Pollution and People

Radiation exposure and the protection of the community

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Decisions about nuclear power clearly entail value judgments. But the issues also have to be looked at in the wider context of radiation exposure from all sources—and in the context too of controversy about the theoretical aspects. Radiation dose limits are recommended by the International Commission on Radiological Protection,[1] but some people are arguing that they are set too high.[2]

Epidemiological evidence, as discussed in the last article (p 1479), does not show clearly how we should extrapolate from the long-term effects of high or moderate radiation doses to those of low doses.[3] Authorities differ in the weight they attach to experimental data, but neither do these at present permit a definite decision between the different possible dose-response models (effect proportionate to the dose or to the square of the dose, for example): we first need fuller knowledge of the processes of cancer development in man.[4] According to the most widely held view, however, the cellular and other mechanisms indicated by radiobiological research strongly suggest that the risk from low doses of low-LET (linear-energy-transfer) radiation is not underestimated by linear extrapolation from the risk at moderate levels—it may be somewhat (perhaps considerably) overestimated.[5] For low doses of high-LET radiation on the other hand a linear extrapolation is likely to give good estimates. High doses of any radiation kill many cells—in fact they may preferentially kill transformed cells[6]—and so cancers are likely to be relatively fewer, with a turn-down of the dose-response curve (fig 1, last article, p 1480).

According to most (but not all) of the data on animals exposed to low-LET radiation, linear extrapolation does give an overestimation of risk for low doses or dose rates.[7] This is explained on the grounds that cellular repair mechanisms can make good much of the damage to the DNA produced by low-level low-LET radiation. Radford,[4] who—though chairman of the carcinogenic effects subcommittee—presents a dissenting view in the third report of the Biological Effects of Ionising Radiations Committee (BEIR III), comments that the committee was strongly influenced by animal studies in adopting the intermediate linear-quadratic dose-response model. He points out the well-known limitations of work on animals: for example, they may have different types of tumours, with perhaps quantitatively different mechanisms in response to radiation; they have a shorter life span than man in which to develop tumours; and in a laboratory environment they are little exposed to cancer-promoting agents, so that radiation must be sufficient to act as a "complete carcinogen" and not just an initiator. Unlike genetic defects, where the BEIR Committee does consider that risk is proportionate to dose, many processes (probably differing in importance from species to species) are accepted as modifying or facilitating the development of tumours once the initial damage has occurred; they include immunological, hormonal, and probably viral factors. Radford, however, proposes that they are independent of radiation dose and that the same model suits both genetic effects and cancer.

He particularly questions the idea that pairs of cellular "sublesions" are needed to initiate all cancers—this would indeed plausibly make risk proportionate not to the dose but to the square of the dose (a quadratic relationship) for low-LET radiation with its less frequent "hits"; and he also criticises the BEIR Committee for proposing a linear-quadratic dose-response relationship for solid tumours as well as for leukaemia. The chromosome abnormalities found in leukaemia, notably chronic granulocytic leukaemia, do point to a "two-break event" damaging the DNA, and thus to a dose-squared relationship; but these chromosome abnormalities suggest, he says, a different mechanism from that underlying solid tumours —and the much shorter latent period in leukaemia also points to a different mechanism.

Finally, recent work on cellular effects challenges traditional concepts, claims Radford: for example, DNA repair mechanisms may not necessarily entail a relatively smaller carcinogenic effect of low-LET radiation at low doses. One cell culture study showed that splitting a given radiation dose actually increased oncogenic transformations at low doses, though it reduced the effect at high doses.[8] If applicable to man (and it may be a large "if"), this could be relevant to the repeated small doses from occupational and environmental radiation. The BEIR Committee itself discusses the evidence for relatively increased effects at low dose rates (ch V, appendix B) and concludes that

Radiobiological protection and the ICRP

Radiation protection, says the International Commission on Radiological Protection (ICRP), "is concerned with the protection of individuals, their progeny, and mankind as a whole, while still allowing necessary activities from which radiation exposure might result."[1] It has long held that no radiation greater than that from the natural background (in Britain around 1 mSv (100 mrem) a year) can be considered safe, so that "justifiable exposures" should be kept "as low as is reasonably achievable, economic and social factors being taken into account." Thus no practice should be adopted unless it produces "a positive net benefit." It recommends radiation limits designed to restrict the probability of cancers and genetic defects; the latest recommendations[1] are in the process of being adopted in Britain. The annual whole-body radiation exposure must not exceed 50 mSv (5 rem) for workers or 5 mSv (0·5 rem) for the general public; but exposures should generally be well below these limits.

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more work is needed on the possible role of cell membranes in carcinogenesis.[3]

Miscellaneous sources of radiation

If there is no threshold dose for long-term radiation effects we must look critically at all sources of exposure.[9 10] For many people medical irradiation is much the most important source and even when averaged over the population it is the largest man-made source, diagnosis accounting for the greater part of the genetically significant dose.[9] Despite the improvements prompted by the Adrian Committee over 20 years ago, it is still thought to offer the greatest scope for reduction in the radiation exposure of the population as a whole.[9 11] For example, even though Britain compares well with other countries in the genetically significant dose from this source,[12] the variation between different hospitals in the dose to the gonads from a given type of examination is just as great now as in the late 1950s, the highest doses being three or four times the lowest.[13] The potential of current equipment for limiting the radiation dose does not appear to be fully exploited, and gonad shields are often not used for patients who should have them.[13]

Fallout from nuclear weapon testing in the atmosphere has been the main source of environmental contamination,[14] though it should soon contribute less to the average dose to the population than consumer products and other sources (fig 1).[9] Of the

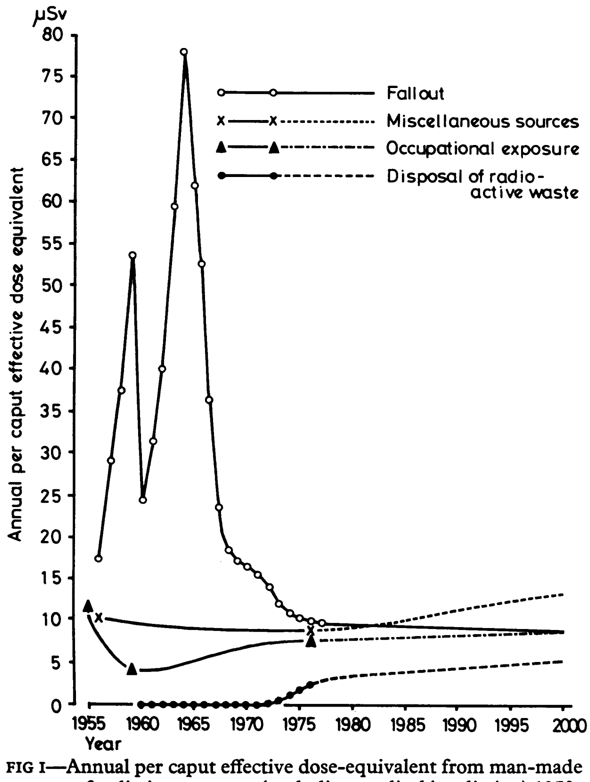

FIG 1—Annual per caput effective dose-equivalent from man-made sources of radiation exposure (excluding medical irradiation) 1950-2000. (1 µSv=0·1 mrem.) Reproduced by courtesy of the National Radiological Protection Board from *Radiation exposure of the UK population*.[9]

various other sources of radiation exposure,[14] air travel (because of increased exposure to cosmic rays with altitude) and wearing luminous watches make the largest contributions to the average dose in Britain.[9] While most modern watches are luminised with tritium paint giving a negligible radiation dose, old watches have radium-226 luminous paint that may produce considerable radiation (several tens of mSv or several rems a year to the wrist). Television receivers though ubiquitous produce little exposure. A scheme for mandatory approval of consumer products giving off radioactivity is to be introduced in Britain, though this is not expected to make much difference as a voluntary scheme is already in operation. Because large numbers of people may be affected, radioactive products and materials must always be scrutinised—and alternatives developed if the radioactivity is not essential, or else their use discontinued if possible.[10]

Nuclear power and the risk of accidents

Part of the case against the development of nuclear power centres on the potentially catastrophic consequences of accidents at nuclear power plants—however rarely a serious accident might occur. (According to an American analysis, one "extremely serious" reactor accident might have a perhaps 25% chance of occurring in 5000 reactor years of operation given a combination of the most unfavourable assumptions; but the probability was thought more likely to be 10 or 100 times lower.[15]) The most notorious accident so far has been the one at Three Mile Island, near Harrisburg, Pennsylvania.[16] Despite the alarming series of technical and human failures and shortcomings the release of radioactivity was modest, giving average doses equivalent to about one month's background radiation (nearly 0·1 mSv or 10 mrem) in the surrounding 8 km,[17] though some doses up to about 0·9 mSv were received. One or two extra deaths from cancer are possible but not certain, according to the President's Commission (compared with the 325 000±1000 likely to occur in total among the population of 2 million)[18]—though very large figures have also been suggested.[19] How close the reactor was to a larger disaster remains unclear. The commission concluded that the system had put too much emphasis on equipment and regulations and not enough on people: safety, it said, could not be achieved merely through technical "fixes," which is not entirely reassuring. The Health and Safety Executive has pointed out that the UK system is free of many of the weaknesses that made the Three Mile Island accident possible, though there are lessons to be learnt; and that the projected British pressurised water reactor need not therefore be abandoned in favour of another of the advanced gas-cooled reactors.[17] This is a point of considerable controversy.[20] Moreover, the American recommendation that remote sites should be used would be difficult and not necessarily appropriate for Britain to follow.

Less spectacular but still worrying from the viewpoint of human fallibility is the occurrence of the various radioactive leaks at Windscale. Before the latest one was discovered the management had not believed the liquids in the building concerned to be radioactive and had not thought it necessary to check them.[21] More generally, Britain's good nuclear safety record may be put in jeopardy by the diminishing viability of the Nuclear Installations Inspectorate.[20]

At the Windscale Inquiry various projections were made for an accident arising from the storage of highly active waste[2]: for example, a 0·1-0·3 probability of one or more cancers among the public as a result of loss of cooling in radioactive tanks and ponds; 50-200 deaths after a "worst case" accident; and—as a consequence of prolonged loss of cooling of spent fuel ponds, with a radioactive cloud passing over Manchester and Liverpool —over 5000 deaths and over 55 000 cancers later. This is not, however, necessarily a plausible scenario. An American analysis, however, calculates, for an "extremely serious" accident, 3300 immediate deaths, 45 000 cases of early illness, 45 000 cancers and 240 000 cases of thyroid nodules in 30 years, and 30 000 genetic defects in 150 years.[15]

One possible type of accident that is much discussed concerns the transport of nuclear waste.[22] What would happen to a flask of radioactive spent fuel elements en route to Windscale if there were a serious rail accident? The Central Electricity Generating Board considers that only minor radioactive contamination up to 50 metres from the flask is possible (from leaking water), pointing out that tests have shown the flasks to remain unbroken.

Others disagree, however, and the calculations of one group suggest six immediate deaths and 600 deaths from cancers after a bad accident.[22] The UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimates the risk of a transportation accident as about one in a million per vehicle-mile, severe impact or fire occurring in under 1%.[14]

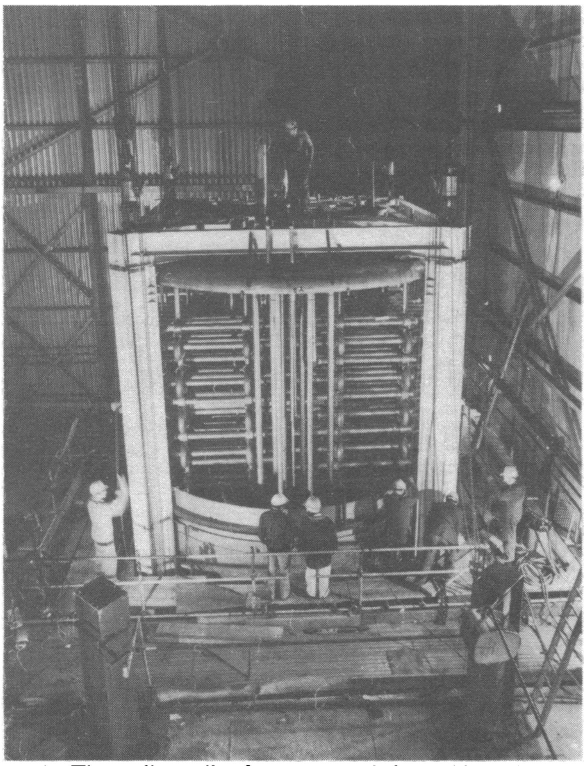

FIG 2—The cooling coils of a storage tank for highly radioactive fission product waste shown during insertion into a newly completed tank at the Windscale works, Cumbria. Reproduced by courtesy of British Nuclear Fuels Limited.

Radioactive waste

The disposal of radioactive waste raises both immediate and long-term problems.[23] Discharges of low-level radioactivity from nuclear power plants into the atmosphere and into the sea must be such that absorbed doses are kept well within the limits set by ICRP; highly active waste from reprocessing must be stored and cooled safely until it becomes more manageable; and arrangements must be made for permanent disposal. While for most fission products the half life is under 30 years, for several of the actinides it is hundreds of thousands of years (the actinides, which include plutonium, are heavy atoms resulting from nuclear transformation following fission of uranium nuclei and irradiate people chiefly when ingested or inhaled). For permanent disposal in the future, vitrification is most favoured, the idea being to bury secure containers holding the glass blocks in stable geological formations or possibly on or below the sea bed.[23] This is argued to provide the safest form of disposal; according to one estimate the resulting radiation exposure, in a hypothetical "worst case," would give a dose under 2% of the ICRP limit after 100 000 years.[23] Some people, however, question the likelihood of long-term geological stability.

The principles governing discharges of low-level waste are that, irrespective of cost, no one must receive more than the ICRP dose limit, that all practices giving rise to waste must be justified in terms of the "overall net benefit," and that radiation exposures should be kept "as low as reasonably achievable" in the light of economic and social factors.[24] The expectation of an expert group that reported last year was that the average dose to the public would be not more than 0·05 mSv (5 mrem) in a year.[24] The main source of population exposure is at present fish contaminated with (chiefly) radiocaesium originating from the fuel element storage ponds at the reprocessing plant. Monitoring shows that the doses to the "critical" groups of the population are mostly a tiny fraction of the ICRP limit of 5 mSv (0·5 rem) a year, though the fishing community near Windscale and Calder in 1977 were estimated to have reached 31% of the limit from eating fish and shellfish.[25] But some believe that there are gaps in the monitoring system,[2] and during the Windscale Inquiry special tests were therefore carried out on Manchester water supplies, Isle of Man potatoes and scallops, the air at nearby Ravensglass, and local fish consumers. Results were reassuring—provided that no one ate anything approaching 6 kg of local fish a week.[26] But critics have also questioned the reliability of the predictions of maximum possible doses, and have emphasised too the possibility of multiple sources: someone may regularly eat fish and shellfish, walk on contaminated silt sediments, and breathe suspended plutonium.[2] Moreover, the exact risk from inhaled plutonium particles is a matter of dispute.[2]

Social judgments and decision making

There are thus many sources of controversy about the risks to the health of the community from nuclear power; yet some decisions have to be made now and the arguments may seem to be finely balanced.[27 28] The issues do not, of course, all concern health and safety. Fears of terrorist activities and the loss of civil liberties that might be necessary in a "plutonium economy" are widespread. Making home-made bombs from stolen nuclear fuel does not appear to be an effective possibility at present[29]; on the other hand, reactor-grade plutonium, it has been argued, could be used for nuclear explosions and power reactors could plausibly be used for military production.[30]

These apparently remote risks, however—as well as some risk to health and safety—should arguably be taken if developing nuclear power now is the only way to stave off a serious energy shortage in the next century.[27 28] Here again opinions differ profoundly. Some maintain that conventional energy sources would be more than sufficient if we were serious about energy conservation and developed more efficient engines, etc. Others argue that some of the "alternative" sources of energy, such as solar, wind, and wave power, will become viable in the future,[31] and that in any case nuclear power will provide only a small fraction of the needed energy for a long time to come.[32]

No one believes that the radiation risks from nuclear power are non-existent, but it is claimed that with vigilance they are comparable to those arising from many activities and natural disasters that people take into their stride.[33] This idea was developed at the Windscale Inquiry: the extra risk associated with 0·1 mSv (10 mrem) was said to be comparable to, say, smoking five cigarettes a day, rock climbing for 90 seconds, or being a man of 60 for 20 minutes.[26] More recently the National Radiological Protection Board has proposed a system of cost-benefit analysis for balancing the benefits and "detriments."[34]

Perhaps the most powerful argument in defence of nuclear power is that at present it appears safer than alternatives.[35] Every source of energy presents some hazards.[19] According to Pochin, the current estimates predict about the same rate of harmful long-term effects in "nuclear" workers as of fatal accidents in typical factory employment in Britain—that is, 3 or 4 per 100 000.[5] This assumes, however, that exposures continue at the current average of 5 mGy (500 mrad) a year; if the annual average rose to 30 mGy the risk would be equivalent to that in the coalmining and construction industries, which have about 20 accidental deaths per 100 000.[5] An American analysis concludes that new coal-fuelled power plants meeting the highest current standards will probably take a much higher toll in life and health, for workers and the public, than new nuclear plants, though there are large uncertainties in the estimates.[15]

But with both types, the report points out, health risks could be much reduced in the future—by limiting sulphur dioxide and other emissions in the case of coal-fuelled plants and by improved siting and safety controls in the case of nuclear plants.

Because of the various studies that have seemed to suggest a greater risk from low-level radiation than the ICRP recommendations allow, some people urge that the limits should be reduced by a factor of 10 or 20. But this should not surely be done without more definitive evidence, for an overestimation of risks could make for misleading comparisons with other sources of energy. Nevertheless, nuclear power has the disadvantage that some hazard, of an uncertain degree and hard to reverse, will accumulate in the genes and in the environment of our descendants (the BEIR estimate is 5-75 additional serious genetic disorders per million liveborn offspring in the first generation from 10 mSv of radiation exposure in the general population[3]). The current principle underlying permitted radiation exposure is "as low as reasonably achievable"[1] (known as ALARA). This demands the question "What is reasonable?" It is a question that should be answered by as many people as possible, on the basis of the fullest quantitative information.

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Why do patients given beta-blockers for conditions other than hypertension not develop hypotension?

The supposition behind the question is incorrect. Beta-blockers can produce a fall in blood pressure, even in normotensive individuals. The original discovery of the antihypertensive effect of the beta-blockers resulted from close observation of patients with angina who did not have appreciable hypertension. With all antihypertensive drugs the magnitude of the fall in pressure tends to be proportional to the pretreatment level. Thus the fall in pressure with a beta-blocker in a patient with hypertension will be larger, and therefore more noticeable, than in a normotensive individual. There are also some conditions where beta-blockers will not lower blood pressure and may even raise them. The most familiar example is in a patient with excess catecholamines such as might result from an infusion of adrenaline or excess sympathoadrenal activity in a phaeochromocytoma or during clonidine withdrawal. The rise in pressure in these conditions is due to the unopposed effect of alpha-receptor blockade after the peripheral beta-receptor mediated vasodilatation has been blocked by the beta-blocker. There is also some evidence that certain individuals are less susceptible to the hypotensive effect of beta-blockers and that some may even respond with a rise in pressure. The best-documented example is the reduced hypotensive response in low renin hypertension. This is of some importance with black patients as many of them have a low plasma renin concentration. Whether there is any additional reason for a small rise in pressure in some patients is a speculative question, but some people think that there is.

What is the likely cause of and treatment for a patient complaining of burning in the feet, mainly at night?

Burning of the feet is an uncommon symptom that sometimes defies accurate diagnosis and treatment. It may be a feature of neurological disease, such as in peripheral neuropathy. Some years ago it was a classic hallmark of mercury poisoning, the so-called acrodynia, but in 1980 this is most unlikely. Vascular problems should also appear on the diagnostic list, particularly vascular insufficiency and erythrocyanosis. A localised form of burning in the feet is often seen in chilblains, and sometimes early forms of eczema, such as a constitutional eczema, may present with this odd sensation. A further cutaneous explanation is erythropoietic porphyria, in which the patient may present with attacks of acute painful swellings in the limbs, although the hands are more usually affected. Finally, psychological causes including hysteria should not be forgotten. The treatment of the symptom is related to the aetiology; sometimes the treatment is relatively obvious but some of the reasons cause difficulties.