangers, the instructions for work are appropriate to the radiation hazard, the surroundings are monitored and the radiation level is recorded.

Safety devices and measuring instruments have to be designed, checked and verified by qualified experts. The radiation emitted by the individual sources is measured regularly to determine its nature, quality and quantity; the same applies to the radioactive substances in the air. These measurements are used for evaluating the individual doses received by the workers if individual measurements are not possible.

It is, however, the rule that all workers employed in an area where radiation is liable to exceed three-tenths of the limit value (category A) must systemtically undergo individual measurements.

The results of personnel monitoring are submitted to an approved medical practitioner, who assesses their health implications. They are kept in archives for at least 30 years, as are any other data which can be consulted at any time to obtain a picture of earlier radiation doses a worker may have received.

For every category A worker a medical file is therefore kept which contains the results of all the monitoring he has undergone. On recruitment the worker is examined to see whether he is fit to work at the intended workplace: any earlier exposures of an occupational or medical nature and the results of clinical or other examinations are taken into account. No worker may be employed, for example, who lacks the necessary concentration or dexterity to avoid conduct which might pose a danger to himself or to others. Aptitude for radiation exposure must be assessed in accordance with a list of indicative criteria drawn up by each Member State for its doctors.

Medical supervision is continued on a regular basis throughout the employee's working life. The approved medical practitioner has access to the documents necessary for assessing the state of health of the worker and the conditions in which he works. He examines the worker and checks his medical record as least once a year. Questions have occasionally been raised as to the need for such examinations to check whether or not a worker is still fit to continue carrying out his duties, in view of the fact that dose limits are currently so low. Examinations are not confined, however, to noting down the numerical details of cases of exposure to radiation and monitoring the consequences, but cover the general state of health and fitness of the worker.

The medical practitioner carries out examinations and in cases of emergency can prescribe courses of treatment. He also intervenes if the dose limits are exceeded and his permission has to be obtained if an employee is to work in conditions where there is a risk of further exposure.

Radiological monitoring of workers in category B — those not liable to receive a dose greater than three-tenths of the annual dose limits — can be limited to collective dosimetric monitoring and medical supervision in accordance with standard practice in industrial medicine.

In the 'basic standards' directive no distinction is made between regularly exposed workers — for example those whose work normally involves the manipulation of equipment or substances emitting ionizing radiation and who are employed in the vicinity of the radiation sources — and workers who are only occasionally exposed but for whom protection still seems more difficult to provide and to supervise.

If a worker is instructed to carry out a one-off repair job in an active zone, the risk is small. However, if the same job is to be carried out at several of the firm's installations or in similar plants, this no longer constitutes an occasional intervention. This is particularly the case with maintenance done in a nuclear power plant during its annual shutdown. Experts in various fields belonging to outside firms regularly carry out work of this kind in several power stations in the course of any year.

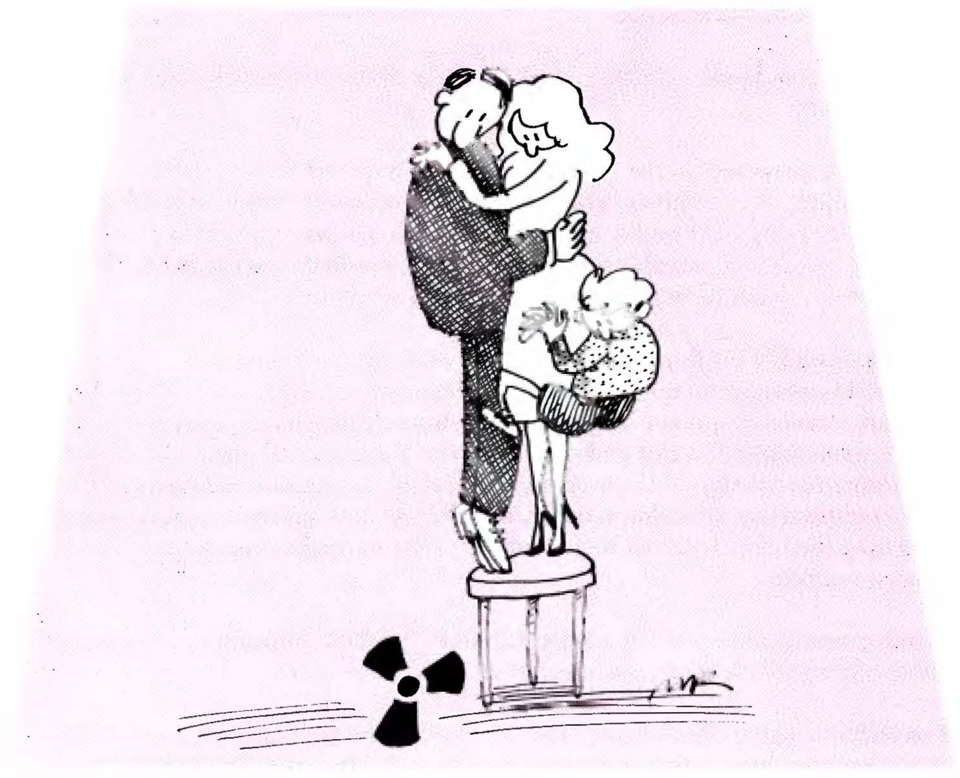
These workers are therefore regarded as being occupationally exposed to radiation in just the same way as the power station personnel, and must be subject to similar monitoring. In their case, however, there is the additional problem of measuring the doses received in each installation. The solution is for the worker always to be accompanied by his radiation protection file, as is also the case, if an exposed worker moves to another firm. For this reason some Member States have devised a system using an irradiation record sheet or a radiation card recording all the radiation a person has received in the course of his or her life.

The Commission is also concerned with the practical problems of protecting the health of workers and is endeavouring in particular to harmonize the existing national systems for measuring radiation doses.

Any installation which represents an exposure risk or a danger of radioactive contamination must set up a special radiation protection service. The Directive adopted in 1976 also provides that serveral installations can have such a service at their disposal jointly but that this is not permissible in the case of production and operating units.

Along with the progressive development of the system of health protection embodied in the basic safety standards and in particular the improvement of radiation protection itself, the refinement of dosimetry and the intensification of medical surveillance, the mean radiation dose to which workers in the nuclear sector are exposed is being substantially reduced.

C. Protection of the general public



As is the case with all technical progress, the aim of expanding nuclear activities is to raise the standard of living of the general public. To avoid this being at the expense of injury to the health of the workers involved, strict precautionary measures are taken in the Community. Just as much care needs to be taken to ensure that the benefit sought for the population as a whole is not outweighed by a deterioration in living conditions, especially as regards health and the environment.

The system of health protection set up in the Community under the basic standards for radiation protection therefore cover the general public as well. The level of radioactivity in the environment in the Member States is monitored by a network of measuring stations and the readings are compared. The Commission also checks that the disposal of radioactive wastes has no harmful effects.

(a) The basic standards

In the basic standards, dose limits are set not only for workers but for the general public as well.

This limit is governed by the same principles as those set for workers, namely that activities likely to involve exposure to ionizing radiation must be justified by the benefits they bring and that the number of occasions when exposure is possible must be kept as low as is reasonably practicable. The individual dose limits for the general public are one-tenth of those applied to exposed workers.

The responsibility for fixing national limits valid for the population as a whole lies with the Member States taking account of their own circumstances. They also have to ensure that any exposure of the population resulting from a particular activity is kept to a minimum. To this end they supervise the design of plant, the installation and proper functioning of the most suitable safety devices and the systems for measuring radioactivity. In addition the Member States have precise ways and means for evaluating the doses received by the public under normal circumstances and in the event of accidents.

In each country an inspection service monitors the state of health of the population and checks that dose limits are adhered to.

If an accident occurs which leads to an exposure of the population it must, if circumstances require, be reported immediately to the neighbouring Member States and to the Commission of the European Communites.

(b) Monitoring radioactivity in the environment

Continuous monitoring of the level of radioactivity in the air, water and soil and in the food chain is an important requirement for keeping to the standards for protecting the general public and the environment. Provision is therefore made in the Euratom Treaty for each Member State to establish the measurement and control facilities necessary to monitor the radioactivity in its territory.

There is now a Community-wide network of measurement stations and sampling systems in operation which is used for continuous measurement of the artificial radioactivity in the air at a large number of sites. In addition the radioactivity of the fall-out in rain, snow, etc., is measured.

Regular sampling and analysis of surface water, groundwater, seawater, drinking water and occasionally urban sewage is carried out at many locations. The food chain is also monitored by sampling and analyzing milk, which is regarded as a significant indicator.

The Commission is obliged to supervise the monitoring network to ensure that it is working correctly and efficiently. It is endeavouring to standardize procedures and units of measurement in order to keep the results as comparable as possible. Another fundamental concern is the improvement of measuring equipment and techniques, and efforts are also being made to improve radiometric methods.

The effectiveness of European efforts to protect the public and the environment against radiation does not, however, depend solely on precision and comparability of results. It depends to an equal extent on the speed with which the radioactivity in the environment and in the food chain can be measured. This speed is necessary if the national and Community authorities are to be able to act in an effective and harmonized manner to protect the public and the environment, and if the limit values laid down in the basic standards are not to be exceeded.

The measurement results and the conclusions drawn from them are published by the Commission.

(c) Disposal of radioactive liquid waste

Most human activities, especially in industry, result in various products, some of them harmful, being emitted into the environment. From the point of view of radiation protection, the problem is radioactive liquid waste.

This comes not only from nuclear activities as such. Medical installations, some chemical factories and so on also dispose of waste that can pose a health problem.

Disposal of radioactive liquid waste can have consequences that spread beyond the borders of the country discharging the waste.

The Euratom Treaty therefore lays down that the Member States should provide the Commission with all general data, in whatever form, relating to any plan for the disposal of radioactive waste, be it in the form of gas, aerosol, liquid or solid. This information can be used to decide whether the implementation of such a plan is liable to result in the radioactive contamination of the water, soil or atmosphere of another Member State.

After consulting experts the Commission delivers its opinion on the likely risk of cross-border effects. This opinion is addressed both to the Member State which has notified the plan and to the neighbouring Member States which may be affected.

So far about 100 such plans have been subject to this procedure. In some cases, the Commission has made recommendations for improving the conditions for carrying out the disposal operations and for supplementing safety precautions. These recommendations have always been taken into account.

The electrical power of nuclear stations in the Community has gradually increased and is still rising. The capacity of these power stations has also increased and ranges from 200 - 250 MWe for the first industrial power stations to 1 000 or even nearly 1 500 MWe for the most modern plants.

The amount of substances discharged increases proportionally more slowly than the size of power stations, but even so, the increase in total power means an increase in the quantity of waste to be disposed of. The problems of preventing contamination of the environment by radioactive waste become greater, of course, as the quantity of waste disposed of increases.

As the nuclear industry has developed, trans-frontier radiological problems have arisen, which need to be studied at Community level. In a communication to the Council[1] the Commission drew attention to these problems and in a draft resolution it asked for support for Community projects in this field that are planned or under way.

These problems concern the accumulation of radioactive substances in river basins or marine waters in and around the Community. Of the European Community's rivers, the Meuse is particularly important since it both takes the radioactive waste of three countries and supplies drinking water to several million people in Belgium and the Netherlands. It is also used for irrigation, fishing and sludge dredged from it is used as a fertilizer in agriculture. A similar problem could occur in sea water where radioactive wastes are dumped. The Commission is carefully examining the question of accumulation and how it develops.

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[1] Communication from the Commission to the Council concerning the Community's role as regards the safety of nuclear installations and the protection of public health (COM(83) 472 final of 22. 7. 1983).

There are also a number of nuclear installations in the Community from which radiation could pass to a neighbouring Member State.

Several Member States with common borders have already concluded bilateral agreements on trans-frontier emergency plans and other agreements are shortly to be concluded. The Commission feels that it should be involved, however, so that the European dimension is taken into account in all agreements, thereby avoiding major divergences within the Community.

The Commission regularly publishes for the whole Community balance sheets of disposals of radioactive waste from nuclear power stations and reprocessing plant. The most recent of these publications appeared in March 1983 and covers the period from 1976 to 1980. The measurements show that the maximum doses received by the public in the vicinity of nuclear installations is generally substantially below 1% of the dose limits laid down in the basic standards. The collective radiation dose to the Community population as a whole caused by waste disposals in 1980 was less than 0.1% of the collective dose from natural background radioactivity.

D. Research work in the radiation protection field

The steady improvement of nuclear plant safety and radiation protection is a matter of considerable concern to the European Community. It calls for a continuous effort to deepen scientific knowledge of radiation effects, measurement techniques and safety measures. In this field the European Treaty has provided for specific research work to be carried out in a series of multi-annual programmes aimed at determining the effects of ionizing radiation by scientific methods and objectively assessing the risks they present to human health and the environment.

The purpose of this research is to improve knowledge of the variety of aspects characterizing the exposure of man to radiation and the contamination of the environment. The scientific foundations on which preventive and protective measures and treatment of radiation accidents are based are to be extended. Another goal is to determine, as accurately as possible, the doses to which workers and the general public are exposed. The more knowledge these studies produce, the less guesswork will be necessary in the practical application of radiation protection.

The importance of this research work is undisputed and the Euratom radiation protection programme hardly suffered at all from the problems and the crisis of confidence that dogged Community research efforts between 1968 and 1975. In fact this was one of the few areas in which it was possible to keep up the continuity so essential to effective research.

The 1980-84 programme as it has developed so far shows a continuation and further development of the earlier research efforts in radiobiology and health protection. It is a shared-cost programme in which the Commission acts as coordinator and provides financial support for numerous contracts with research institutes, national centres and universities.

Funds amounting to 59 million ECU have been allocated to this programme. The work carried out or still in progress comprises 275 research contracts with almost 450 different projects. The programme is characterized by broad cooperation at the European level. The work put into this programme amounts to more than 100 man-years for scientists and more than 800 man-years for technicians. About 1 000 publications stemming from the programme have substantially enhanced scientific knowledge about radiation protection in recent years and thereby assured the furtherance of the concept and principles of radiation protection. The radiation protection programme has likewise improved knowledge of the consequences, detection, treatment and risks of ionizing radiation and promoted an intensive exchange of results and information within the Community.

The main fields of interest are the development of dosimetric methods, the long-term behaviour of radionuclides in water, soil, plants and animals, the treatment of local and general consequences of an exposure to ionizing radiation, the influence of radiation dose and dose rate on carcinogenesis, the role of repair in radiation-induced genetic damage and the study of populations exposed to radiation.

The Commission recently proposed a new multi-annual programme intended to continue research into radiation protection between 1985 and 1989.

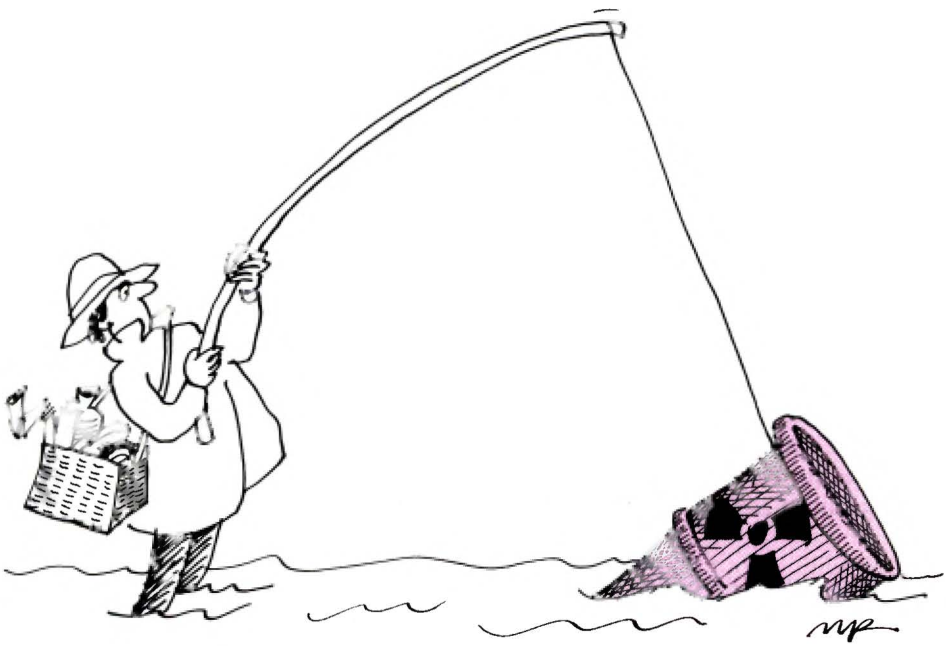
Given the present level of knowledge and the needs of radiation protection as they now stand, research into certain specific priority areas will have to be given priority in the future.

Pollution of the environment by man is an inevitable consequence of human activity. There was a time when it was only acknowledged, and remedial measures taken, if it caused actual harm.

Radioactive pollution from natural or artificial sources can be detected far below the threshold of intensity at which man and the environment are damaged. Moreover, there are many ways for it to be transmitted to man. Numerous studies of the transmission of radioactive contamination have already been carried out, but more detailed information on the normal operation of nuclear industries under specific conditions is required. The effects of waste disposal and the possible consequences of accidents also have to be carefully examined so that appropriate countermeasures can be developed. Finally, a better understanding is needed of the ways in which radioactive pollution is transmitted into the environment, to help forecast the extent and possible long-term effects of environmental pollution.

The number and seriousness of accidents can be reduced but they will never be totally eliminated. Each accident provides a lesson for the future, but it is better to analyze in advance the situations that can lead to accidents in order to develop adequate preventive measures and, if an accident does occur, to limit its consequences. Analysis, forecasting and dealing with the consequences of accidents for man and the environment are important aims of research and must be continously adapted to industrial progress.

The following subjects are among the wide range of research themes covered: the study of factors which can cause contamination, the rehabilitation of contaminated terrain, the diagnosis and treatment of internal or external exposure to radiation,



radionuclides which can enter the human body by various routes and damage the health. Information and models to do with the transport, metabolism and effect of radionuclides in the human body need to be improved. This research also makes an indirect contribution to the protection of man against other pollutants in the environment.

Irradiation with small doses from natural or artificial radiation sources presents a possible risk to human health. The problem is widespread. For example improving thermal insulation of houses to save energy reduces air circulation and thereby raises exposure of the public to natural radioactivity (from radon, thoron and their daughter products) emanating from the soil or from building materials. Since the effect of such small doses cannot be studied experimentally, the results obtained by irradiation with higher doses must be supplemented by study of how radiation affects cells and carcinogenesis.

Cancer is the second most common cause of death; it can be caused or aggravated by a large number of endogenous or environmental factors, the effect of radiation on the whole only playing a minor part. The relative probability that radiation causes cancer is low compared with other carcinogenic factors, but there are probably interactions between the development of radiation-induced cancers and cancers caused by other factors. How radiation-induced cancer can be prevented and treated must therefore be investigated. In recent years great advances have been made in the understanding of carcinogenesis, not least as a result of research work on radiocarcinogenesis, but so far neither the molecular and structural changes which turn a healthy cell into a cancer cell after irradiation, nor all the factors which influence these changes and ultimately allow a malignant tumour to form have been identified. Any progress made in this field is beneficial not only to radiation protection but also to our general understanding of carcinogenesis and hence its prevention.

Genetic changes are the only radiation-induced injuries to man that affect future generations as well. There are already many cases of genetic defects, deformities and disorders. Although exposure to artificial radiation seems to contribute only slightly to the problem, everything should be done to avoid further genetic damage. For this reason the mechanism of such damage must be further clarified and the processes leading to the repair of premutagenic and precarcinogenic damage must be more clearly defined. Likewise, the hereditary changes which raise sensitivity to radiation and encourage cancer formation have to be investigated.

Epidemiological surveys of sufficiently large population groups are essential for defining the different effects of exposure to radiation. Surveys of this kind already exist, for example for the survivors of atomic bomb explosions and for patients exposed in the course of medical treatment. There are in fact only a small number of population groups and individuals who come into consideration for epidemiological studies of this kind. The analysis of risks to man cannot, however, be based solely on animal experiments, and all appropriate population groups therefore have to be carefully studied. Coordination of studies is the best way to collect sufficient numbers of people to show the effect of small doses, find suitable controls and finally carry out the data gathering, statistical evaluation and extrapolation of risk on a joint basis.

Exposure to ionizing radiation during medical examinations and treatment goes hand in hand with the benefit which the advance of medicine has brought humanity. In societies with a high standard of living it is the chief cause of exposure of the public by human influence and it is almost on a par with exposure from natural background radiation. The optimum use of ionizing radiation in medicine by way of a more precise determination of the doses administered in the various techniques is therefore an important objective, the overall effect of which will be to permit a reduction of the radiation dose to the population.

Exposure to radiation is only one of the risks which human beings constantly face. These different kinds of risks have to be correctly evaluated. Quantification of risk by effect and frequency, development of methods for evaluating risk and risk analysis studies have all recently become topics of research, not least as a result of growing public awareness of the potential risks of ionizing radiation.

In line with these basic themes, the radiation protection research programme for 1985-89 covers the following areas; radiodosimetry and its interpretation, behaviour and monitoring of radioactive products in the environment, non-stochastic effects of ionizing radiation, radiation-induced carcinogenesis, genetic effects of ionizing radiation, evaluation of irradiation risks and optimization of protection.

The programme thus devised responds to the justified concern of the public with regards to the potential risks of exposure to natural or artificial ionizing radiation; its purpose is to evaluate objectively and to minimize these risks by way of European cooperation.

Conclusion

The European Community, together with the individual Member States, is endeavouring to take the most effective and far-reaching precautions possible to ensure nuclear safety. In the first instance, the onus is on the Member States, in view of their direct involvement in the field and their national legal and administrative regulations. The task of the European institutions is to adopt the necessary safety precautions jointly with the Member States in a common safety policy designed to protect the general public and those employed at nuclear installations.

Like other forms of pollution, radioactive substances discharged into the environment as a result of the peaceful use of nuclear energy cross the Member States' borders and therefore transfrontier action at European level is required.

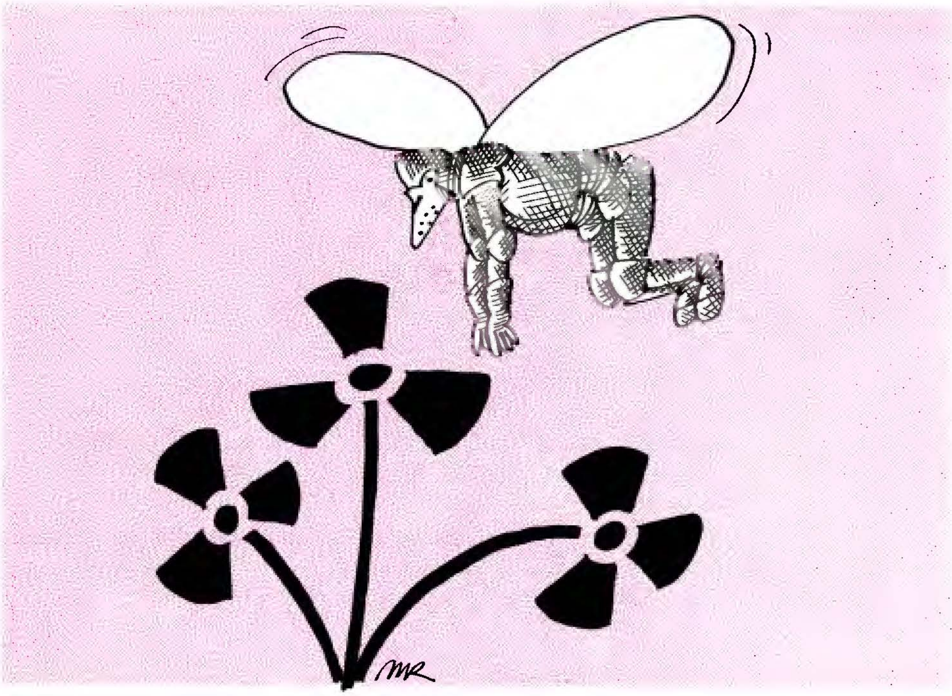
Nuclear safety is therefore a Community responsibility as laid down in the Treaty establishing the European Atomic Energy Community (Euratom), signed in Rome in 1957.

The preventive nuclear safety policy set up by the European Community and its Member States since the Euratom Treaty entered into force has proved its value. The best possible protection of the public and the environment is guaranteed by regulations issued by the Member States on the basis of Euratom radiation protection directives.

Man has always been exposed to radiation from natural sources. Radiation exposure caused by the peaceful use of nuclear energy corresponds to only a very small fraction of natural background radiation and is far below internationally recognized limits.

None of the accidents that has taken place in the nuclear sector has yet caused serious radiation damage in the Community.

The nuclear installations currently in operation have been designed so that radioactive substances are released into the air, soil and water only in very small quantities. These levels are maintained in accordance with Directives adopted by the Council of the European Communities, laying down basic safety standards for the protection of the public and workers against the dangers of ionizing radiation. These are regularly



revised and updated. The measures described in this brochure offer approriate protection to people employed in the nuclear sector and to the general public.

Nuclear safety policy is in a continuous state of development as technology progresses. This involves an intensive European research effort carried out with the aid of Community funds for the benefit of all Member States and their citizens. The results of this research are taken into account in the revision of Euratom basic safety standards for protection of the public and nuclear sector workers and in the national regulations and safety measures implemented by the individual Member States.

The battery of safety measures that have been devised and the research effort they involve are neither easy to carry out nor cheap. But they have made possible the expansion of nuclear exploitation regarded as necessary by the Community.

The high standards of nuclear safety achieved for workers and the general public can serve as an example to other sectors of industry. The European Commission is working to apply the experience gained in safeguarding against ionizing radiation to protection against other forms of radiation, such as microwaves and laser beams, and to other areas as well.

Glossary

Absorbed dose: the quotient of the mean energy imparted by ionizing radiation to matter in a volume element and the mass of matter in that volume element.

Accident: an unforeseen event that causes damage to an installation or disrupts the normal operation of an installation, and is likely to result for one or more persons in a dose exceeding the dose limits.

Alpha particle: A distinct particle spontaneously emitted from the atomic nuclei of some radioactive elements, identical with the nucleus of a helium atom (1/2 He) and having the mass number 4 and an electrostatic charge of + 2. It has low penetrating power and a short range. The highest-energy alpha particles do not generally penetrate the skin. There is a danger if a substance with alpha-emitting isotopes enters the lungs or the alimentary canal.

Alpha ray: A stream of helium nuclei emitted with high energy; highly ionizing radiation with low penetrating power.

Approved medical practitioner: A medical practitioner responsible for the medical surveillance of workers of category A, whose capacity to act in this respect is recognized by the competent authorities.

Beta particle: A small particle spontaneously emitted from the nucleus of a radioactive element. It has the mass of the electron and a charge of − 1 (− 1) or + 1 (+ 1) and its mass is 1/1 840 of that of a proton or neutron. It has low penetrating power and a short range. The highest-energy beta particles penetrate the skin and tissues. Injury takes the form of skin burns.

Beta ray: A stream of beta particles emitted from a nucleus, with more penetrating power but less ionizing radiation than alpha rays per unit of path length; in certain types of radioactive disintegration a stream of beta particles is emitted.

Breeder: A reactor which generates more nuclear fuel than it consumes. A non-fissile isotope bombarded with neutrons is turned into fissile material — for example, plutonium — which can be used as a fuel. Scientists are working on being able to use this technique in all reactors some day.

Chain reaction: A chemical or nuclear reaction in which certain reaction products exert an effect on further molecules of their partners in the reaction. Once the chain reaction has started it provides the conditions for its own continuance.

Committed dose: The dose to an organ or to a tissue over a period.

Controlled area: An area subject to special rules for the purposes of protection against ionizing radiation and to which access is controlled.

Core: The heart of a nuclear reactor, where the nuclei of the fuel split and release energy. The core is normally surrounded by a reflector material which reflects stray neutrons back into the fuel.

Critical assembly: an assembly of fissile materials in which it is feasible to maintain a chain reaction.

Disintegration: The process of spontaneous fission of an atomic nucleus, with separation of a particle and/or a photon. The disintegration rate of a quantity of a given radioactive nuclide is dependent upon the number of atoms present and a decay constant characteristic of the nuclide in question.

Dose limits: The limits laid down for the doses resulting from the exposure of exposed workers, apprentices and students, and members of the public, excluding the doses resulting from natural background radiation and exposure of individuals as a result of medical examination and treatment undergone by them. The dose limits apply to the sum of the doses received from external exposure during the period considered and the committed doses resulting from the intake of radionuclides during the same period.

Effective dose: The sum of the weighted average dose equivalents in the various organs or tissues.

Electromagnetic radiation: A self-propagating wave motion resulting from changes in electrical or magnetic fields. Common electromagnetic radiations range from the short-wavelength X-rays (and gamma rays) through the ultraviolet, visible and infrared spectral ranges to the relativiely long-wavelength radar and radio waves. All electromagnetic waves move at the speed of light in a vacuum.

Electron: A negatively charged particle, the fundamental component of all atoms. A unit of negative electricity equal to 4.802×10^{-10} electrostatic units. Its rest mass is 0.000548 AMU and about 1/1 840 of the mass of the hydrogen atom. It is not present in the nucleus of the atom but orbits around the nucleus.

Exposed workers: Persons subjected, as a result of their work, to an exposure liable to result in annual doses exceeding one-tenth of the annual dose limits laid down for workers.

Exposure: Any exposure of persons to ionizing radiation. A distinction is made between:
(i) external exposure: exposure resulting from sources outside the body;
(ii) internal exposure: exposure resulting from sources inside the body;
(iii) total exposure: the sum of external and internal exposure;
(iv) continuous exposure: prolonged external exposure the intensity of which may, however, vary with time, or internal exposure due to continuous intake although its level may vary with time;
(v) single exposure: external exposure of short duration, or internal exposure resulting from the intake of radionuclides over a short period;
(vi) whole-body exposure: exposure regarded as uniform throughout the body;
(vii) partial-body exposure: exposure predominantly of part of the body or of one or more organs or tissues, or exposure which is not regarded as uniform throughout the body;
(viii) planned special exposure: an exposure causing an annual dose to exceed one of the annual dose limits laid down for exposed workers, permitted exceptionally in certain situations during normal operations when alternative techniques which do not involve such exposures cannot be used;
(ix) accidental exposure: exposure which is of a fortuitous and involuntary nature and whereby one of the dose limits laid down for exposed workers is exceeded;
(x) emergency exposure: an exposure justified in abnormal conditions in the interests of bringing help to endangered individuals, preventing exposure of a large number of people or saving a valuable installation, whereby one of the dose limits laid down for exposed workers is exceeded, and whereby the limits for planned special exposures may also be exceeded. Emergency exposures shall apply only to volunteers.

Fall-out: The soft radioactive particles which fall back to the earth's surface after they have been sucked up or thrown into the atmosphere in the event of nuclear explosions.

Fission: Process in which the nucleus of a given heavy element splits into (as a rule) two nuclei of lighter elements. The most important fissile materials are uranium – 235 and plutonium – 239.

Fission products: A general term for the complex mixture of materials produced by nuclear fission. A distinction is made between these materials and the immediate fission products or fission fragments formed by the actual splitting of the nuclei of heavy elements. In about 40 different kinds of fission of a given fissile material — e. g. uranium – 235 or plutonium – 239 — some 80 different fission fragments are produced. Since these fragments are radioactive they immediately start to decay, forming additional (daughter) products; the result is that the complex mixture of fission products formed in this way contains some 200 different isotopes of more than 30 elements.

Fusion (thermonuclear reaction): A nuclear reaction in which light nuclei are fused together to form heavier nuclei; the energy for the reaction is supplied in the form of kinetic energy from violent thermal motion of the particles at very high temperatures. If the colliding particles are appropriately selected and the movement is strong enough, energy is released in the reaction.

Gamma radiation: Short-wavelength electromagnetic radiation (photons) spontaneously emitted from the nucleus of a radioactive element.

Germ cells: The reproductive cells of an organism.

Half-life: The time taken for the activity of a particular radioactive element to decay to half its original value. The half-life is a characteristic constant for each radioactive element and independent of the quantity or state of that element.

Induced radioactivity: Radioactivity which is generated in certain materials as a result of nuclear reactions — especially neutron capture — and which is accompanied by the formation of unstable (radioactive) nuclei.

Intervention level: A value of absorbed dose or dose equivalent or a derived value fixed in connection with the drawing-up of emergency plans.

Ion: Any atomic particle, atom or chemical radical (group of chemically combined atoms) with a positive or negative electrical charge caused by a surplus or lack of electrons.

Ionizing radiation: Radiation consisting of photons or of particles capable of producing ions directly or indirectly.

Ionization: The division of a normally electrically neutral atom or molecule into electrically charged constituents. The term is also used to describe the degree or extent to which this division takes place. Ionization is the direct or indirect dislodgement of an electron (negative charge) from the atom or molecule, leaving a positively charged ion.

Ionizing radiation: Electromagnetic radiation (X-rays or gamma rays, photons, quanta) or particle radiation (alpha particles, beta particles, electrons, positrons, protons, neutrons and heavy particles) which can generate ions by direct or secondary processes.

Irradiation: Exposure to radiation.

Isotopes: Different forms of a chemical element with the same properties but differing in their mass number (since they have different numbers of neutrons in their nuclei) and in their nuclear properties, e. g. radioactivity, fission. Hydrogen for instance has three isotopes with masses of one, two and three atomic mass units (AMU). ^{2}H and ^{3}H are called deuterium and tritium respectively. The first two forms are stable (non-radioactive) but the third is a radioactive isotope. Other examples are the common isotopes of uranium with masses of 235 and 238 AMU respectively, which are radioactive and emit alpha particles; they have different half-lives. Uranium – 235 can be split by neutrons of all energy ranges, but in the case of uranium – 238 fission can be produced only by means of high-energy neutrons.

Members of the public: Individuals in the population, excluding exposed workers, apprentices and students during their working hours.

Moderator: A substance used to slow down neutrons from the high energy range in which they are released to lower energy levels (as a rule thermal). The neutrons lose energy in scattering collisions with the nuclei of the moderator.

Molecule: The smallest particle in a chemical compound which can exist independently and still retain all the chemical properties of the original substance.

Natural background radiation: All ionizing radiation from natural terrestrial and cosmic sources, to the extent that the exposure which it causes is not significantly increased by man.

Neutron: Neutral particle (i. e. with zero charge) which has a mass of almost unity and is present in all atomic nuclei apart from the nuclei of common (or light) hydrogen. Its rest mass is 1.00893 AMU. Neutrons are used for initiating the fission process and large quantities of neutrons are produced in fission and fusion reactions in nuclear explosions (atomic explosions).

Photon: An energy particle, emitted or absorbed in the form of electromagnetic radiation, whose energy is the product of its frequency and Planck's constant ($E = hv$).

Proton: An elementary particle with a positive electrical charge identical to the negative charge of the electron. Rest mass: 1.007575 atomic mass units.

RAD: Abbreviation for 'radiation absorbed dose'. The unit of energy dose equal to 100 erg/g.

Radiation:

(a) Emission and propagation of energy in space or through a material medium in the form of waves, e. g. electromagnetic waves, or in the form of sound and elastic waves.

(b) The energy that is propagated in space or through a material medium in the form of waves, e. g. electromagnetic or elastic waves. The term 'radiation' or 'radiation energy' normally refers, unless more precisely defined, to electromagnetic radiation; this radiation is generally graded according to its frequency as Hertzian waves, infrared radiation, visible radiation (light, ultraviolet radiation, X-rays (roentgen rays) and gamma rays.

(c) Emissions such as alpha and beta rays or rays of mixed or unknown type, e. g. cosmic rays.

Radioactive contamination: the contamination of any material, surface or environment or of a person by radioactive substances. In the specific case of the human body, this radioactive contamination includes both external skin contamination and internal contamination irrespective of method of intake.

Radioactive substance: Any substance that contains one or more radionuclides, the activity or the concentration of which cannot be disregarded as far as radiation protection is concerned.

Radioactivity: Spontaneous emission of radiation, normally alpha or beta particles often accompanied by gamma rays, from the nucleus of an (unstable) isotope. As a result of this emission the radioactive isotope is transformed into the isotope of another element which can also be radioactive (it decays). Ultimately, as the result of one or more phases of radioactive decay, a stable (non-radioactive) end product is formed.

Somatic cells: Cells of the body which normally, unlike germ cells, have two sets of chromosomes.

Source: An apparatus or substance capable of emitting ionizing radiation.

Supervised area: An area subject to appropriate supervision for the purpose of protection against ionizing radiation.

X-rays (roentgen rays): Penetrating electromagnetic radiation with a wavelength very much shorter than that of visible light rays. X-rays are normally generated by bombarding a metal target with fast electrons in a high vacuum. In nuclear reactions the photons produced in the nucleus are called gamma rays and those originating in the parts of the atom outside the nucleus are termed X-rays. X-rays are also called 'roentgen rays' after their discoverer, W. C. Roentgen.

Whole population: The entire population, including exposed workers, apprentices, students and members of the public.

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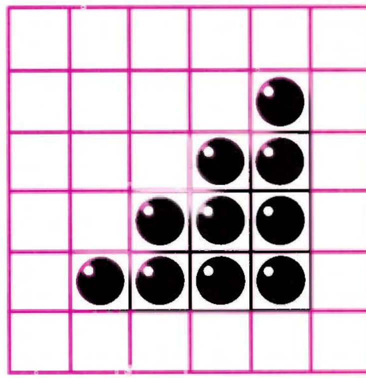

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