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Hazards of Radioactive Waste :

Odourless, Tasteless and Dangerous

When the dangers of radioactive fallout were disclosed, a worldwide outcry went up. Public alarm compelled military and political leaders to curtail - at least somewhat - their headlong and shortsighted programmes for testing nuclear weapons. The nuclear arsenals remain the gravest threat to our survival; there must be no diminution of concern on that front. But the peaceful applications of atomic radiation and nuclear energy also raise increasingly serious questions.

When you don't want something, you throw it away. You pour it down the sink or toss it in the dustbin, and somehow or other it disappears. That's the last you see of it, and the last you think of it. Unfortunately, this casual, carefree approach to waste disposal is becoming increasingly indefensible. The situation is serious enough when the waste in question can be successfully recycled by the biosphere - the overworked bacteria in the sewage plants are already hard pressed to keep up with us. But the problem acquires a new and even more challenging dimension when the waste is radioactive.

Natural Background

The radioactivity of our surroundings is by no means entirely our own doing. Human beings have always eaten, drunk and breathed radioactive substances which are part of the natural environment. Your body contains about one ten-thousand-millionth of a gram of radium. That may not sound like much; but in each second about four of these atoms of radium undergo radioactive disintegration, firing destructive alpha -particles through your body-tissues. The familiar element potassium, essential to your physiology, includes with its stable atoms a significant proportion of radioactive ones, emitting beta particles at a rate of perhaps four thousand per second inside you, Like it or not, you yourself are radioactive. You are also exposed to a steady crossfire from outside, cosmic rays from above and beta and gamma-radiation from uranium and thorium products in the earth and air.

These various internal and external radiations make up what is called the natural background. On average your body-tissues receive a dose of about 0.3 millirads (see accompanying table of units) per day from this natural background - that is, they absorb about 0.03 ergs of energy per gram of body weight. Is this harmful? In a sense the question is academic: the natural background is an inescapable part of the biophysical system we share. Nonetheless there is abundant evidence that energy absorbed from so-called 'ionizing' radiations like these is invariably disruptive to the delicate structures of living tissue. Evidence from Hiroshima and Nagasaki and from accidents involving radioactive materials indicates that a whole body exposure to 600 rads will kill 95 out of 100 human beings, death coming within two weeks of the irradiation.

The Genetic Question-mark

In the seventy-five years since Roentgen discovered X-rays man has been generating ionizing radiation in addition to the natural background. The International Commission on Radiological Protection (ICRP) maintains a continuing review of all available information on the biological effects of radiation. As we shall see, British standards for the control of man-made radioactivity are based on ICRP recommendations. But agreement on such standards is far from unanimous. If it were possible to demonstrate convincingly that there is a threshold radiation dose level below which no damage to tissue occurs, it would be relatively easy to establish guidelines for man-made radiation. But no such demonstration has been achieved. On the contrary it seems probable that the amount of tissue damage is proportional to the dosage, and that even very low doses may cause damage which we are simply unable to measure, whose consequences may not materialize for many years.

Radiation requires peculiarly stringent control not only because of the possible harm to individuals but also because of the long-term ge netic effects. A fleeting exposure to radiation may have no noticeable significance for the person exposed; but the radiation may nonetheless produce minute alterations in the genetic information stored in his reproductive cells. If one of these altered cells participates in the formation of his offspring the genetic alterations will be perpetuated in the next generation, with unforeseeable results. Experiments dating back to the Nobel Prize-winning work of Muller in the 1920s indicate that irradiation of chromosomes increases the rate of mutations in succeeding generations. The odds against such occurrences are extremely high in single instances; but the collective effect of even a small increase in the radiation-exposure of a whole population may not be negligible. We don't know, nor can we in honesty make any valid predictions. In such a context, the question of radioactive waste becomes a matter for urgent concern.

Man-made Radioactivity

By far the largest man-made addition to the radioactive burden of the earth has been the fallout from detonation of nuclear explosives. The additional radioactivity released into the environment during the years of active nuclear weaponstesting in the atmosphere amounted to thousands of millions of curies. A considerable proportion of this nuclear debris consists of isotopes with a long 'half-life', whose radioactivity will persist for decades. Nuclear explosions are still being triggered; France and China test nuclear weapons, and the American Atomic Energy Commission proceeds with its programme, persuasively named Plowshare, for industrial use of nuclear explosives, with the eager backing of French, Belgian and West German descendants of the vast Nobel armaments complex.

Such massive injections of added radioactivity into our surroundings demonstrate an appalling lack of concern for the possible consequences, and must be deplored. But as the build up of environmental radioactivity from nuclear explosions slows somewhat, a new factor is beginning to enter the picture: the 'planned release'. Many industrial, medical and research applications of radioactivity involve the production of waste material which has become radioactive. This waste can be anything from a paper handkerchief used in a radiotherapy ward to intensely radioactive fission products from the spent fuel elements of a nuclear reactor. The difficulty is that radioactivity, once turned on, cannot be turned off. You can pour radioactive dishwater down the sink, but wherever it goes it will still be radioactive, and potentially dangerous. The radioactivity of many materials will die away rapidly; if you store the waste for a few days or a few weeks its activity will then be nothing to worry about. But the radioactivity of some substances remains almost undiminished for centuries, and the requirements for storage are of a wholly different order. If you pour such substances down the sink, literally or figuratively, you are executing a 'planned release', adding new radioactivity to the environment.

Radioactive Waste in Britain

In Britain radioactive waste is produced by hospitals, universities, some industries, the Central Electricity Generating Board, the South of Scotland Electricity Board, the Royal Navy, and - above all - the United Kingdom Atomic Energy Authority. Such waste is subdivided into three grades: low activity (such as the paper handkerchief aforementioned), medium activity (such as liquid body waste from the same ward), and high activity (such as fission products from reactor fuel). The waste is also subdivided into solid, liquid and gaseous.

An abundant literature details handling and disposal procedures for the various classes of waste. The most important are the Nuclear Installations (Licensing and Insurance) Act 1959, and the Radioactive Substances Act 1960. The former Act lays down the regulations as they apply to the electricity generating boards and the Atomic Energy Authority, the latter as they apply otherwise. These Acts are administered by the Ministry of Housing and Local Government; in the case of nuclear installations the responsibility is shared with the Ministry of Agriculture, Fisheries and Food. Elaborate directives specify procedures for disposal and limits on amounts. An explanatory memorandum entitled *Radioactive Substances Act 1960*, available from HMSO for 1s 6d, gives details. Low activity radioactive waste is disposed of, with certain restrictions, just like other waste: gaseous waste is discharged through chimneys and liquid waste into sewers; solid waste is buried on local-authority dumping-sites. But more active wastes receive more careful handling, as will be described shortly.

Prosecution and penalties are provided for failure to comply with regulations, although evasions seem relatively infrequent; a Ministry spokesman could recall only a single case in 1969, an illegal disposal of used luminous material that resulted in a fine of £100. Agencies of the Ministeries carry out spot checks on liquid and gaseous discharges; but the main responsibility for monitoring major discharges lies with the producers themselves, especially the nuclear reactor plants and related installations.

The Lowestoft Reports

Independent monitoring of radioactive discharges from these sources is carried out by the Fisheries Radiobiological Laboratory in Lowestoft, under the direction of the Ministry of Agriculture, Fisheries and Food. Since 1967, the Lowestoft laboratory has published a yearly report, *Radioactivity in Surface and Coastal Waters of the British Isles*. The three reports issued thus far suggest that the control of radioactive discharges is subject to much more scrupulous and stringent policing than any other type of waste discharge. Each separate discharge is followed through its subsequent dispersal in the environment; all special circumstances of possible reconcentration by biological processes are taken into account before the permitted level of discharge is set according to the guidelines of the ICRP.

THE LANGUAGE OF RADIOACTIVITY

The curie*: describes how radioactive a source is (how much radiation it gives off); one curie (originally the activity of one gram of radium) represents thirty-seven thousand million atoms undergoing 'decay" (emitting radiation) per second.*

The roentgen*: describes how effectively a beam 'ionizes' (knocks electrons off) molecules; strictly applicable only to air.*

The rad*: describes how much energy is delivered to living tissue by ionizing radiation;one rad delivers 100 ergs per gram of tissue, about equivalent to one dental X-ray. A beam of one roentgen produces an exposure of one rad for most radiation.*

The most famous example is the small group of people in Wales who eat a type of bread called laverbread, made partly from seaweed. The seaweed used in laverbread concentrates certain radioactive isotopes from the coastal waters where the seaweed grows. These isotopes originate primarily from the Windscale establishment of the UKAEA in Cumberland. A spokesman for the UKAEA observes accordingly that the laverbread-eaters of south Wales determine the permitted level of effluent radioactivity from Windscale: this level is set to assure that the so-called 'critical group' eating laverbread do not under any imaginable dietary circumstances ingest an amount of radioactivity approaching the ICRP recommended maximum for safety. Similar individual assessments are applied to each separate discharge.

In view of the possible hazards this intensive scrutiny is entirely appropriate; but if other industries were compelled to maintain similar standards of effluent-control there's no doubt that the air and water of Britain would be much cleaner and healthier than they are. The nuclear industry and its government monitors could teach their colleagues some valuable lessons. Nonetheless, there must be no resting on laurels. The number of major sources recorded in the Lowestoft report has increased every year. The ICRP recommendations are cautious in the extreme; but environmental radioactivity can never be regarded as completely innocuous.

Atlantic Dumping

A major problem with low activity waste is its sheer bulk. Broken glassware from radiochemical laboratories, contaminated paper and fabric, et cetera, accumulate at a rate which can make adequate burial difficult. In 1965 the European Nuclear Energy Agency, a sub-section of the Organisation for Economic Co-operation and Development, undertook a massive project ultimately reported under the title of 'Radioactive Waste Disposal into the Atlantic 1967'. Preliminary consideration of the dumping project involved oceanographers, marine biologists, fishery experts and radiation protection specialists drafted from the top levels of the professions in several countries. The feasibility of the project was established by the initial Hazard Assessment (the capitals are in the report). A team of waste-treatment specialists convened to determine the best procedure, and laid down detailed specifications for preparation of the material to be dumped. Land and sea transport men from the five participating countries, Britain, France, West Germany, Belgium and the Netherlands, set out elaborate logistical timetables for movement of the cargo to the ports; in the event these time-tables were adhered to with few and minor deviations. Scrupulous monitoring throughout the various road and rail journeys and five sea voyages indicated that exposure of personnel and public remained well below ICRP-recommended levels.

The dumping itself took place from 30 May 1967 to 14 August 1967. A total of 35,790 specially sealed oil-drums with a gross weight of 10,895 tonnes and a measured radioactivity (at the time) of 7,889 curies were dumped overboard in a location in 'the North East Atlantic Ocean' where the depth exceeded 5,000 metres. The precise location of the dumping area is one of the few details not given in the report.

At the time, and since, understandable doubts have been expressed about operations of this kind. The long-term effects of such dumping cannot be foreseen with any guarantee of completeness. But a fair appraisal of this report suggests that virtually no possible detail was overlooked or undervalued. The report makes absorbing reading. It is commendably direct and forthright, free of jargon and unexpectedly reassuring.

Nevertheless, there is no room for complacency. Dumping of radioactive wastes at sea has not by any means always been subject to such scrupulous care. Furthermore, by any criterion eight thousand curies is a substantial addition to the radioactive burden of the environment. Another dump under ENEA auspices took place in 1969, and was mentioned casually as being 'about the same' as the 1967 dump. It's true that the tonnage dumped in 1969 was lower than that dumped in 1967; but this is trivial. On the other hand, the measured radioactivity dumped in 1969 was some 22,600 curies, nearly three times the activity dumped in 1967. The 1969 dump was referred to only in a brief subsection of an ENEA report; and the question arises whether deep-ocean dumping is coming to be taken for granted. If so, if familiarity makes such undertakings routine, we are incurring an environmental debt that may have to be paid, with incalculable interest, by our children's children.

High Activity Waste

Waste from the various processes involved in operating reactors comes into a separate category, and is a much more serious problem than the low activity waste thus far mentioned. The nuclear reactions occurring in the core of a reactor create a build-up of fission products in the fuel elements. These fission products reduce the efficiency of the reactor until it becomes necessary to reprocess the fuel chemically, to retrieve the unused uranium or plutonium and remove the accumulated fission products. This involves dissolving the spent fuel in acid and treating the solution thus obtained. The unused fuel is recovered for re-use; but the remaining solution is now intensely radioactive, including some isotopes of long 'half-life' whose high activity will persist for tens of thousands of years.

What to do with waste of this kind has been an acutely troublesome question ever since the first plutonium-production reactors went into operation at Hanford, Washington, in the north-western U.S., more than twenty-five years ago. High activity waste from the Hanford plant was stored in underground tanks; the urgency of the wartime Manhattan Project for development of the atomic bomb led to over-hasty planning, the awesome implications of which have been publicised only in recent months. The vast storage 'farm' (officials avoid the term 'burial ground') at Hanford is in fact situated over a major geological fault. If an earthquake were to rupture the tanks the radioactivity released would have an effect fully as devastating as a global nuclear war.

The Hanford tanks underline dramatically the central problem of high activity fission-product waste: it doesn't go away. The Hanford tanks are no longer in active service, but they will continue to boil under their own internally -generated heat for many generations. They will require maintenance, cooling and replacement of corroded tank-walls when the obliteration of Hiroshima is as remote as the fall of Constantinople. Human history offers no prior examples of stewardship whose reliability can be foreseen on a time-scale like this; the prognosis is - to put it mildly - not good.

Windscale

The United Kingdom Atomic Energy Authority operates a fuel-reprocessing plant at Windscale. Waste handling at this plant represents much the most serious challenge to the safety-consciousness of the British nuclear industry. The UKAEA takes a great deal of pride in its safety record, which - with the classical exception of the Windscale reactor accident in October 1957 - compares favourably with those of other British industries. The Authority is far from reluctant to discuss its operations, and seems to feel that it has a responsibility to provide the public with relevant information. Such an attitude is certainly to be commended, offering as it does an opportunity for rational evaluation of problems and prospects. One of the most pressing of these problems is certainly that of the handling of high-activity waste.

Fuel reprocessing at Windscale produces two kinds of high-activity waste, solid and liquid. The outer casings of used fuel elements must be stripped off; these casings, severely contaminated with fission products, are stored underwater in concrete silos on the grounds of the Windscale establishment. After the spent fuel has been dissolved and the reusable uranium and plutonium extracted, the remaining solution is fed into storage tanks elsewhere in the grounds. There are at present nine of these tanks, eight with capacities of 70 cubic m each and one with a capacity of 150 cubic m. Each tank has an inner wall of 1/2 inch stainless steel, enclosed in a separate outer wall of stainless steel and surrounded by reinforced concrete 5 feet thick. The intense radioactivity of the liquid makes it boil with its own internally-generated heat; each tank is equipped with duplicated water cooling circuits. One of the tanks is a standby tank; the radioactive liquid can be pumped from tank to tank if the need arises.

In the last three years the contents of the tanks have increased by 120 cubic m; the rate of increase is now about 45 cubic m per year. The total radioactivity of the liquid now in the tanks is several hundred million curies. For comparison it's worth mentioning that the estimated total radioactivity of all the oceans of the earth is several hundred thousand million curies: the tanks at Windscale already contain about one tenth of one per cent of this activity in a volume less than that of one detached house.

As more and more reactors come into service in Britain the high-activity waste is accumulating ever more rapidly in the silos and tanks at Windscale. The UKAEA also reprocesses fuel from British-built reactors in Italy and Japan; the waste goes into the Windscale tanks. The UKAEA comments, with disarming casualness, that the Windscale tanks will have to be tended 'for 500-1,000 years'. It is difficult to believe that they themselves look upon the situation with such aplomb. Precious few of the works of man have even survived for such a length of time, much less been tended with the assiduousness required to pamper the furious contents of the high-activity tanks.

Needless to say alternative methods of handling high-activity waste are under urgent investigation. Glassification - concentration and scaling of the waste into solid ceramic bricks - appears the most promising. Once glassified, the waste will no longer be capable of escaping into the environment as a result of accident or natural catastrophe. But glassification is still early in the development stage. Furthermore, even if glassified, the high activity waste will continue to accumulate as long as reactors are operating and creating it.

The Energy Dilemma

Our technological culture demands ever more power: were you one of the many uttering imprecations at the Central Electricity Generating Board when your electric fires dimmed last winter? Power must come from somewhere. Fossil-fuel power plants create their own hazards: these include atmospheric pollution with sulphur dioxide, and disturbance of the carbon dioxide balance in the biosphere. Furthermore, the earth's remaining reserves of irreplaceable fossil fuel are limited, and could be better employed as raw materials for many manufacturing processes, Against these considerations must be weighed the increasing burden of man-made radioactivity created by nuclear power generation.

Controlled thermonuclear fusion, the technologists' dream, seems likely to remain a dream for the foreseeable future. Solar power is unlikely ever to make much contribution during a British winter. If we must have more power, there is certainly a strong case in favour of nuclear power. But its drawbacks must also be recognised. As must now be stressed in every industrial context, it is imperative that the true economic picture take into account not only the current balance-sheet but also the long-term environmental debt, which may well be extremely difficult to quantify. At the time of writing, the UKAEA has an application pending, to increase the level of effluent discharge from Windscale into the Solway Firth: from 450 curies per quarter to 2000 curies per quarter. The Ennerdale Rural District Council has registered vigorous opposition to the increase. Asked what would be the consequence of refusal of the application, a UKAEA spokesman said simply, 'We'd have to cut back the nuclear power programme'.

If we want the undoubted benefits of nuclear power, radiotherapy and the many other applications of man-made radioactivity that are becoming part of our everyday life, we must recognise what we are buying, and what we are paying for it. Unfortunately, some of the bills may not arrive until it's no longer possible to return undesired goods.