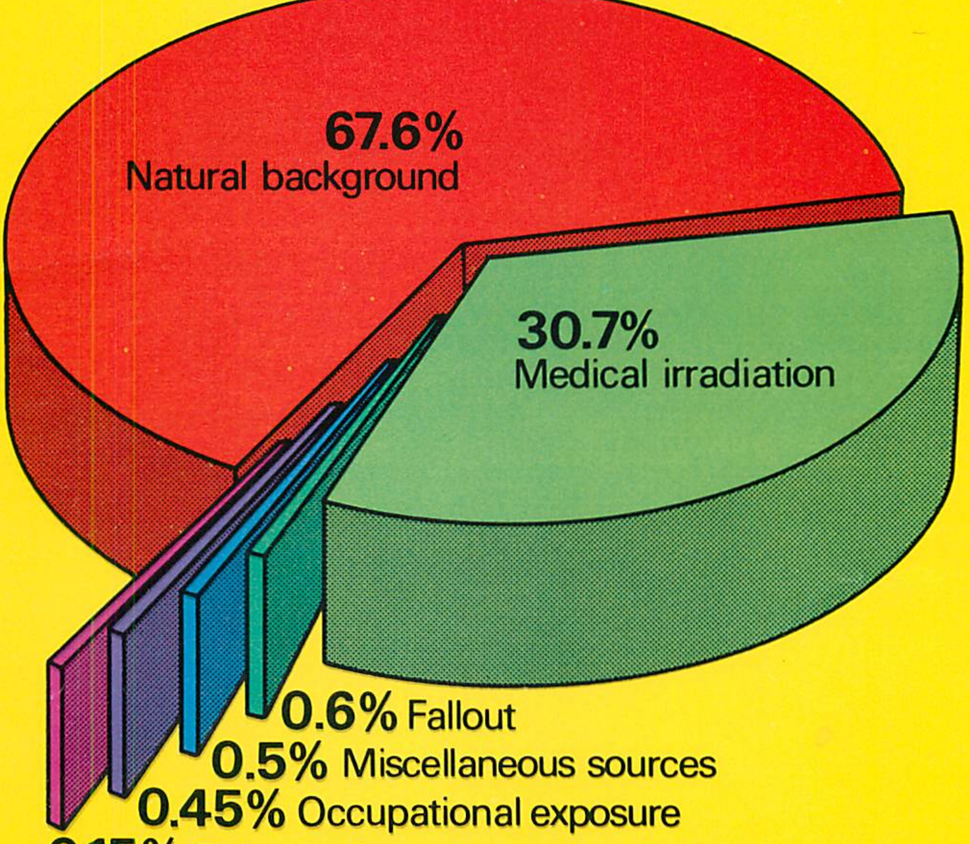
RADIATION – A FACT OF LIFE

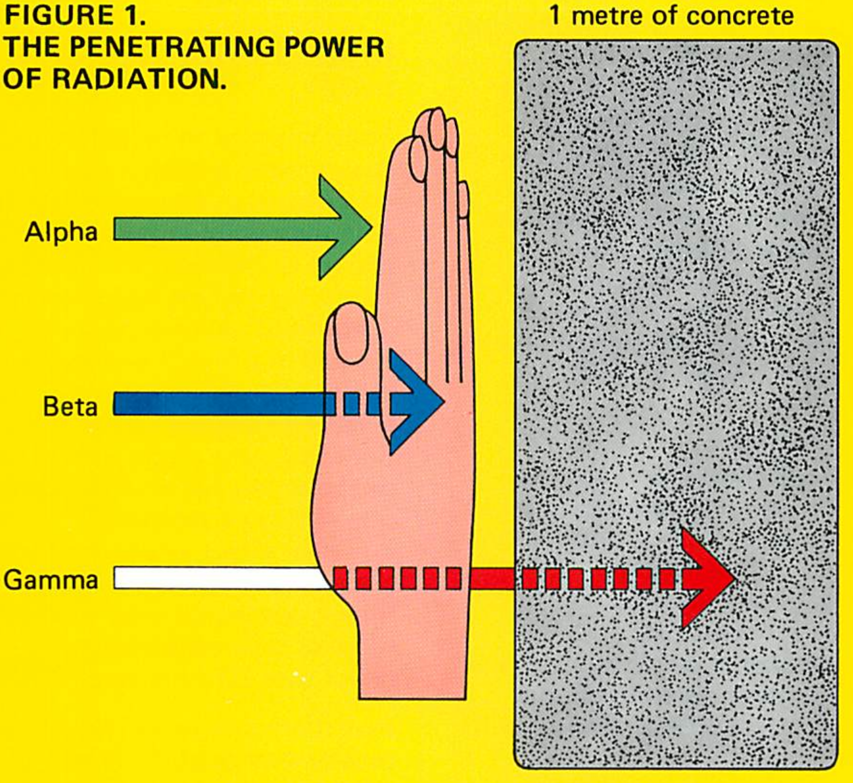


INTERNATIONAL ATOMIC ENERGY AGENCY

Man has always been subjected to natural radiation. He is exposed to radiation from the sun and outer space; naturally occurring radioactive materials are present in the earth, in the structures we inhabit, and in the food and water we consume. There are radioactive gases in the air we breathe and our bodies are themselves radioactive. The levels of this natural (or "background") radiation vary greatly from location to location.

In addition to natural radiation, man is exposed to sources of radiation that he himself created. X-rays and other kinds of radiation used for medical purposes, fall-out from nuclear explosives testing and radioactive materials released in the course of nuclear power production are some examples. Within a decade after X-rays came into use in the late 1890's, it became apparent that this type of radiation could be either beneficial or harmful depending on its use and control, and that protection measures were necessary. In succeeding years it was realized that this also applies to some other kinds of radiation.

**FIGURE 1.
THE PENETRATING POWER
OF RADIATION.**



TYPES OF RADIATION

Although the term "radiation" is very broad and includes such things as light and radio waves, it is most often used to mean "ionizing" radiation, which is radiation that can produce charged particles ("ions") in materials that it strikes. This is true for inanimate as well as living matter; ionizing radiation then can represent a health hazard to man.

There are various types of ionizing radiation: alpha, beta and gamma radiation, X-rays and neutrons, each with different characteristics. Atoms that emit these kinds of radiation are said to be radioactive.

Alpha radiation
consists of positively charged particles and is emitted from naturally occurring elements such as uranium and radium as well as from man-made elements. Alpha radiation will just penetrate the surface of the skin; it can be stopped completely by a sheet of paper. However, the potential hazard that alpha-emitting materials present is due to the possibility of their being taken into the body by inhalation or along with food or water.

Beta radiation
consists of electrons. It is more penetrating than alpha radiation and can pass through 1–2 centimetres of water or human flesh. A sheet of aluminium a few millimetres thick can stop beta radiation. Tritium, one of the materials present in fall-out from nuclear explosives tests, emits beta radiation.

Gamma radiation
can be very penetrating. It can pass right through the human body but would be almost completely absorbed by one metre of concrete. Dense materials such as concrete and lead are often used to provide shielding against gamma radiation.

X-rays
are a more familiar form of penetrating radiation.

Neutrons
can also be very penetrating. They are rarely detected at locations near sea level but are present at greater altitudes. Neutron radiation occurs inside nuclear reactors but efficient shielding against neutrons can be provided by, for example, water.

WHAT IS MEANT BY RADIATION DOSE?

To be exposed to radiation, i.e. to absorb some radiation energy, is to receive a radiation dose. However, as in the case of coffee, brandy or medicine the possible effects can be best evaluated when the quantity of radiation, the rate at which it was received and the manner in which it was received are known. For example, a single glass of whisky can be drunk and no significant side effects experienced. But what effect would drinking ten glasses have? Among other things, one would need to know whether they were drunk over 20 minutes or 20 days.

Radiation dose to individuals is usually expressed in "rem" (or "millirem", i.e. thousandths of a rem)[1]. The rate is then expressed as millirem per hour, per year, etc. As an example, one che[st] X-ray is equivalent to about 20 millirem.

By comparison, the average dose received from other sources of radiation can vary considerably.

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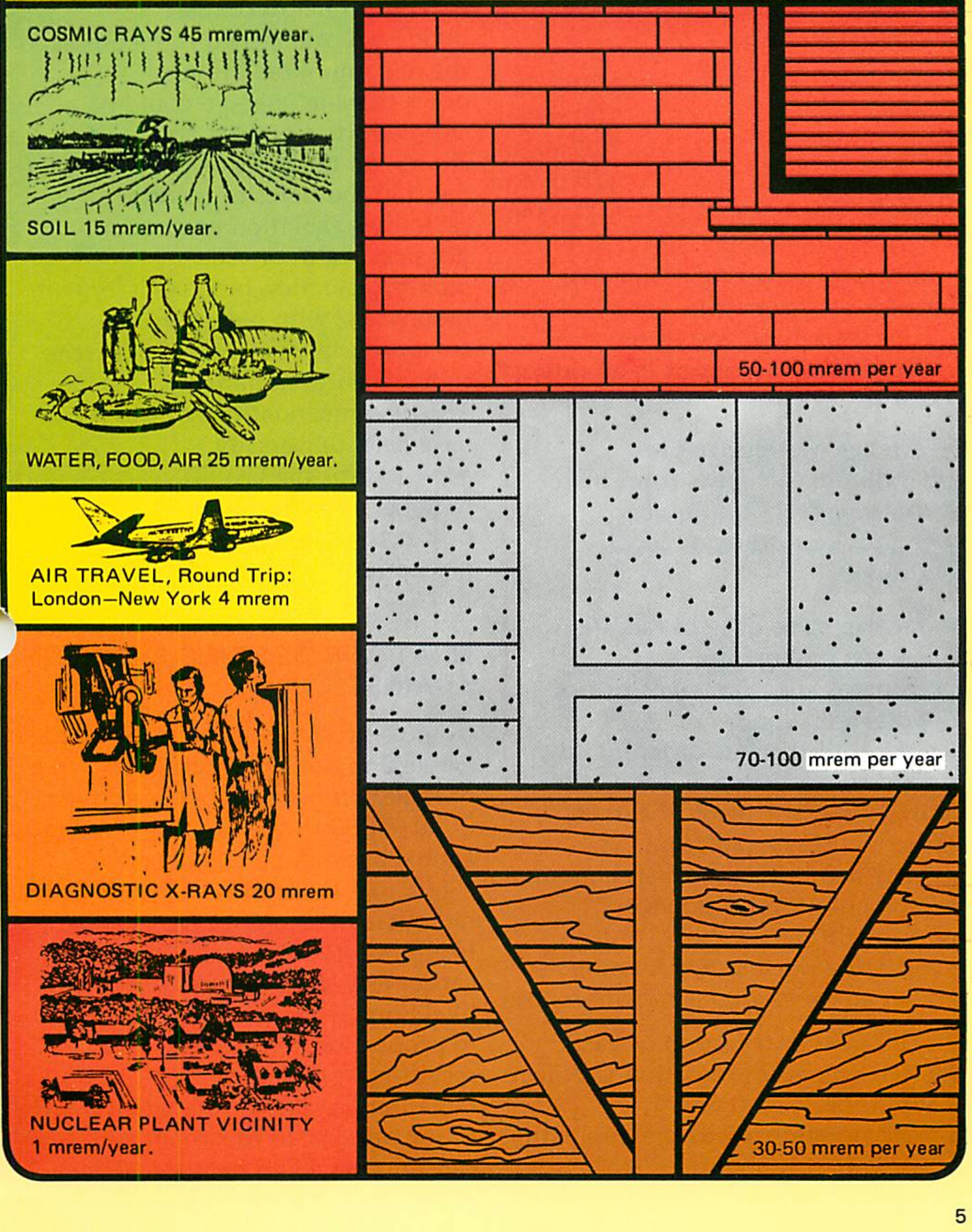
[1] More correctly, "millirem" and "rem" refer to the "radiation dose equivalent", and they have been devised to take into account the different biological effects of different types of ionizing radiation on people.

FIGURE 2.
RADIATION FROM VARIOUS SOURCES.

We receive radiation from a number of sources, both natural and man-made. Depending on how we live, we can receive more or less radiation from some of these sources. For example, living in a brick house contributes between 50 and 100 mrem, in a concrete house 70–100 mrem, and in a wooden house 30–50 mrem per year.



We are exposed to natural ionizing radiation in two ways:

1. Cosmic rays (originating in outer space) and radioactive materials that occur naturally in the earth's crust, result in an **external exposure** (i.e. from radiation sources that are outside the body). The average radiation dose we receive from these sources varies from place to place:

New York		100 mrem
London		100 mrem
Paris		120 mrem
Denver		125 mrem
Kerala, India	about	400 mrem

2. Naturally occurring radioactive elements are taken into our bodies in food and water, or are inhaled, and result in an **internal exposure.**

On average, we receive over 100 millirem each year from these natural sources. This number fluctuates depending on local conditions.

We receive some dose of radiation depending on how we live. Houses constructed of bricks, concrete and wood give their inhabitants different amounts of radiation. Dental and other medical X-rays, industrial uses of radiation, watches with luminous dials containing radium, colour television sets, and living in the general vicinity of a nuclear reactor add varying amounts to our radiation dose.

The relative contribution of each of these sources of radiation is shown in another way in figure 4, in this case referring to the population of the United Kingdom.

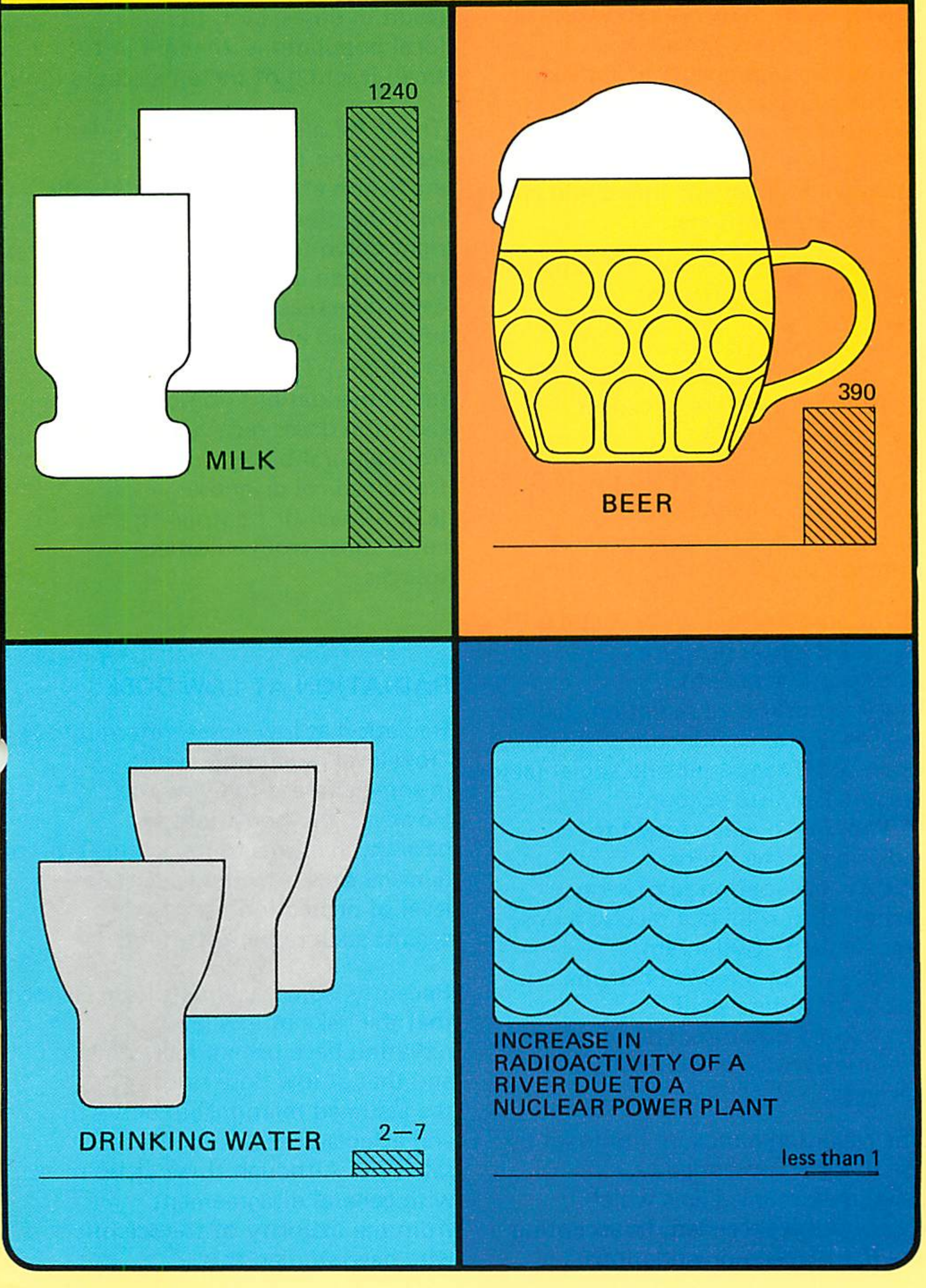
WHEN DID RADIATION PROTECTION BEGIN?

As radiation came to be more and more widely used, for example by doctors, the need to regulate radiation doses became apparent. In 1928 the International Commission on Radiological Protection (ICRP), an independent non-governmental expert body, was established to recommend the maximum radiation doses to which people could be safely exposed. Its members are chosen on the basis of their individual merit in the fields of medical radiology, radiation protection, physics, health physics, biology, genetics, biochemistry and biophysics, with regard to an appropriate balance of expertise rather than to nationality. The recommendations of the ICRP have been universally accepted for the last 50 years by both national and international bodies responsible for radiation protection.

WHAT ARE WE BEING PROTECTED AGAINST?

In the extreme case, exposure of the whole body to very high levels of radiation over a short period (e.g. 3000–4000 times the annual backgound dose at once) is fatal. At lower doses, radiation exposure results in some likelihood of developing cancer and leukaemia and this likelihood decreases in proportion to the dose. Doses resulting from natural radiation produce a very small fraction of the number of recorded cancer cases. (This property of

FIGURE 3.
The levels of radioactivity in common liquids differ considerably. In this diagram, the "units" represent relative levels of radioactivity.



inducing cancer, called "carcenogenicity", is one that radiation shares with a large number of chemicals and other materials, both natural and man-made. Examples of these are asbestos, vinyl monomer, many pesticides, and some components of tobacco smoke.) Exposure to radiation as well as to certain chemicals may also cause genetic defects that could appear in future generations.

The two objectives then of radiation protection, as stated by the ICRP, are:

1. To prevent acute radiation effects.
2. To limit the risks of cancer and genetic defects.

To reach these objectives the ICRP has laid out recommendations that are guided by three general principles:

1. No practice shall be adopted unless its introduction produces a net positive benefit.
2. All exposures to radiation shall be kept as low as reasonably achievable, economic and social factors being taken into account.
3. Those who are exposed to radiation in the course of their occupation (e.g. X-ray technicians) shall not receive a dose greater than 5000 mrem per year. For a member of the public, this dose shall not exceed 500 mrem per year nor a lifetime average of 100 millirem per year.

The radiation exposure limits set by the ICRP are intended to be maximum values which must not be exceeded. In accepting the ICRP's recommendations, it is common practice for countries to regulate limits lower than those given in the recommendations. In addition, practices in the nuclear industry, for example, result in doses, even to local populations, that are in turn a small fraction of these regulated limits.

The ICRP also makes the prudent assumption that there are health effects, varying directly with the dose received, right down to zero dose. (Zero dose is however an ideal that cannot be reached because we can never avoid all natural radiation.) The ICRP recommendations do not apply to radiation doses received from natural background radiation or from medical diagnoses (e.g. X-rays) or treatments; they do cover those from all other sources.

RADIATION AT LOW DOSES

Radiation at low doses, referred to as "low-level radiation", results in some damage to living tissues. However, the body does have mechanisms to repair this type of damage thus providing a certain level of protection against such radiation effects.

Recently, some scientists have claimed that the risks of low-level radiation have been underestimated, and that at low dose rates the assumed relationship between dose and effects does not err on the safe side. Although these views meet with general disagreement from the majority of the scientists who have studied this

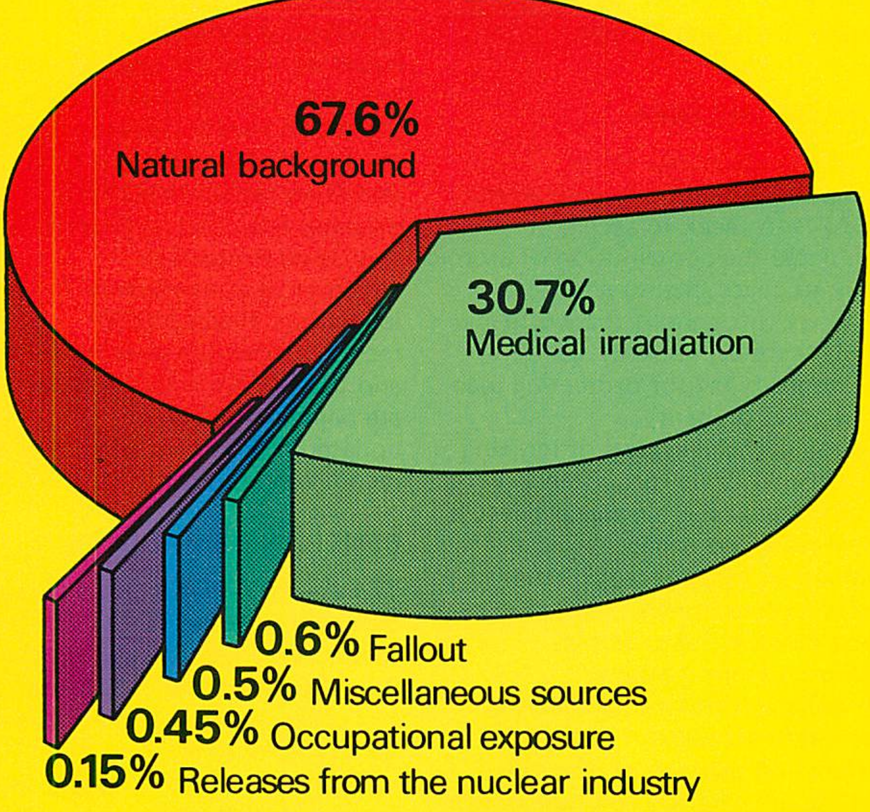


FIGURE 4.
THIS DIAGRAM SHOWS THAT:

- the major contribution to the average dose is from natural background radiation
- the largest man-made contribution is from the medical uses of radiation
- the nuclear power industry is a small contributor to the average radiation dose.

Adapted from National Radiological Protection Board publication NRPB-R77.

question*, a thorough debate is still underway. This important point will be discussed in detail in a separate IAEA publication.

WORK OF THE IAEA

One of the objectives of the International Atomic Energy Agency (IAEA) is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world"; this mandate brings with it a responsibility for protecting man and his environment from the harmful effects of ionizing radiation. Since its formation in 1957, the IAEA has made safety a central issue and it has remained an integral part of the Agency's programmes. (These include, for example, those programmes dealing with radiation and human health, basic safety standards for radiation protection, the safe handling of radiation and radioactive materials in the workplace, environmental surveillance, regulations for the safe transport of radioactive materials, and training in radiological protection.)
Based on the ICRP recommendations and in consultation with the World Health Organization (WHO), the International Labour Office (ILO), and other bodies, the IAEA prepares Basic Safety Standards for Radiation Protection which serve as a reference for national legislation. Revised ICRP recommendations were issued in 1977 and the IAEA's safety standards are being revised and updated to conform with these new recommendations.

BENEFITS OF RADIATION

The uses of radiation have brought tremendous benefits to our everyday lives during the past 20 or 30 years. Radioisotopes and controlled radiation are used, for example, to sterilize medical supplies, to improve the keeping qualities of foodstuffs (e.g. onions, potatoes), in industrial processes and in medical science, in the study of the environment and of environmental pollution, in agriculture and in hydrology.

These benefits are largely taken for granted if they are realized at all.

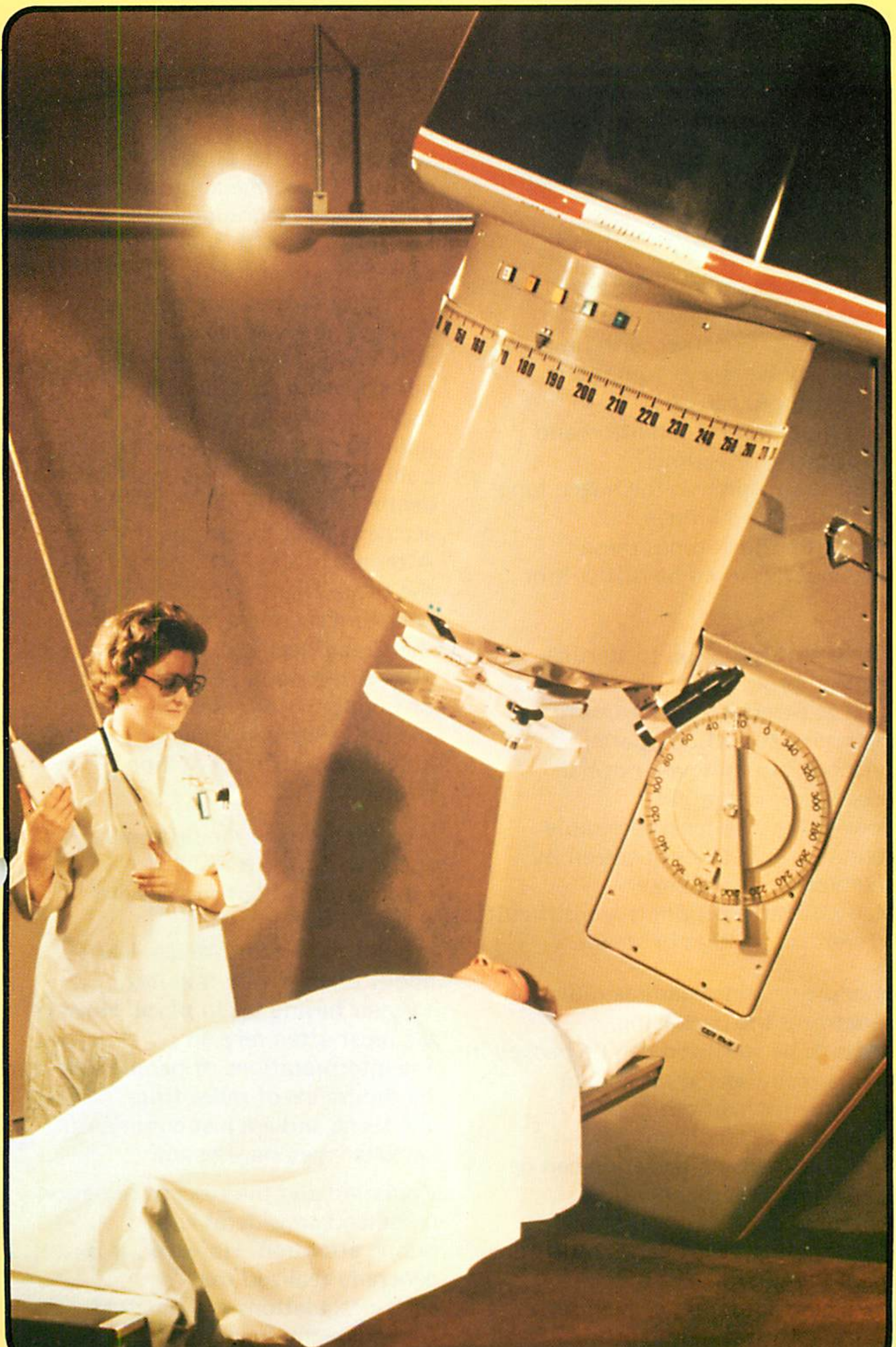
Medical diagnosis and treatment is the main source of public exposure to man-made radiation

Machines such as this have made various types of ionizing radiation important in the treatment of cancer.
Photo: Atomic Energy of Canada Limited

* For example, the ICRP, already mentioned, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the Committee on the Biological Effects of Ionizing Radiation (BEIR).

UNSCEAR was established in 1955 by the United Nations General Assembly as a result of international concern about the effects of fall-out from the testing or nuclear explosives. It was directed to assemble, study and disseminate information on observed levels of ionizing radiation and radioactivity (both natural and man-made) in the environment and on the effects of such radiation on man and his environment. UNSCEAR's most recent report was published in 1977.

The BEIR Committee was established by the Division of Medical Sciences of the U.S. National Research Council and includes eminent American scientists as well as those from other countries.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but the benefit in terms of human lives and health is enormous.

Radiation is a major tool in the treatment of certain kinds of cancer. Irradiating tissues affected by a tumour has proven effective in inhibiting the tumour's growth or in destroying it.

Radioisotopes play an essential part in some medical diagnostic procedures. Together with improved imaging devices and computers, radioisotopes can be used to assess the condition and functioning of various body organs such as the heart, lung, brain, liver and kidney. Without radioisotopes these assessments would be difficult or impossible.

The use of radiation to sterilize medical products, such as surgical dressings, sutures, catheters, spare body parts, syringes, etc. is now a normal procedure. Radiation does not introduce undesirable residues whereas sterilization by chemicals or gases may. Many of these products are difficult to sterilize by heat or steam.

In addition, since gamma radiation penetrates the packaging, items to be sterilized can be packed in hermetically sealed packaging prior to sterilization. Since it is a "cold" process, sterilization using radiation can be applied to heat-sensitive materials, such as plastics (for example, heart valves) and appears to be the only means of sterilizing a number of heat-sensitive pharmaceutical items such as powders, ointments and solutions.

RISK

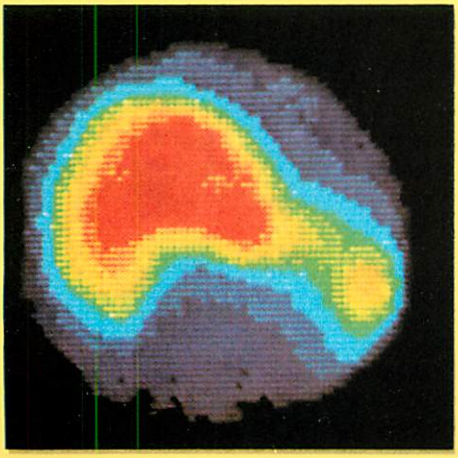
Today we are much more conscious of risks than people were 25 or even five years ago. This is partly because of better education, partly because the applications of science and technology have brought with them new and sometimes imperfectly understood risks, but also partly because of the speed with which news can be brought to our attention. It is not the scale of today's disasters, such as millions of gallons of oil polluting beaches, or hundreds of deaths in a single aviation accident, that makes the difference. After all, in the 14th century the Black Death killed some 25 million people in six years and the Great Plague of 1665 wiped out 20% of the population of London. More recently, the influenza pandemic of 1918 killed more than 20 million people.

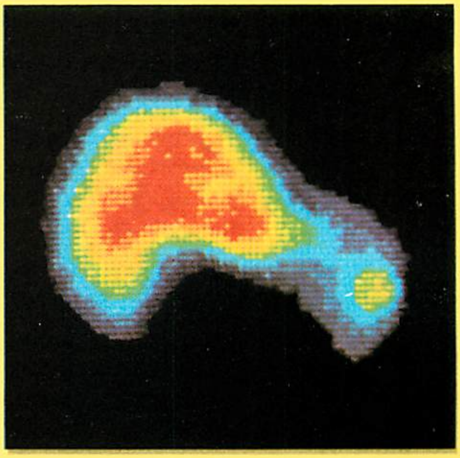
What does make the difference is the speed with which information about such events is now disseminated around the world. We can learn about them within minutes of their having taken place. However, we must often rely on the interpretations of people who may be thousands of miles from the scene and are just commenting on what they have heard.

Radiation and the risks of radiation command considerable public attention. However, it is not generally realized that safety regulations are much stricter for radioactive materials than for other dangerous substances.

For example, nuclear power stations emit radioactive materials; oil- and coal-fired power stations discharge sulphur dioxide (as much as 20 000 to 30 000 tonnes per year from a single large power plant).
But in terms of the corresponding lethal doses of these radioactive materials and of sulphur dioxide, the emission limits for nuclear power stations are 100 times lower than they are for oil- or coal-fired stations.
This is only one facet of air pollution and air pollution in turn is only one factor to be considered in determining the relative merits of different energy sources.
Furthermore, in the case of coal, it has been estimated that in Pennsylvania 30 000 miners died in the mines between 1870 and 1950 — an average of about **one man a day for 80 years.**
Next to such appalling tolls, the safety history of the nuclear power industry is uniquely encouraging. Radioactive elements gradually lose their radioactivity — and their toxicity — with time. Other non-radioactive materials (for example, arsenic) remain toxic forever. It has recently been reported by the director of the Mario Negri Research Institute in Milan, that three years after the accidental chemical release in Seveso, Italy, in July 1976, there is still no sign that the toxicity of the dioxin deposited in the region is diminishing.
Illustrative examples such as this one demonstrate how radiation risks tend to be viewed separately from other, and sometimes greater, risks.

Radionuclide imaging techniques currently used in nuclear medicine provide useful diagnostic information, while minimizing the radiation dose and inconvenience to the patient and the hospital staff.
The picture shows the distribution of the radiopharmaceutical in the liver.





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SUMMARY

- Radiation has always been a part of the natural environment and a large part of the radiation dose we receive naturally is unavoidable.

- The effects of radiation on human health are not unique; many natural and man-made materials can produce similar effects.

- The effects of radiation are better known than those of practically all other harmful agents and the regulations and monitoring measures to protect us against these effects are more complete and more advanced.

- The benefits of radiation and radioactive materials, in their various uses, greatly outweigh the risks.

- The nuclear power industry is a very minor contributor to our total radiation dose.

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