Conference of the British Occupational Hygiene Society on Radiation Hazards in Industry

The third conference of the British Occupational Hygiene Society was held at the London School of Hygiene and Tropical Medicine on November 1, 1954. The President of the Society, Professor E. J. King, was in the Chair. The following papers were read at the conference, and the discussion after each is also presented.

THE HEALTH OF WORKERS EXPOSED TO IONIZING RADIATIONS

BY

A. S. McLEAN

From the Industrial Group of the United Kingdom Atomic Energy Authority

When we consider radioactivity as an occupational health problem we are seldom, if ever, concerned with the consequences of massive doses of radiation. Although much is known about these acute effects, this knowledge is of little assistance when we attempt to weigh up the hazards of radiation work. However, we can turn to an impressive list of patients who have been injured by prolonged and relatively low-level exposure of one sort and another and there is much to be learned from the fate of these unfortunate people.

First and foremost on this list must come the uranium ore miners of Schneeberg in Saxony and Joachimsthal in Bohemia in whom cancer of the lung has long been recognized as an occupational disease. It seems likely that the main aetiological factor in these cases was irradiation of the bronchi and lungs by the radium and its products of decay which are to be found together with uranium in the dust of uranium mines.

There are those who swallowed or inhaled minute amounts of radium and mesothorium in painting instrument dials with self-luminous paints during the first world war and in the 1920s. It was customary for these workers, mainly girls, to point the tips of their brushes with the lips. These cases occurred in America and they have been studied there with customary intensity and, as a result, we now have a clear picture of chronic radium poisoning, affecting, as it does, the blood-forming tissues and bones in particular.

More recently, further information about the effects of rather smaller doses of radium has come from the study of a number of cases which were given radium by the medical profession 20 or 30 years ago in the treatment of high blood pressure and other conditions. These cases have thrown more light upon the delicate intermediate bone changes which precede the more serious and highly malignant growths which were an outstanding feature of the luminous-dial painters. At the last meeting of the Society you heard how this sort of information has been used to estimate maximum permissible levels of radiation, and many of the figures for maximum permissible levels in current use have been derived either directly or indirectly from observations made on the group of luminous-dial painters.

Many of the pioneer radiographers and radiologists sustained injuries of the skin and of the blood-forming tissues. A few years ago it was shown that in America the incidence of leukaemia used to be about nine times greater in radiologists than in the remainder of the medical profession.

Even more recently a number of cases of damage to internal organs have been shown to be due to thorium compounds, including "thorotrast".

These and other observations on human beings have, of course, been corroborated and extended by experimental work with animals, but there is the ever-present difficulty in the application to one species of knowledge gained about another.

From all of these sources of information it is possible to build up a sketch of radiation pathology.

(1) Damage of the blood-forming tissues may be shown by a variety of changes ranging from a reversible diminution in the number of white blood cells to aplastic anaemia and leukaemia, both of which must be regarded as fatal conditions.

(2) There may be a number of degenerative changes in the skin, including chronic dermatitis, nail distortion, wart formation, and malignant disease.

(3) The lens of the eye may show cataract formation.

(4) Impaired fertility may be the result of damage of the gonads.

(5) Radioactive substances deposited in bone may eventually cause peculiar forms of degeneration and malignant disease.

(6) Cancer of the lung may result from the deposition in the lungs of an insoluble radioactive substance.

(7) Radiation appears to be capable of some subtle influence upon the genes, those delicate custodians of our immortality. No effect could be more vital and the full weight of radiobiological research is now being brought to bear upon this problem. In this context, we are thinking, of course, of large populations not of individuals.

A further fact which emerges from these observations is that the susceptibility of any tissue of the body to the damaging effects of irradiation is a function of the state of cellular activity in that tissue. Thus, when all tissues are irradiated equally, the highly active blood-forming and reproductive tissues are more easily injured than, for example, the nerve tissues. Nevertheless, a less sensitive tissue may alone be damaged when it is the site of selective deposition of a radioactive substance in the body.

In this way it is possible to differentiate between two distinct processes which may operate in the production of radiation injury. Damage may result either from the irradiation of whole or part of the body from an outside source or from the irradiation of selected organs after the uptake of a radioactive substance into the body.

In the examples which have already been given, injuries of the blood-forming tissues, skin, eye, and gonads have generally resulted from external irradiation, whereas diseases of bone and lung are examples of damage following assimilation of a radioactive substance. In the latter case, modes of entry into the body are of special interest and it is clear that uptake by inhalation presents the most serious problem because of the high rate of retention

and absorption in the lungs. Nevertheless, the risk of internal contamination by swallowing cannot be neglected, and, just because the hands come into contact so often with the mouth and nose, quite unexpected difficulties may arise. The danger of uptake through skin wounds is of special importance in laboratory operations, for example, where glassware is handled. Following uptake into the body, each element will follow a characteristic pathway which is a function of its chemical properties. Iodine, for example, will concentrate in the thyroid gland, whereas many of the heavy metals, *e.g.*, radium, plutonium, are deposited selectively in bone and are known as "bone seekers".

Before discussing the methods of radiation protection it is necessary to refer again to the small but measurable quantities of radiation which are a part of our environment. It is interesting to divide these into unavoidable and "man-made" sources. In the former category are cosmic radiation and the emissions of naturally occurring radioactive substances such as potassium 40, carbon 14, radon, and uranium. In the "man-made" category are the x and gamma rays used for diagnostic and therapeutic purposes and, unfortunately, for shoe-fitting, the radiation from luminous-dial watches and clocks, and from projection television, and the substantial rise in the natural radioactivity of the atmosphere during smog. Thus, it is clearly impossible to achieve zero concentration in radiation work and we believe that the appropriate maximum permissible levels are both safe and realistic. Certainly, the minimum damaging dose, in terms of the list of injuries I have already given, is considerably greater than the maximum permissible level. It has been accepted that tiny doses of radiation are of minor significance, and "radiation work" has therefore been defined as work involving regular exposure in excess of one-tenth of the maximum permissible level.

There is a perfectly logical sequence of methods by which the hazards of radiation may be confined within tolerable limits, but all of these are dependent upon sound design and planning of operations. For example, in a situation involving an external radiation hazard, the design engineer makes use of radiation-absorbing materials which are placed between the radioactive source and the worker; in planning remotely controlled operations he will perhaps use his knowledge that a considerable amount of radiation is absorbed in air; again he may design so as to avoid continuous exposure of any one operator. But much of what is designed into a plant in the way of safety must ultimately become the springboard of the plant manager, for it

is he who has to quicken and live with the brain-child of the designer. One feature of particular interest has been the development of methods of enclosure and ventilation of the very high efficiency necessary to avoid even minute degrees of contamination.

The training of radiation workers has demanded special attention: in some cases it has been necessary to allay fears arising from the unpleasant associations of radiation with atomic bombs; in others there has been some difficulty in convincing workers of the existence of a hazard which cannot be appreciated by any of the senses. In all cases it has been our aim to present radiation hazards in perspective. Of no less importance has been the dissemination of as much information as possible among the many people who live in the vicinity of our establishments or may have special reasons to contemplate the hazards of radioactivity. It appears that there is a pressing need for popular acceptance of the slight hazard of atomic energy along with its great benefits.

Measurement of radiation hazards, or "monitoring", as it is called, differs from such detection elsewhere in one essential; the maximum permissible levels of radiation and the quantities which can be measured by modern instruments are minute by any comparison. For example, the maximum permissible level for plutonium in air is only a few millionths of a millionth of a gram per cubic metre (less than one-millionth of the comparable figure for lead) and this amount can be measured quite easily. Health physics is a new, exact, and elaborate science, and the health physicist has come into his own as a fully fledged specialist. The responsibilities of the health physicist and the medical officer are, of course, closely related, and the monitoring of the environment and of the outside and the inside of the worker himself are regarded as complementary.

Of special interest to the medical officer, however, is the monitoring of the excreta for traces of radioactive contamination. In the case of plutonium, for example, the maximum permissible body content is six-tenths of a microgram. The body content is usually estimated from the amount excreted each day in the urine and this requires the analytical chemist to separate and measure a few micro-micrograms of plutonium from, say, $1\frac{1}{2}$ litres of urine containing 60 or 70 grams of total solids.

The protection of the individual worker may require the use of a variety of types of protective clothing and breathing apparatus, many of which are conventional, although some have been developed to meet special requirements.

From the start, the atomic energy industry has

provided health physics and medical services at each establishment. The medical profession is expected to contribute by providing expert advice about occupational and public health risks and about the measures necessary to reduce them to innocuous or tolerable levels. Conventional methods are used in a variety of clinical and laboratory examinations and in the provision of treatment for casualties. Less ordinary techniques have been developed to deal with the problems of radioactive contamination of the skin and of the inside of the body. As a matter of good industrial health practice and in view of the long latent periods involved in the production of radiation injuries, it is important that the story of the health of radiation workers should be kept in the form of detailed records.

These are the principal techniques of radiation protection. The extent to which any or all of them may be required will depend upon the type and quantity of radiation or radioactive substance handled and upon the method of its application. Radiation protection accounts for a substantial part of the cost of atomic energy development, yet the price is paid ungrudgingly, although thoughtfully, for we are convinced of the great benefits that are in store for mankind.

Discussion

Dr. E. F. EDSON (Pest Control, Cambridge) said that the author had dealt with the general principles by which radiation protection could be attained in a large organization such as the United Kingdom Atomic Energy Authority. At the present time, small though very important quantities of radioactive substances were being used in laboratories, in industry, in hospitals, and in research institutions. The same problem of protection, but on a smaller scale, must arise in these small units. One of the functions of the Society, therefore, must be to spread the gospel of protection.

There were three main points of which one had to be constantly aware. The first was the intrinsic danger of the material being handled; with chemicals it was acute, subacute, or chronic toxicity. With radiochemicals it was their capacity to produce radiation injury to the cells. The second was the habits of the worker. It must not be forgotten that most workers, and indeed almost everybody, if not effectively supervised, tended to be somewhat dirty in their methods of work. With that must be linked the dirtiness of the equipment which the management provided for the worker. The third was the duration of the exposure. Those conditions he represented in the formula $D \times D \times D$ —the dangers of the material or job, the dirtiness of the methods applied, and the duration for which the individual worker was exposed.

He asked Dr. McLean to say something more about medical diagnosis and treatment. No matter how well the planning was done, casualties did occur in the laboratory, the factory, and the home.

He also asked Dr. McLean to explain what measures could be taken to determine that a worker had had in fact too much radiation or had absorbed too much radioactive substance, and how over-exposure should be treated.

In reply Dr. McLEAN said that because the maximum permissible levels were set considerably below the minimum damaging levels and because, also, of the very long latent periods involved in the production of radiation effects, the use of clinical tests to diagnose small degrees of over-exposure was not likely to be very helpful. The whole basis of diagnosis of slight total body over-exposure was physical rather than chemical and would be discussed in detail in other papers.

The clinical tests, which might be regarded as complementary to the physical tests for total body exposure, would be the examination of the number and distribution of the white blood cells in the circulating blood. This was not a sensitive test. There was an international agreement that where the average radiation exposure was less than one-third of the maximum permissible, it was most unlikely that examination of the blood would yield any useful information.

A blood count as a routine tool in radiation protection was very much in decline. This view was supplied by Mr. D. G. ARNOTT, of the London Hospital, from his experience of protecting hospital workers. At the London Hospital they did a blood count before exposure but afterwards relied on physical methods.

For internal contamination Dr. McLEANS said that the most accurate measure of what a man had absorbed was generally the estimate of the total body content made on the basis of the amount excreted in the urine. Where the radioactive material gave out a high penetration gamma radiation, as radium does, this might be measured directly by an arrangement of ionization chambers round the body of the worker.

The treatment of over-exposure was of interest,

perhaps particularly to those concerned with civil defence arrangements. The biological effects of radiation on mammalian tissues were so generalized that no one drug could be expected to provide the answer, unless it was aimed at counteracting the fundamental mechanism by which radiation produced its effect on tissue.

The sort of things which had been investigated for treating external radiation over-exposures were anaesthetics, sedatives, antibiotics, autonomic drugs, blood and blood derivatives, derivatives of the reticulo-endothelial system, hormones, alcohol, pyrogens and antipyretics, and physical methods such as variations in oxygen tension, particularly the effect of anoxia, variations in the temperature and the metabolic rate of the animal, and shielding of various portions of the body. The major conclusion arising from these investigations was that there were widespread differences of opinion about the possible usefulness of almost all these materials and methods. The only really useful method of treating radiation injury seemed to be a combination of antibiotics with certain blood derivatives. In the search for a substance which might be expected to influence the fundamental action of radiation on tissues, a promising approach had recently been suggested through investigating the relationship which appeared to exist between radio-sensitivity and the phagocytic functions of the cells of the reticulo-endothelial system.

With internal radiation it was necessary to interfere with the deposition of radioactive materials in tissues, to displace them from tissues, and to enhance the excretion rate. Metal displacement therapy with zirconium, for instance, had been tried and had been slightly effective in certain cases. Ethylenediamine tetracetic acid and its calcium disodium salt had been investigated thoroughly and was to some extent effective for contamination with certain elements such as yttrium, and one in much more common use, lead, but it was much less effective for plutonium and radium.