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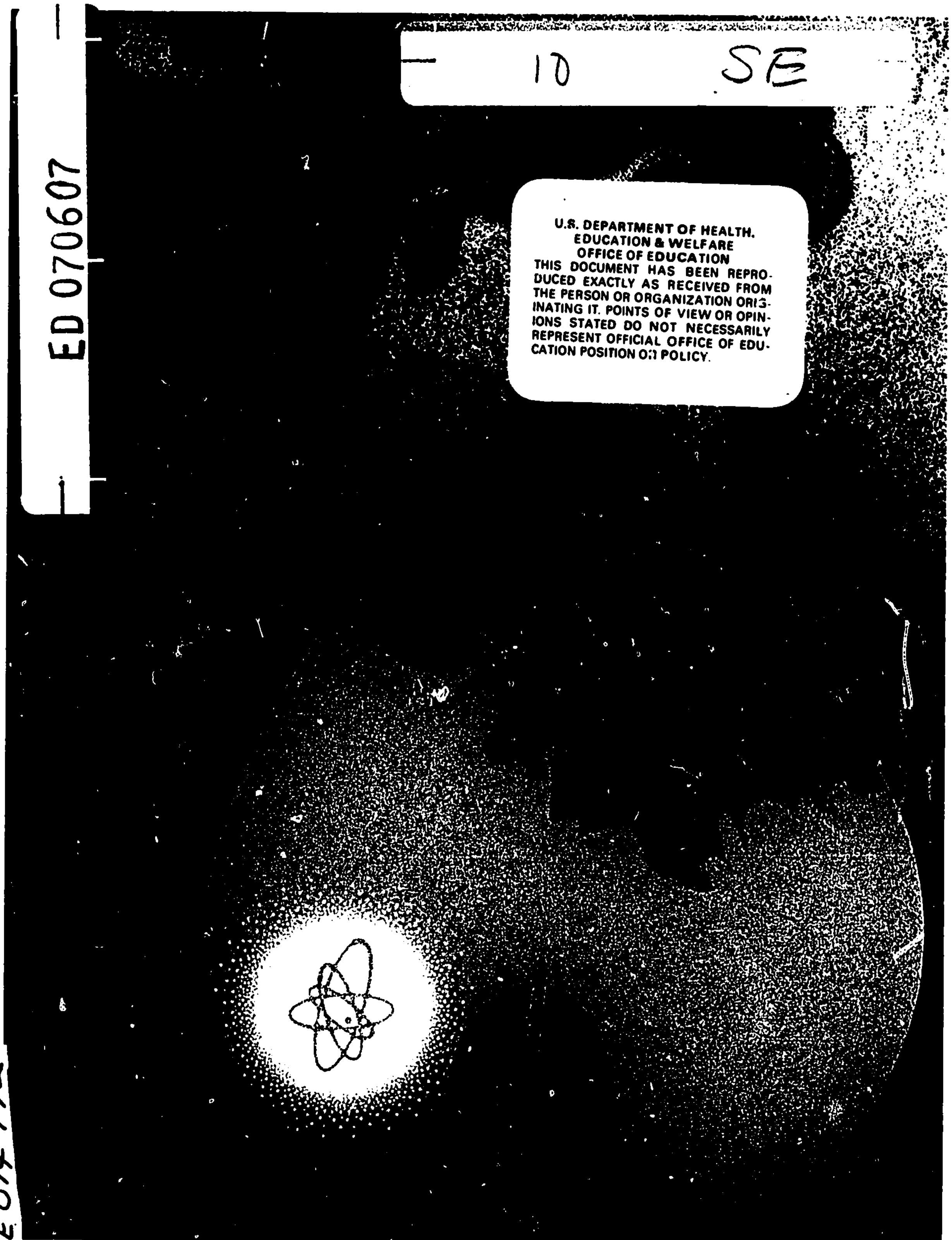
ABSTRACT

"Nuclear Energy and the Environment" is a pocket folder of removable leaflets concerned with two major topics: Nuclear energy and Nuclear Techniques. Under Nuclear Energy, leaflets concerning the topics of "Radiation--A Fact of Life," "The Impact of a Fact: 1963 Test Ban Treaty," "Energy Needs and Nuclear Power," "Power Reactor Safety," "Transport," and "Waste Management" will be found. Leaflets concerning the topics of "In Air," "In Water," "Agricultural Resources," "In Medicine," and "In the Future" are included under Nuclear Techniques. A list of International Atomic Energy Agency Publications on nuclear energy, the environment, and pollution is also included. (LK)



Nuclear Energy and the Environment

48

RADIATION — A FACT OF LIFE

THE IMPACT OF A FACT, 1963 Test Ban Treaty

ENERGY NEEDS AND NUCLEAR POWER

POWER REACTOR SAFETY

TRANSPORT

WASTE MANAGEMENT

Radioactive wastes — solids, liquids and gases — are produced at all nuclear industrial and research establishments.

Three basic philosophies are applied to the management of nuclear wastes:

- dilute and disperse;
- delay and decay;
- concentrate and contain.

Typical radioactive wastes and disposal methods

Type of waste radioactivity	Source of waste	Form of waste	Typical isotopes	Disposal methods
Natural activity	Mining of uranium ores	Solids	Uranium-238	Pile in open
		Liquids	Thorium-230	Seep into ground
		Gases and dusts	Radon-222	Ventilate mine
	Fuel fabrication plants	Solids	Uranium-238 Uranium-235	Decontaminate
		Liquids (acid)	Uranium-238 Uranium-235	Neutralize, concentrate, and bury residue
		Dusts	Uranium-238 Uranium-235	Ventilate, filter, and disperse to air
Fission-product activity	Fuel irradiation and processing	Solids (from purposeful solidification)	Strontium-90 Caesium-137	Encase in container and store permanently (~ 600 years)
		Liquids (with strontium and caesium removed)	Technetium-99 Ruthenium-103 Cerium-144	Store in tanks for several years; then solidify in place
		Gases	Iodine-131	React with chemicals to bind in solid, e.g., silver iodide
			Krypton-85	Disperse to air
Activation-product activity	Reactor materials unavoidably irradiated during operation	Solids	Aluminium-28 Manganese-56	Package and ship for land burial
		Liquids (dissolved material)	Cobalt-58	Evaporation or ion-exchange; bury residue
		Gases	Nitrogen-16	Hold for decay (very short life); then disperse to air
	Purposeful irradiation to produce useful isotopes	Solids	Cobalt-60	Ship for burial when no longer useful (long life)
			Phosphorus-32	Store for decay to safe levels (short life)

Table from: Radioactive Wastes by C.H. Fox, Understanding the Atom Series, USAEC, 1969 rev. pp 6-7

● **DILUTE AND DISPERSE:**

Most of the gaseous and liquid wastes generated at nuclear reactors are sufficiently low in radioactivity that they can be released directly to the environment where they are rapidly dispersed and diluted.

● **DELAY AND DECAY:**

In some cases the level of radioactivity of effluents is significantly reduced by holding the wastes for a period of time to allow decay of short-lived radionuclides.

● **CONCENTRATE AND CONTAIN:**

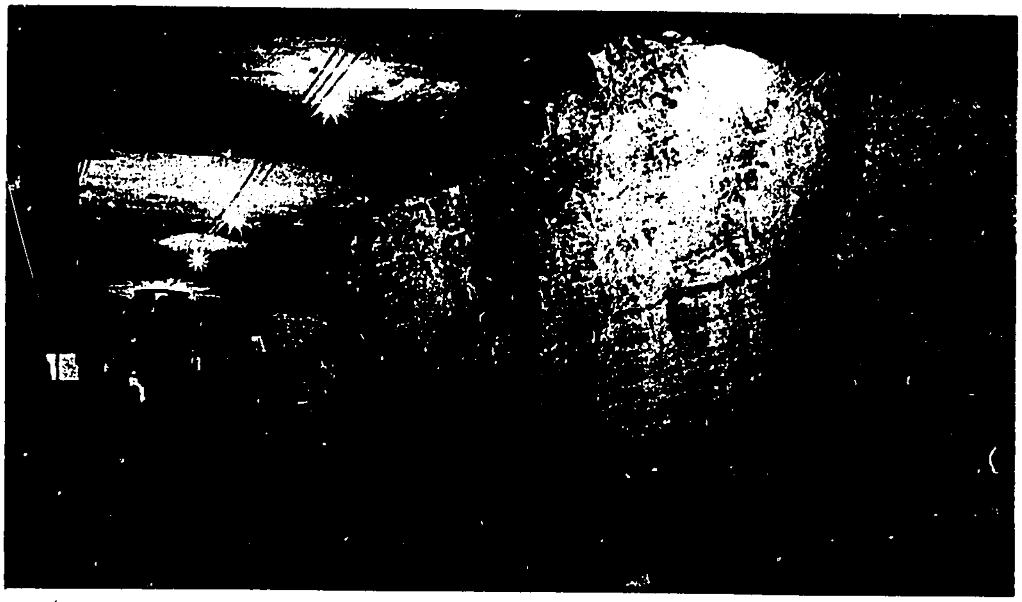
Liquid wastes that are too radioactive for direct discharge to the environment are treated by ion exchange, precipitation, filtration, evaporation or calcination. The major part of the radioactivity is thereby removed and contained so that the treated effluent can be safely released. The remaining solids sometimes are mixed with concrete or bitumen, placed in steel containers and buried near the surface or placed in mines that are no longer used for production.

All of the high-level solid wastes accumulated between now and the year 2000 are expected to occupy less than 1% of the volume of salt that is excavated annually.

DUMPING WASTE INTO THE SEA?

The content of radionuclides in sea-water is

Salt formations are particularly suited for such storage as they are practically always dry, they have good heat transfer properties, they are plastic (hence any fractures are self-sealing) and they should be stable for millions of years.



reduced by two processes: radioactive decay and the physico-chemical transfer from the water to the bottom sediments. Packaged solid radioactive wastes of low and intermediate activity have been disposed into the deep sea under controlled conditions at selected disposal sites.

THERMAL EFFECTS IN WATER?

All steam-electric generating plants, fossil-fuelled as well as nuclear, release heat to the environment. The heat, mostly spent steam that was used to drive the turbine, is converted back into water in a condenser, which is cooled directly by water from nearby rivers, lakes or oceans or indirectly through the use of cooling towers or artificial ponds.

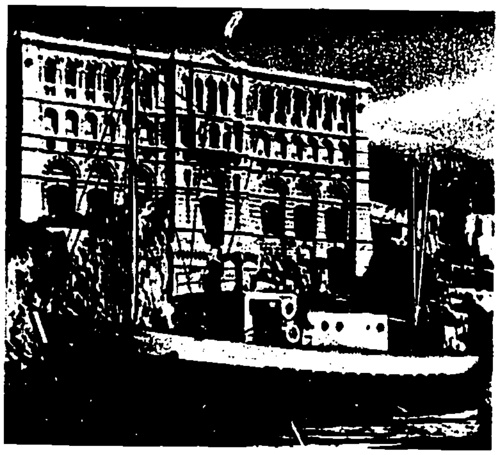
There is no doubt that uncontrolled releases of waste heat could be detrimental to aquatic life. Careful studies, however, at a number of operating nuclear power plants over a period of years have not revealed any discernible harmful effects upon the ecological systems. In some cases the discharge of waste heat could even be beneficial, for example, heated water could be used to irrigate crops and warm the soil, thereby extending the growing season, or northern water ways could be kept open during the winter season.

It seems likely that international action to control industrial pollution may deal first with the conservation of the seas and oceans. Since

The Connecticut Yankee Atomic Power Plant at Haddam Neck,
the largest operating commercial nuclear power plant in the United States.
Credit: Connecticut Yankee Atomic Power Company

its inception, the Agency has been concerned with the control of radioactive contamination of the oceans that might arise from the peaceful uses of atomic energy.

In November 1970 a panel, convened to prepare a report on the principles for limiting the release of radioactive wastes, recommended the establishment by the IAEA of an international register of all substantial releases of radioactive wastes into the seas and oceans. In co-operation with WHO the Agency is also considering a formal proposal to become a central depository of data on radioactivity released into the environment as a whole in connection with the civil uses of atomic energy.



In Monaco, the International Laboratory of Marine Radioactivity, a co-operative venture between the IAEA, UNESCO, the Monegasque Government, and the Oceanographic Institute of Monaco, is studying the effects of radioactivity in the marine life.

TO KNOW MORE

Radioactive Wastes, Charles H. Fox, Understanding the Atom Series, USAEC, Division of Technical Information, 1969 rev.

Das Problem der Radioaktiven Abfälle in Kernkraftwerken, Dr. H. Lengweiler & Dr. H.R. Lutz, Atom-Pressedienst, No.9, Sept. 1968, Schweizerische Vereinigung für Atomenergie (SVA)

Kernenergie, Schweizerische Vereinigung für Atomenergie (SVA), Dec. 1971, Bern

Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters, Proceedings of a Symposium in Vienna, IAEA, 1966.

Management of Low- and Intermediate-Level Radioactive Wastes, Proceedings of a Symposium in Aix-en-Provence, IAEA, Vienna, 1970.

TRANSPORT

Traffic – as we know it today. But did you know that one of the cars passing by might carry a radioactive parcel?

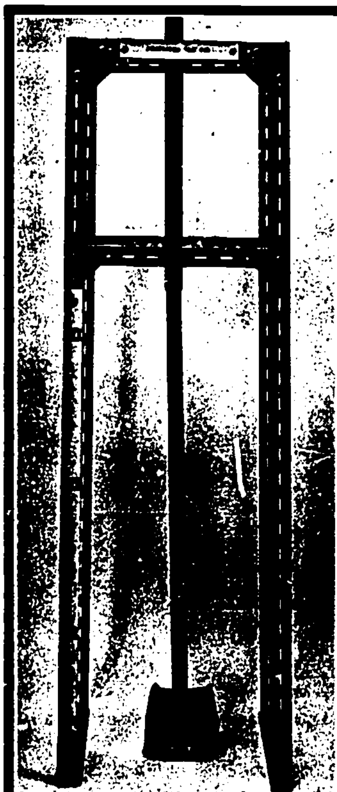
Radioactive materials must be transported safely and quickly by road, rail, sea and air. Other potentially dangerous substances such as explosives and chemicals are frequently transported and therefore regulations have been developed to allow radioactive materials to be transported at least as safely as these other substances.

Transport workers handling radioactive materials in containers have no special training and it is this radioactive material that comes into close contact with the public and with other goods. A release of such contents could lead to irradiation of the public and contamination of the environment.

There are two types of packaging which contain built-in safety in the package design. Specimens of these package designs are subjected to a series of tests.

Type A: will withstand normal transport conditions including rough handling. The tests for Type A simulate the effects of the normal rough handling to be expected during transport.

Type B: will withstand damaging effects of very severe accidents. The tests for Type B simulate the damage that could be foreseen in serious accidents — these tests include drops from a height of 9 metres and exposure to fire. The design of Type B packages requires approval by competent national authorities in order to give assurance that all safety features are observed.



Type A test
Testing penetration

Type B test
A container used in transporting radioisotopes, total weight 4.4 tons, is dropped from a height of 9 metres onto one corner, then from a height of 1 metre onto a steel rod.
Credit: Australian Atomic Energy Commission

A host of special regulations existed for different modes of transport of radioactive materials in various countries. The IAEA has contributed towards a harmonization of these rules by convening panels of experts to formulate international safety standards. Today the Agency's Transport Regulations are accepted and implemented by all international transport organizations:

All modes of transport:
Regulations for the Transport of Radioactive Materials, Council for Mutual Economic Assistance (CMEA), 1966

Post:
Detailed Regulations for Implementing the Universal Postal Convention, 1966

Rail:
International Regulation Concerning the Carriage of Dangerous Goods by Rail (RID), 1967

Sea:
International Maritime Dangerous Goods Code, IMCO, 1967

Road:
European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), 1968

Air:
Regulations Relating to the Carriage of Restricted Articles by Air, IATA, 1970

Inland waterways:
Draft European Agreement Concerning the Carriage of Dangerous Goods by Inland Waterway (ADN)

Example of package label

TO KNOW MORE

The Safety Transport of Radioactive Materials, by R. Gibson, Pergamon, 1966

Transportirovanie radioaktivnyh veščestv, by Leščinskij Nikolaj Ivanovič, translation from Russian: The transportation of radioactive materials, Washington, OTS, 1964

La réglementation internationale du transport des matières radioactives; tendances actuelles, by Claude Salleron, Paris, Centre français de droit comparé, 1964

Regulations for the Safe Transport of Radioactive Materials, Safety Series No.6, IAEA, Vienna, 1967

Nuclear Law for a Developing World, Legal Series No.5, IAEA, Vienna, 1969

Tests on Transport Packaging for Radioactive Materials, Proceedings of a Seminar, IAEA, Vienna, 1971

700 REACTOR YEARS OF OPERATING EXPERIENCE 0 ACCIDENTS

The whole reactor represents
an ultraconservative design enclosed in a
"containment system".
In no other engineering activity has safety
been considered in such detail and
with such conservatism.

Containment,
A system of duplicates and back-up alternatives within a massive shield of concrete,
steel or both can be likened to a series of pots,
one within another.

700 reactor years of operating experience
0 accidents

These are the figures for the over 100 nuclear power reactors operating in the world today. The few accidents we read about have all occurred in research reactors, in fuel processing plants, in weapons programmes, but not in the commercial nuclear power stations supplying us with energy.

In his Message to Congress on Energy in June 1971 President Nixon said:
"... the safety record of civilian power reactors in this country is extraordinary in the history of technological advances. For more than a quarter of a century — since the first nuclear chain reaction took place — no member of the public has been injured by the failure of a reactor or by an accidental release of radioactivity. I am confident that this record can be maintained..."

In 1971 the Swiss Federal Commission for Radiation Protection made a similar announcement. "In the field of nuclear energy, we are in the unique position that the safety provisions preceded technical realization, and do not, as in the field of water and air pollution, lag behind."

The composition of the fuel in a nuclear power reactor is such that it will under no circumstances permit the reactor to explode.

DESIGN FOR SAFETY:

When constructing a nuclear reactor 3 safety barriers are built-in:

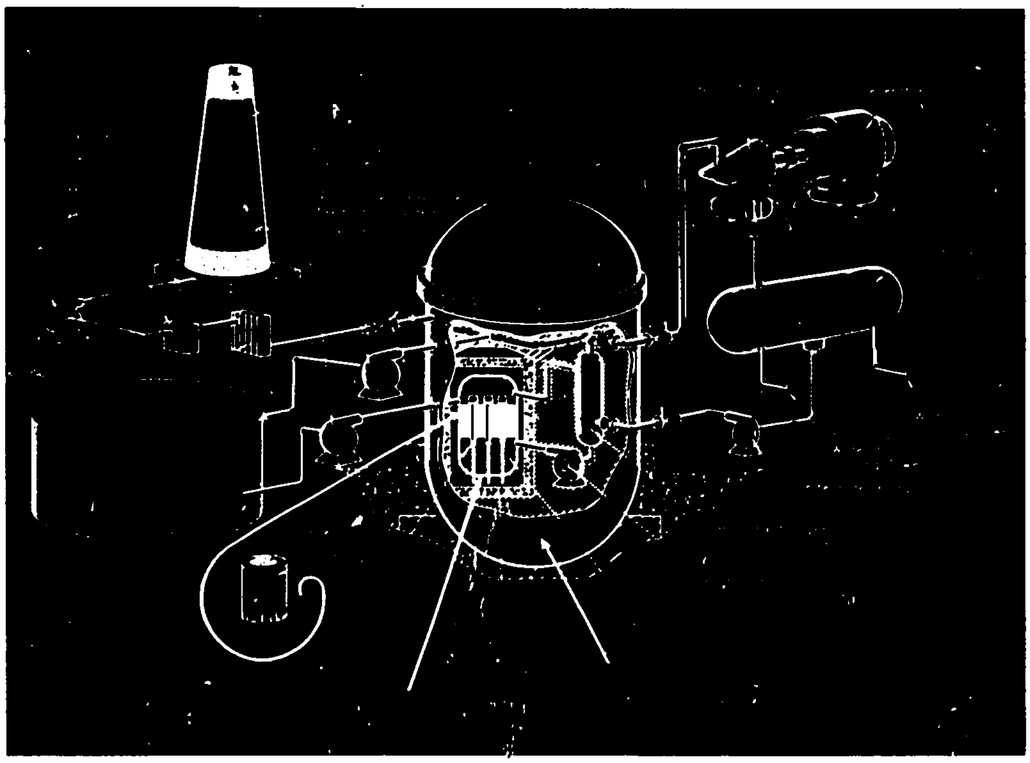
(1) the fuel-cladding
(2) the reactor vessel
(3) the containment structure

There are also other control devices to slow down and regulate the nuclear chain reaction. Instruments independent from each other measure the various aspects of reactor operations; each one of them is wired into a safety mechanism that would automatically trigger off a shut-down of the reactor in case a malfunction would occur.

ECONOMICS:
The concern for safety accounts in a large measure for the cost differential between nuclear and conventional plants. This cost differential which ranges from 100% for a 100 MW(e) reactor and drops to 50% for a 1000 MW(e) unit also affects the influence of safety costs on savings of scale, a fact which makes nuclear power-stations especially attractive in larger sizes.

INSURANCE:
Under the nuclear insurance rating system, in the USA for instance, substantial portions of premiums paid are placed in reserve and if not used to cover losses, are returned after 10 years. The two pools, Nuclear Energy Liability Insurance Association and Mutual Atomic Energy Liability Underwriters, note that in their 14 years of operation not a single liability claim has been filed. These pools insure every utility-operated power reactor as well as many test and research reactors and other nuclear installations for up to $82 million in liability claims per facility.

"This very high rate of refunds — 97.08% — directly reflects the success of the nuclear safety programme." (Atomic Industrial Forum, Info.39, July 1971).



The 3 safety barriers of a nuclear power reactor. Credit: Idaho National Reactor Testing Station, U.S.A.

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Nuclear News, Publication of the American Nuclear Society, Vol.15, No.1, Jan.1972, "Nuclear reactor safety – an opinion" by Norman C. Rasmussen

Nuclear Safety, Vol.12, No.4, Jul-Aug. 1971, "Nuclear liability insurance: a brief history reflecting the success of nuclear safety" by J. Marrone

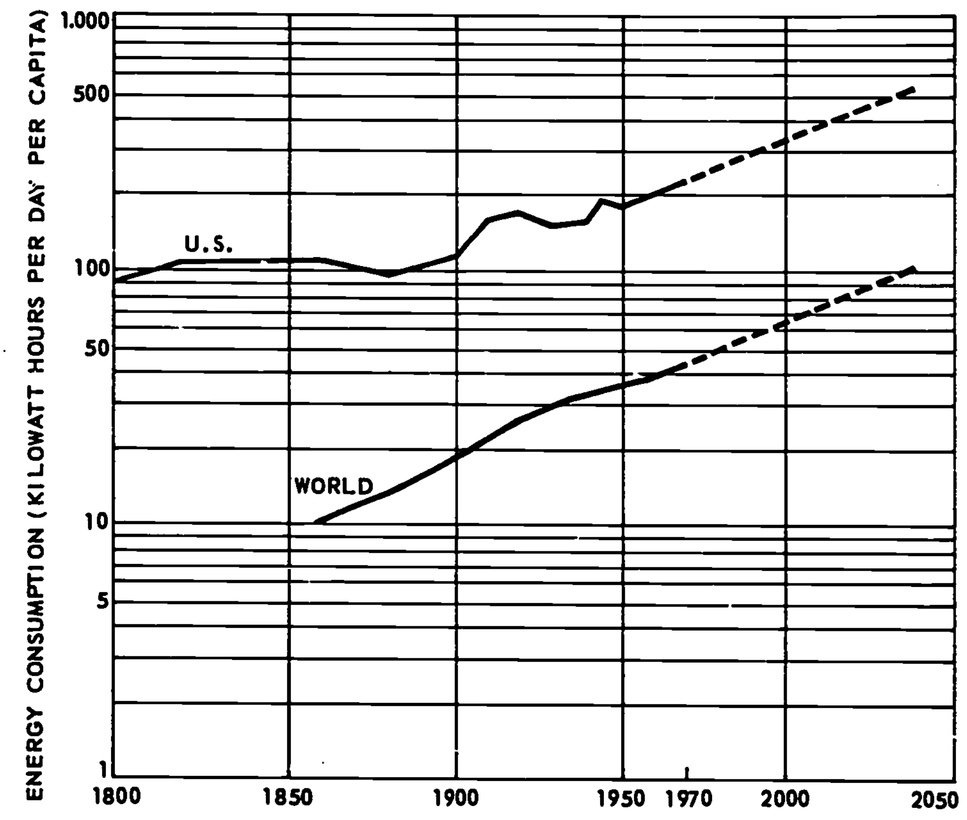
AEC News Release,Vol.2, No.50, Dec.15, 1971, USAEC, "The future of the breeder, its impact on the environment, and its regulatory aspects", remarks by William O. Doub.

Nuclear Power and the Environment, USAEC, Division of Technical Information, 1969

Peaceful Uses of Atomic Energy, Proceedings of the Fourth International Conference in Geneva 6-16 th Sept. 1971, Volume 2, Performance of Nuclear Plants, Costing of Nuclear Plants, Fuel Management; UN/IAEA, Vienna, 1972

● It is said that between 1970 and 2000 the world will consume as much energy as it has in the past 20 centuries.

Glenn T. Seaborg, Chairman, USAEC, at Joint Conference of the Chemical Institute of Canada and the American Chemical Society in Toronto, Canada



GROWTH IN ENERGY DEMAND in the U.S. is at the annual rate of about 1 percent per capita. For the world as a whole per capita consumption is growing about a third faster.

The Scientific American, September 1971

● Nuclear power has become increasingly important as a supplier of these vast energy requirements today.

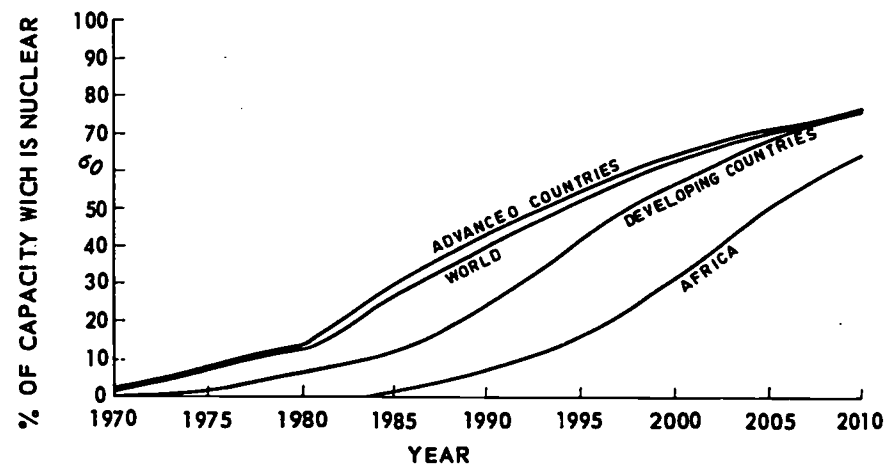
In 1970 about 2% of the total global generation capacity was produced by nuclear plants
In 2000 over 50% is expected to be produced by nuclear plants:

WORLD GENERATING CAPACITY (MW)

	Total	Nuclear
1962	700 000	-
1970	1 100 000	20 000
1980	2 200 000	330 000
2000	6 800 000	3 800 000

● All continents and all countries will participate in this expansion of electrical generating capacity due to increase of population and to the growth of the consumption of primary energy.

In looking at future energy demands, the question is not should more energy be produced, but how to produce the necessary increase with minimal side effects. In an age where pollution control is necessary, it must be remembered that pollution control itself is a new growth industry that will create an additional energy demand. Nuclear energy can help to meet those needs.



Nuclear share of electrical generating capacity.

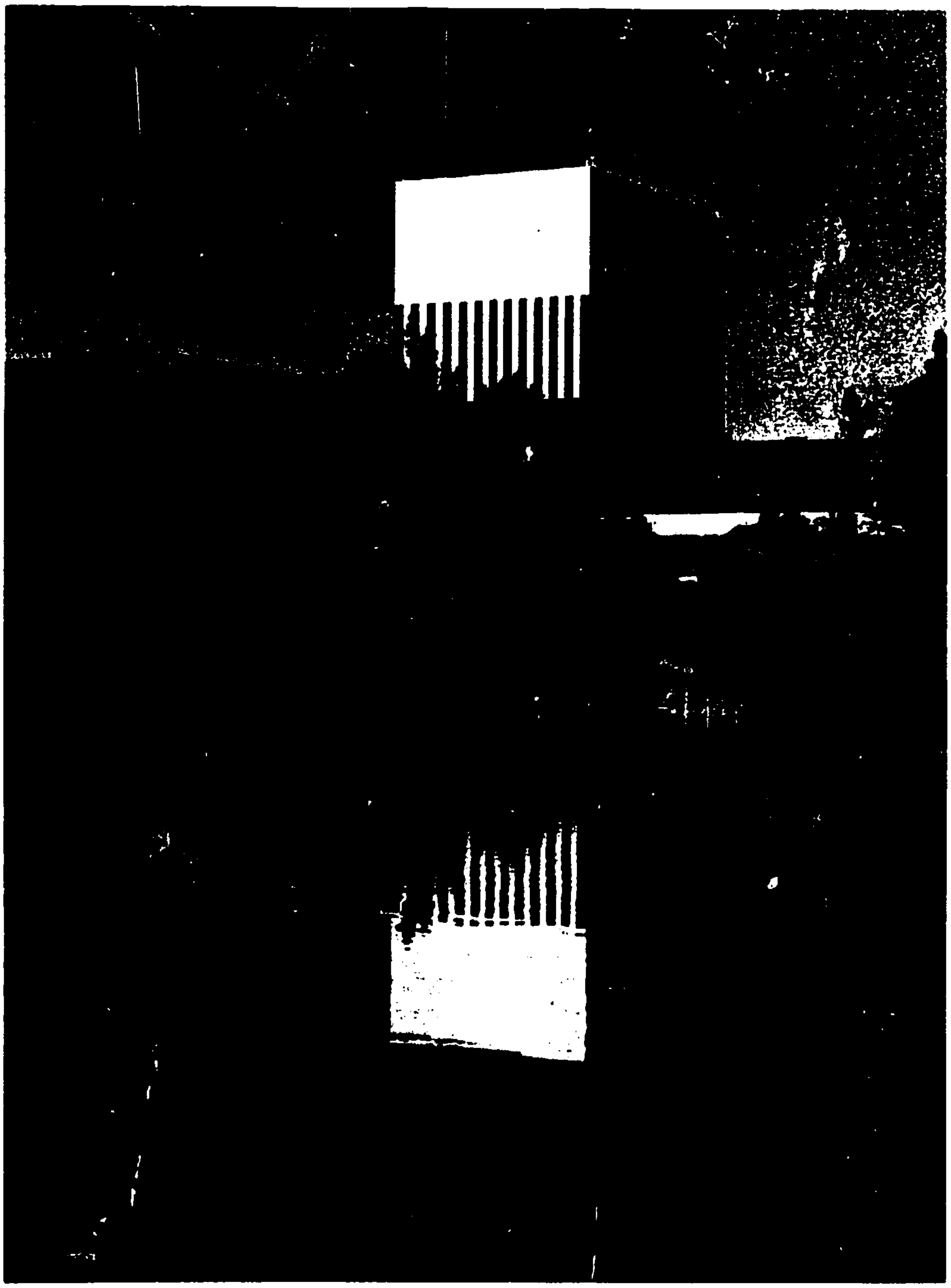
"The Role of Nuclear Power in Meeting World Energy Needs", by B.I. Spinrad
Symposium on "Environmental Aspects of Nuclear Power Stations", New York, August, 1970

● There is a limited reserve of oil and coal and natural gas that has been depleting rapidly with increased energy demands. Using nuclear fuels extends this reserve which is the basis of much of the organic chemical industry from synthetic fibers to plastics.

DEPLETABLE SUPPLY (10^{12} WATT-YEARS)	WORLD
COAL	670 – 1000
PETROLEUM	100 – 200
GAS	70 – 170
SUBTOTAL	840 – 1370
NUCLEAR (ORDINARY REACTOR)	~3.000
NUCLEAR (BREEDER REACTOR)	~300.000
CUMULATIVE DEMAND 1960 TO YEAR 2000 (10^{12} WATT-YEARS)	350 – 700

The Scientific American September 1971

ECONOMICALLY RECOVERABLE FUEL SUPPLY is an estimate of the quantities available at no more than twice present costs. Fossil-fuel reserves are barely equivalent to twice the cumulative demand for energy between 1960 and 2000. Even nuclear fuel is none too plentiful if one were to use only the ordinary light-water reactors. By employing breeder reactors, however, the nuclear supply can be amplified roughly a hundredfold. (10^{12} watt-years equals 29.9×10^{15} B.t.u.)



Oskarshamn Nuclear Power Station Unit No.1, Sweden, 440 mw

Credit: USAEC

TO KNOW MORE

Peaceful Uses of Atomic Energy, Glenn T. Seaborg, USAEC, Oak Ridge, Tenn., 1970

Nuclear Power, W.G. Jensen, G.T. Foulis and Co., Ltd., Cambridge, 1969

The Future of Power Generation, study prepared for Centennial Celebration of Koninklijke Machinefabriek Stork N.V., Henelo, the Netherlands, 1968

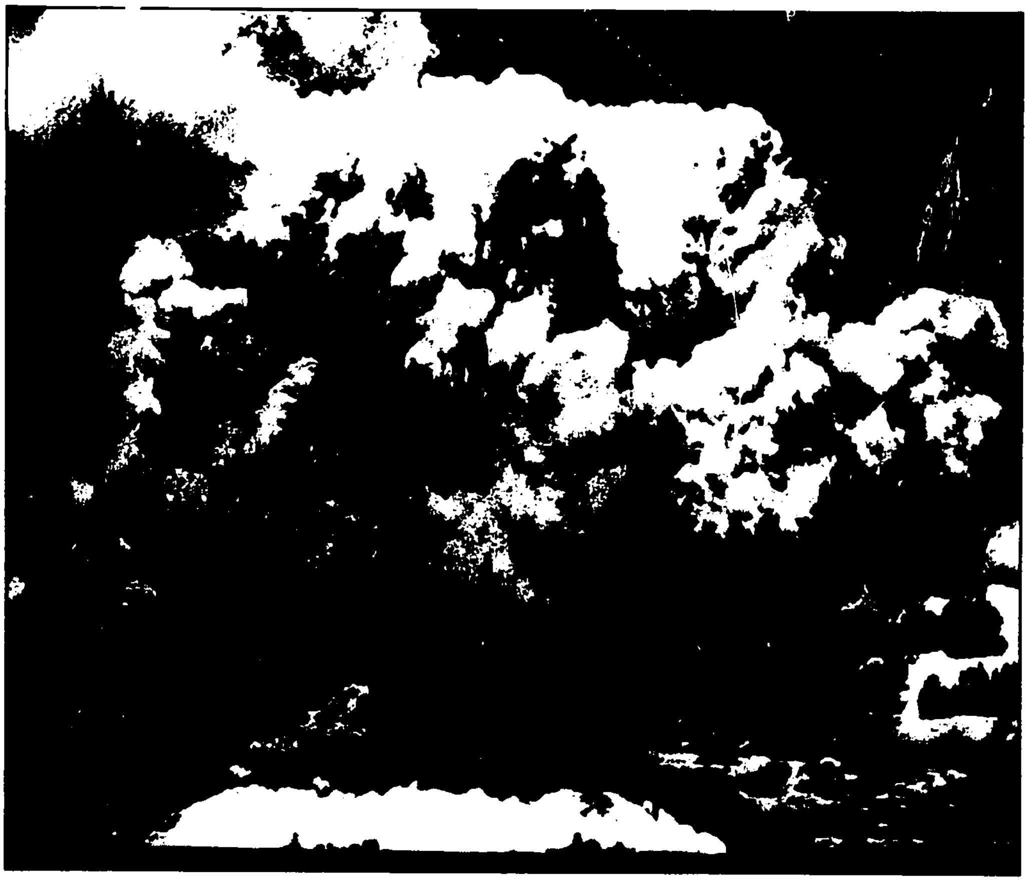
Nuclear Energy Costs and Economic Development, Proceedings of a Symposium, Istanbul, IAEA, Vienna, 1970

"Global effects of increased use of energy", A.M. Weinberg and R. Philip, paper presented at the 4th International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1971

"World energy requirements and resources up to the year 2000", Resources and Transportation Division, United Nations paper presented at the 4th International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1971

THE IMPACT OF A FACT: 1963 Test Ban Treaty

"Before the Test-Ban Treaty, almost 200 million tons of radioactive debris had found its way into the atmosphere from atomic blasts."
Newsweek, November 22, 1971



"THE AMOUNT OF STRONTIUM-90 DEPOSITED ON THE EARTH IN 1970 WAS JUST 5% OF THE AMOUNT THAT FELL IN 1963"

Nature, 234, Nov.12, 1971

ANNUAL DEPOSITION OF STRONTIUM-90

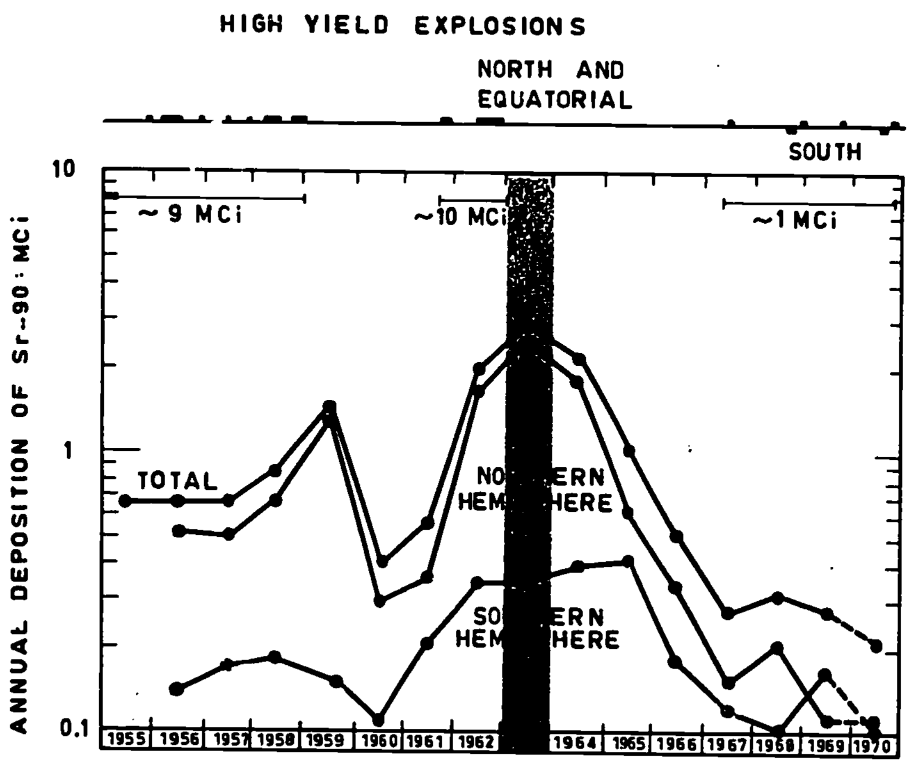


Fig. 1 SHOWS THE ANNUAL DEPOSITION OF STRONTIUM-90

International concern about the effects of radioactive fall-out from the testing of nuclear weapons led the United Nations General Assembly to establish the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) already in 1955, i.e. 2 years before the IAEA was established. This Committee has set up a world-wide system of reliable radioactivity measurements and publishes yearly reports.

CUMULATIVE DEPOSITION OF STRONTIUM-90

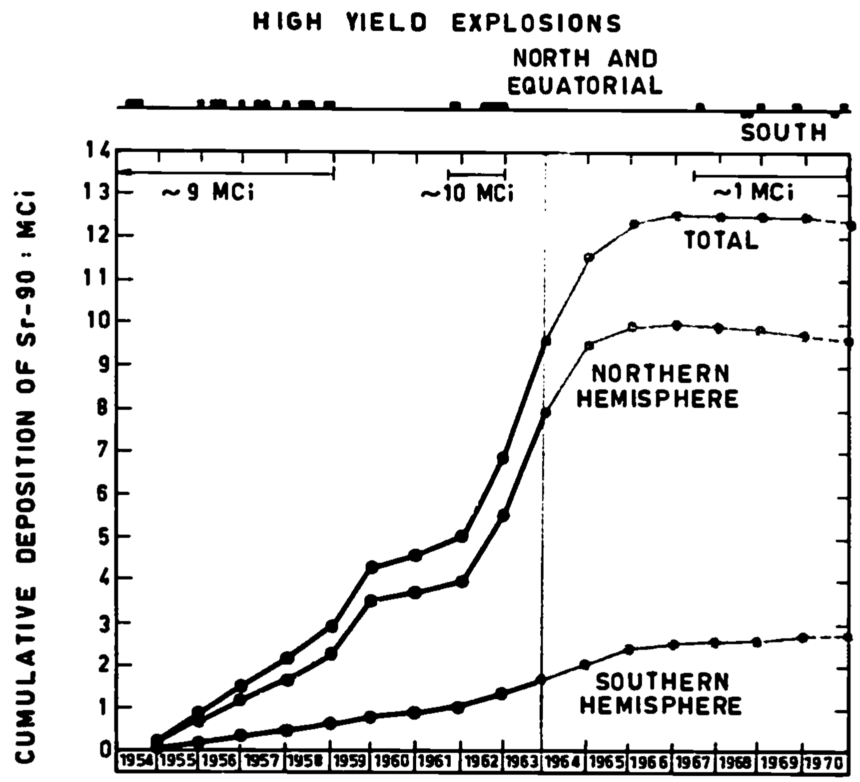


Fig. 2 SHOWS THE CUMULATIVE DEPOSITION OF STRONTIUM-90

CUMULATIVE DEPOSITION: A description of the history of the deposition of strontium-90 is given in Fig.2, shows the cumulative amounts corrected for radioactive decay.

The accumulated deposit in the northern hemisphere remains about four times that in the southern hemisphere.

NUCLEAR TEST BAN

Treaty banning nuclear weapon tests in the atmosphere, in outer space and under water.
Done at Moscow, August 5, 1963;
Ratification, accession or notification of succession deposited by:

Afghanistan
Australia
Austria
Belgium
Bolivia
Botswana
Brazil
Bulgaria
Burma
Byelorussian Soviet Socialist Republic
Canada
Central African Republic
Ceylon
Chad
Chile
China
Costa Rica
Cyprus
Czechoslovakia
Dahomey
Denmark
Dominican Republic
Ecuador
Egypt, Arab Rep. of
El Salvador
Finland
Gabon
Gambia, The
Germany, Dem. Rep. of
Germany, Fed. Rep. of
Ghana
Greece
Guatemala
Honduras
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Ivory Coast
Japan
Jordan
Kenya
Korea, Rep. of
Kuwait
Laos
Lebanon
Liberia
Libya
Luxembourg
Madagascar
Malawi
Malaysia
Malta
Mauritania
Mauritius
Mexico
Mongolia
Morocco
Nepal
Netherlands
New Zealand
Nicaragua
Niger
Nigeria
Norway
Panama
Peru
Philippines
Poland
Romania
Rwanda
San Marino
Senegal
Sierra Leone
Singapore
South Africa
Spain
Sudan
Swaziland
Sweden
Switzerland
Syrian Arab Rep.
Tanzania, United Rep. of
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Uganda
Ukrainian Soviet Socialist Rep.
Union of Soviet Socialist Republics
United Kingdom
United States of America
Uruguay
Venezuela
Western Samoa
Yugoslavia
Zaire, Rep. of
Zambia

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Federal Radiation Council, Rep. No.4 (US Govt. Printing Office, Washington, DC, 1964)

Cambray, R.S., Fisher, E.M.R., Brooks, W.L. and Peirson, D.H.: Radioactive Fallout in Air and Rain: Results to the Middle of 1970, AERE-R6556 (HMSO, London, 1970)

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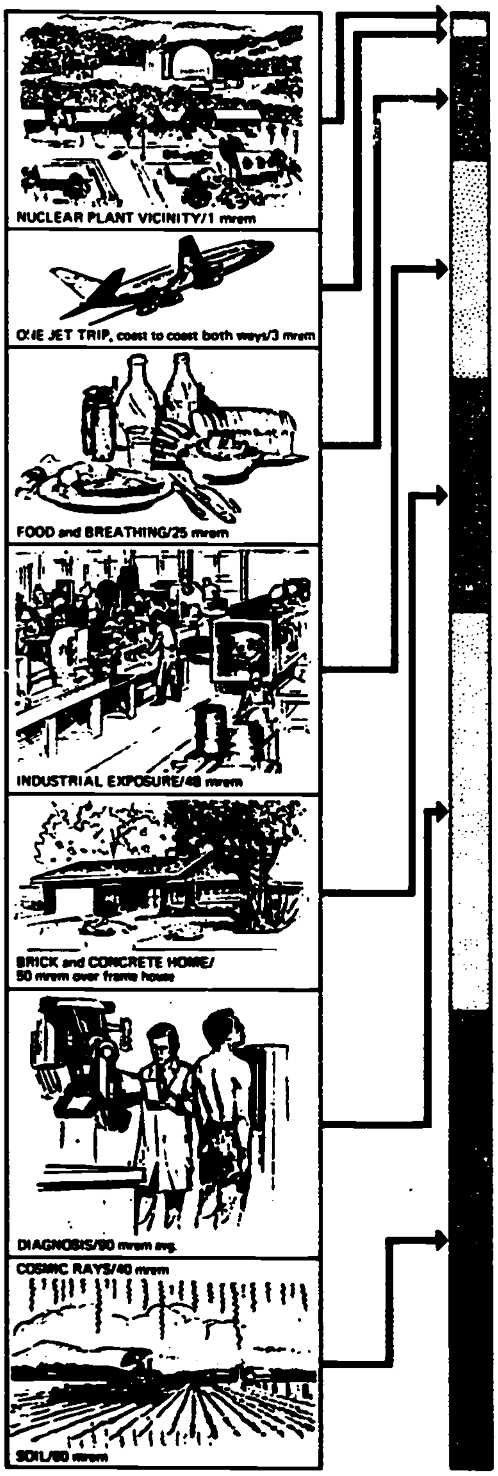
Volchock, H.L., Worldwide Deposition of Strontium-90 through 1969, HASL-227, I-70 (USAEC, New York, 1970)

Peirson, D.H., A.E. Research Establishment, Harwell, Nature, 234, Nov.12, 1971: Worldwide Deposition of Long-Lived Fission Products from Nuclear Explosions.



YEARLY RADIATION DOSAGE FROM VARIOUS SOURCES

Atomics International, North American Rockwell, 1972.

- From all natural sources we are exposed to 170-195 millirems of radiation per year.

- People living in the general vicinity of an operating reactor receive less than one added millirem a year or about 1% of what they receive from natural sources.

- Who decides how much radiation can be tolerated?

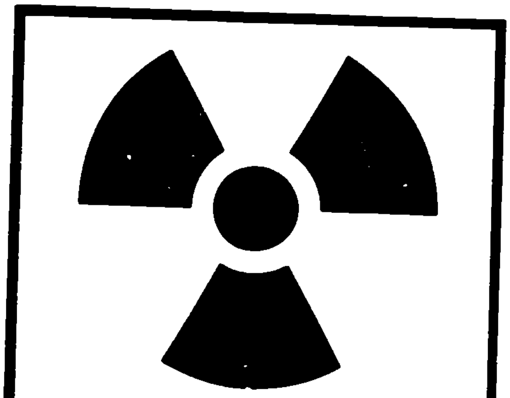
The International Commission on Radiological Protection (ICRP), an independent non-governmental body established in 1928, acts in an official advisory capacity to the World Health Organization (WHO) and its rules are universally accepted both by national and international bodies responsible for radiation protection.

- How much radiation can one tolerate?

The present recommendations set for workers allow for an exposure not exceeding 5 rems/year on the average. Thus, the lifetime dose for a worker (50 years) is 250 rems. Present operating rules are so stringent that workers in radiation laboratories are exposed to much less than that.

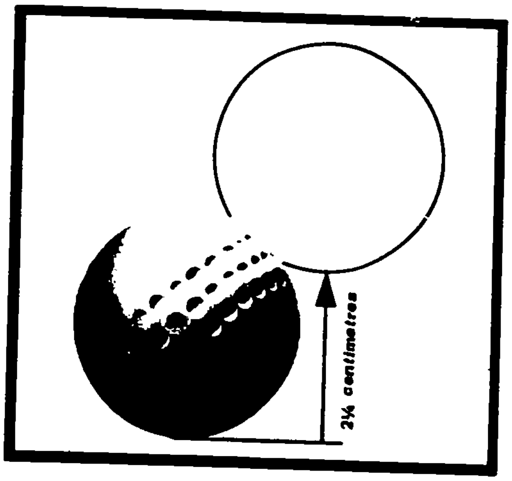
- The IAEA in consultation with ILO, WHO and other organizations has promulgated Basic Safety Standards for Radiation Protection which conform to ICRP recommendations and usually serve as a reference for national legislations.

Soon after the discovery of man-made sources of ionizing radiation (ionizing means formation of charged fragments) it became apparent that radiation could either cure or poison, depending on how it is used. Since one cannot smell or see ionizing radiation, special health physics instruments have been developed for detection and measurement. These dosimeters indicate the quality and measure the quantity of radiation.



The symbol of ionizing radiation

Today the most widely used unit of radiation is the rad, the word stemming from radiation absorbed dose. One rad is the quantity of radiation that delivers 100 ergs (units of energy) of energy to 1 gram of substance. Now, 100 000 ergs of energy is not much by our usual standards. It is about equal to the amount of energy delivered by a golf ball dropping 2 1/4 centimetres.



The biological measure of radiation effect on man is the rem. It is roentgen equivalent man; one rem is numerically equal to the product of absorbed dose, the quality factor, the dose distribution factor and possibly other modifying factors.

As soon as X-rays and other radiation devices began to be widely used by doctors, the need for regulating radiation doses arose. The International Commission on Radiological Protection (ICRP) set the maximum doses to which doctors, patients and other persons could be safely exposed. Dose limits for radiation protection have also been worked out for the general public.

Summary of dose limits for members of the public	
Organ or tissue	
Gonads, red bone-marrow	0.5 rem in a year
Skin, bone, thyroid	3 rems * in a year
Hands and forearms; feet and ankles	7.5 rems in a year
Other single organs	1.5 rems in a year
* in case of children 1.5 rems a year should not be exceeded.	
Source: Recommendations of ICRP, Publication No.9, Pergamon Press, London, 1966.	

On the other hand, the genetic dose to the population as a whole is 5 rems/generation (30 years).

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

(1) To prevent acute radiation effects: in 40 years of working experience of ICRP it has become evident that this objective can be achieved in normal

Not an astronaut, but a technician wearing a radiation protection suit. Credit: UKAEA

circumstances. Also to be excluded are such late effects as somatic injuries such as opacification of the lens of the eye, skin damage, impaired fertility and serious haematological effects. Today acute effects and the described late effects only arise when faulty apparatus or techniques give rise to doses greatly in excess of the Commission's recommended dose limits.

(2) To limit the risk of late effects, such as malignancy and genetic effects to an acceptable level.

All states with nuclear power programmes today have set up national licensing systems which require notification and registration prior to building a nuclear reactor. The national safety regulations are also subject to continuous controls.

TO KNOW MORE

Principles of Radiation Protection,
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Safe Handling of Radioisotopes: Medical Addendum;
1961 Regulations for the Safe Transport of Radioactive Materials:
Notes on Certain Aspects of the Regulations;
The Packaging, Transport and Related Handling of Radioactive Materials;
1962 The Use of Film Badges for Personnel Monitoring;
The Vinča Dosimetry Experiment;
Safe Handling of Radioisotopes;
1963 Diagnosis and Treatment of Radioactive Poisoning;
A Basic Toxicity Classification of Radionuclides;
1964 Assessment of Radioactivity in Man;
Radiation Quantities and Units;
Radiological Health and Safety in Mining and Milling of Nuclear Materials;
Training in Radiological Protection: Curricula and Programming;
1965 The Provision of Radiological Protection Services;
The Basic Requirements for Personnel Monitoring;
Personnel Dosimetry for Radiation Accidents;
1966 Environmental Monitoring in Emergency Situations;
Guide to the Safe Handling of Radioisotopes in Hydrology;
Manual on Environmental Monitoring in Normal Operation;
Techniques for Controlling Air Pollution from the Operation of Nuclear Facilities;
1967 Risk Evaluation for Protection of the Public in Radiation Accidents;
Respirators and Protective Clothing;
Regulations for the Safe Transport of Radioactive Materials;
Radiation Protection Standards for Radioluminous Timepieces;
Neutron Monitoring;
Basic Safety Standards for Radiation Protection;
Assessment of Airborne Radioactivity in Man;
1968 Medical Supervision of Radiation Workers;
Radiation Protection in the Mining and Milling of Radioactive Ores;

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Planning for the Handling of Radiation Accidents;
Quick Methods for Radiochemical Analysis;
Manual on Safety Aspects of the Design and Equipment of Hot Laboratories;
Handling of Radiation Accidents;
Environmental Contamination by Radioactive Materials;
1970 Air Filters for Use at Nuclear Facilities;
Guide to the Safe Design, Construction and Use of Radioisotopic Power;
Generators for Certain Land and Sea Applications;
Monitoring of Radioactive Contamination on Surfaces;
Nuclear Accident Dosimetry Systems;
Personnel Dosimetry Systems for External Radiation Exposures;
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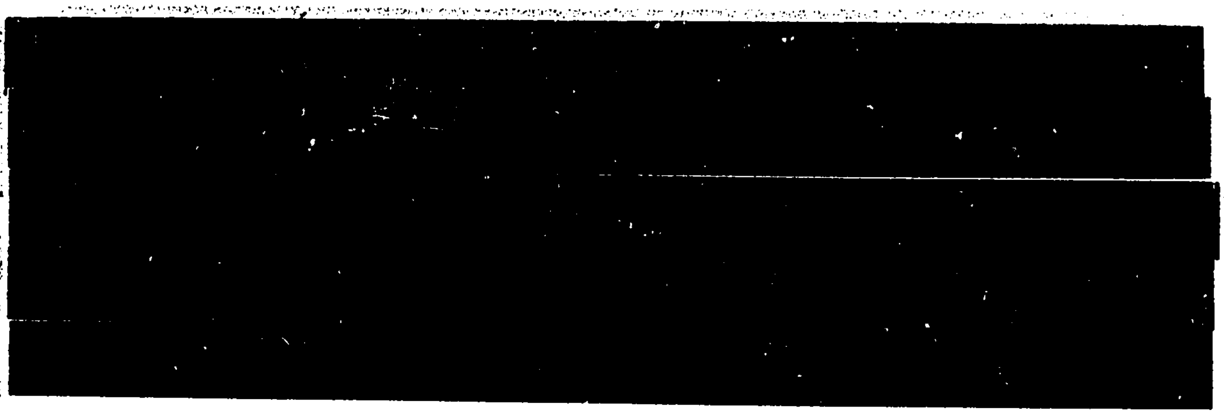
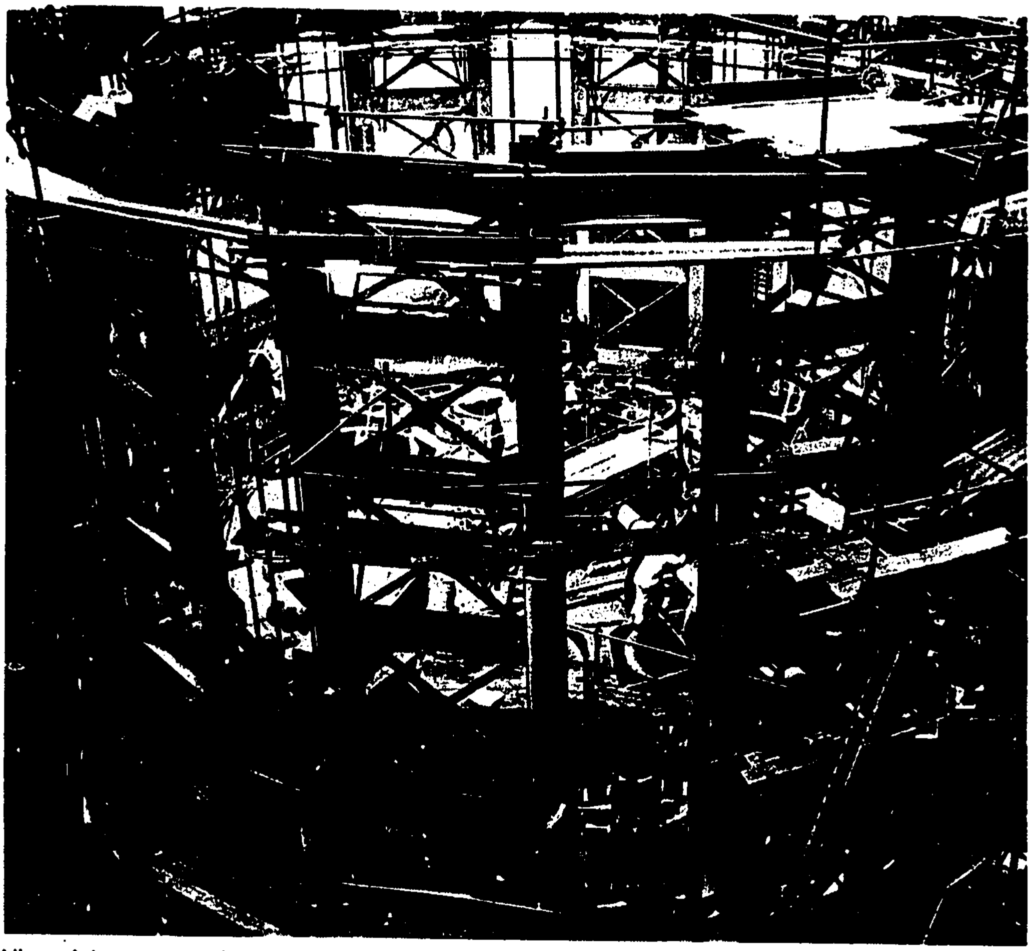


FAST BREEDER REACTORS

Today's nuclear power reactors are using up too much uranium and resources will not last forever. A new reactor concept is being developed, the fast breeders, which will produce more fuel than they consume.

Within the reactor the non-fissionable isotope of uranium-238 will be converted into plutonium-239 which is nuclear fuel. "Breeding" occurs because a greater neutron surplus is being proceeded from the chain reaction than is necessary for the self-sustaining reaction. The stockpile of fissionable material is thus steadily increased. In a period of about 10 years double of the amount put in originally will have accumulated.



View of the prototype fast reactor at Dounreay, Scotland, during construction. It will pave the way for the large power fast reactors of the future; UKAEA

NUCLEAR FUSION

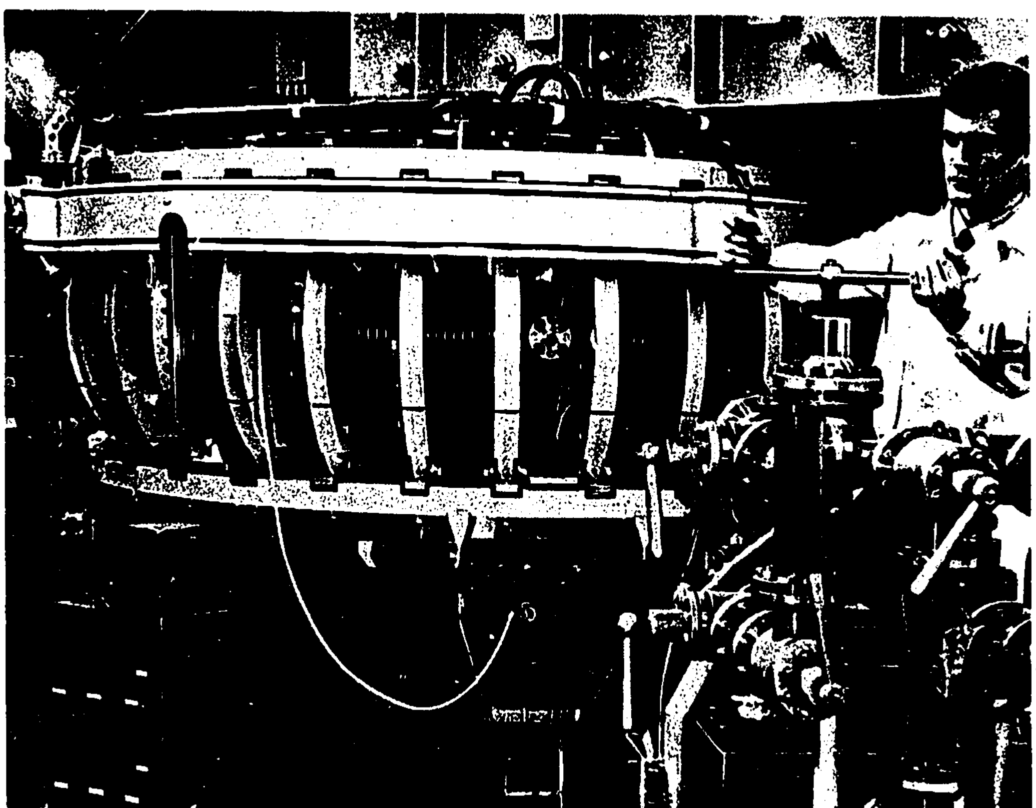
The energy of the sun and the stars is produced by the fusion of atoms of light elements. To exploit this energy source on earth, a gas of the heavy isotopes of hydrogen — deuterium and tritium — must be raised to a very high temperature and then confined at sufficiently high density for a certain time. Currently much research is being undertaken on the use of magnetic field in order to isolate the plasma, a very hot gas, from its container walls; this problem has not yet been solved.

In a fusion reactor, energy will be produced not only in the plasma, but in a surrounding "blanket" which will deliver heat to conventional steam turbines.

The advantages of nuclear fusion would be:

- cheap and almost inexhaustible fuel, i.e. deuterium or heavy water from the oceans of the world;
- the quantity of radioactive wastes might be significantly reduced;
- the energy of the charged particles of the hot plasma might possibly be directly converted to electrical energy without going through a thermal cycle.

Fusion research at the Tokamak-3 machine, USSR

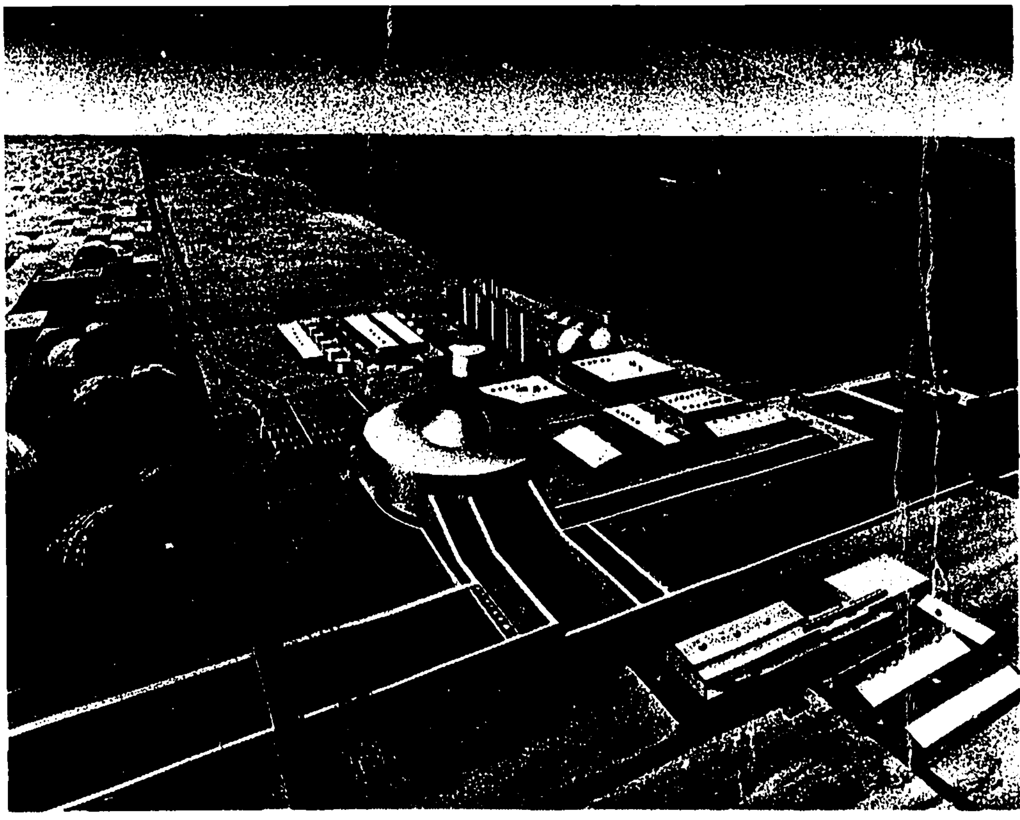


AGRO-INDUSTRIAL COMPLEXES

What is a Nuplex? The word stands for nuclear energy complex and might present one of the possible keys to economic development of arid countries.

Forerunners of Nuplex would be the dual-purpose nuclear power plants, where part of the nuclear energy produced would be used for the desalination of sea water, the other part being fed into the normal energy grid. Agro-industrial complexes would constitute the next step by adding fertilizer plants and then other chemical production facilities to the intensive farming area irrigated by desalted water. From this complex Nuplexes could evolve – whole new communities built around the atom.

Artist's impression of a nuclear powered agro-industrial complex; Oak Ridge National Laboratory, U.S.A.



NUCLEAR EXPLOSIONS FOR PEACEFUL PURPOSES

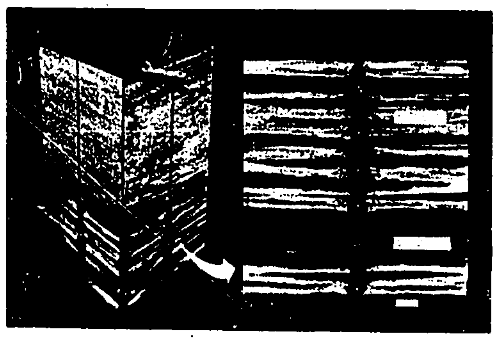
Nuclear explosions may be the cheapest source of raw energy available for large industrial applications. 10.000 tons of TNT would cost almost 15 times as much as an equivalent nuclear explosive. Like any powerful tool, it must be handled with great care due to possible radiation exposure, seismic and air blast damage.

There are two kinds of nuclear explosions: excavation blasts, explosions which are relatively close to the surface and vent to it. This technique could be used for

- reservoir construction
- canal construction
- harbour construction
- uncovering of mineral deposits;

contained blasts, explosions which are relatively deep underground, the products of which – gases and fragmented material – do not penetrate the surface:

- exploitation of oil and natural gas deposits
- creation of underground cavities for the storage of natural gas or biologically dangerous industrial wastes
- underground working of ore deposits.



Gas reservoir
stimulation using multiple nuclear explosives

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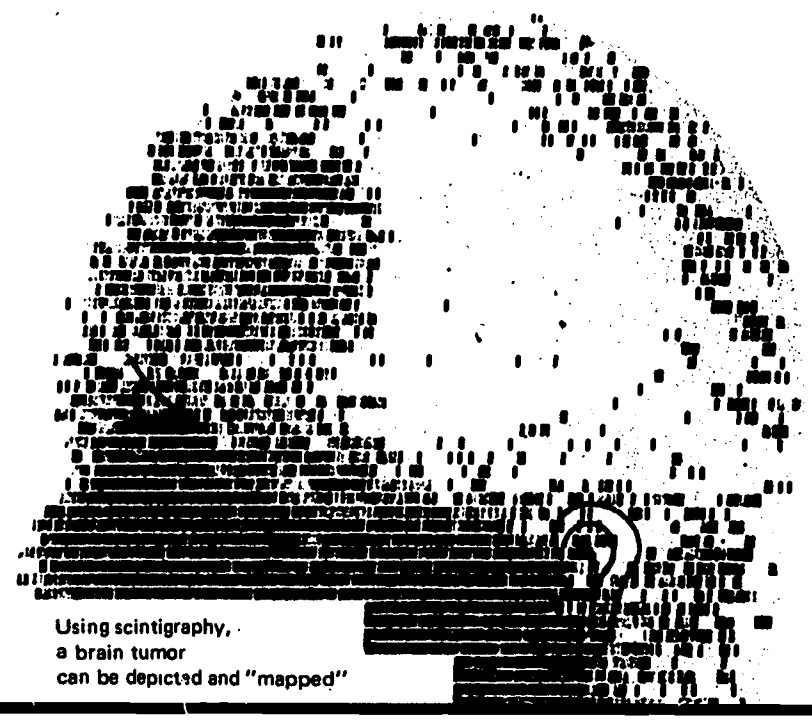


Using scintigraphy, a brain tumor can be depicted and "mapped"

Nuclear techniques in the medical field are becoming an indispensable tool.
There are four main areas in which radio-isotopes are used:

- clinical diagnosis
- therapy
- medical research
- sterilization of medical products

CLINICAL DIAGNOSIS

The importance and growth of nuclear techniques in clinical medicine have been so great that it has come to be recognized as a separate speciality in many countries. Radioisotopes provide information that is otherwise less accurately or not at all obtainable. Main uses are:

- scintigraphy to depict abnormalities in various organs or body tissues.

In scintigraphy, a radioactively labelled substance is given to the patient in a small dosage. The substance is then taken up by the organ or tissue of interest which can be "mapped" by the distribution of radioactivity in it. Abnormalities caused by various diseases can then be depicted.

- investigation of the functional state of various body organs or systems.

Using radioisotopes for this is well established, particularly for cardiac, renal, and thyroid functions and blood flow studies. Radioisotopes permit observation of the uptake, turnover and excretion of different substances and determination of malfunctions that might exist.

- measurement of biologically active substances in blood, urine or other specimens.

Blood and urine samples taken from a patient can be studied in detail in a laboratory using radioisotopes. This allows for repeated studies and avoids radiation exposure to the patient.

THERAPY

Radiation is a major treatment for certain kinds of cancer. Applying radiation to an organ affected by a tumor has proven effective in inhibiting the growth or in destroying the cancerous cells. There are three established methods of administering radiation:

- teletherapy – a beam of radiation from a radioisotope source is directed at a target area
- brachytherapy -- the radioisotope source is confined in a suitable container which is physically inserted or brought into contact with the target area
- radiopharmaceutical therapy -- the radioisotope source is administered in a suitable chemical form so that it will concentrate in a target area

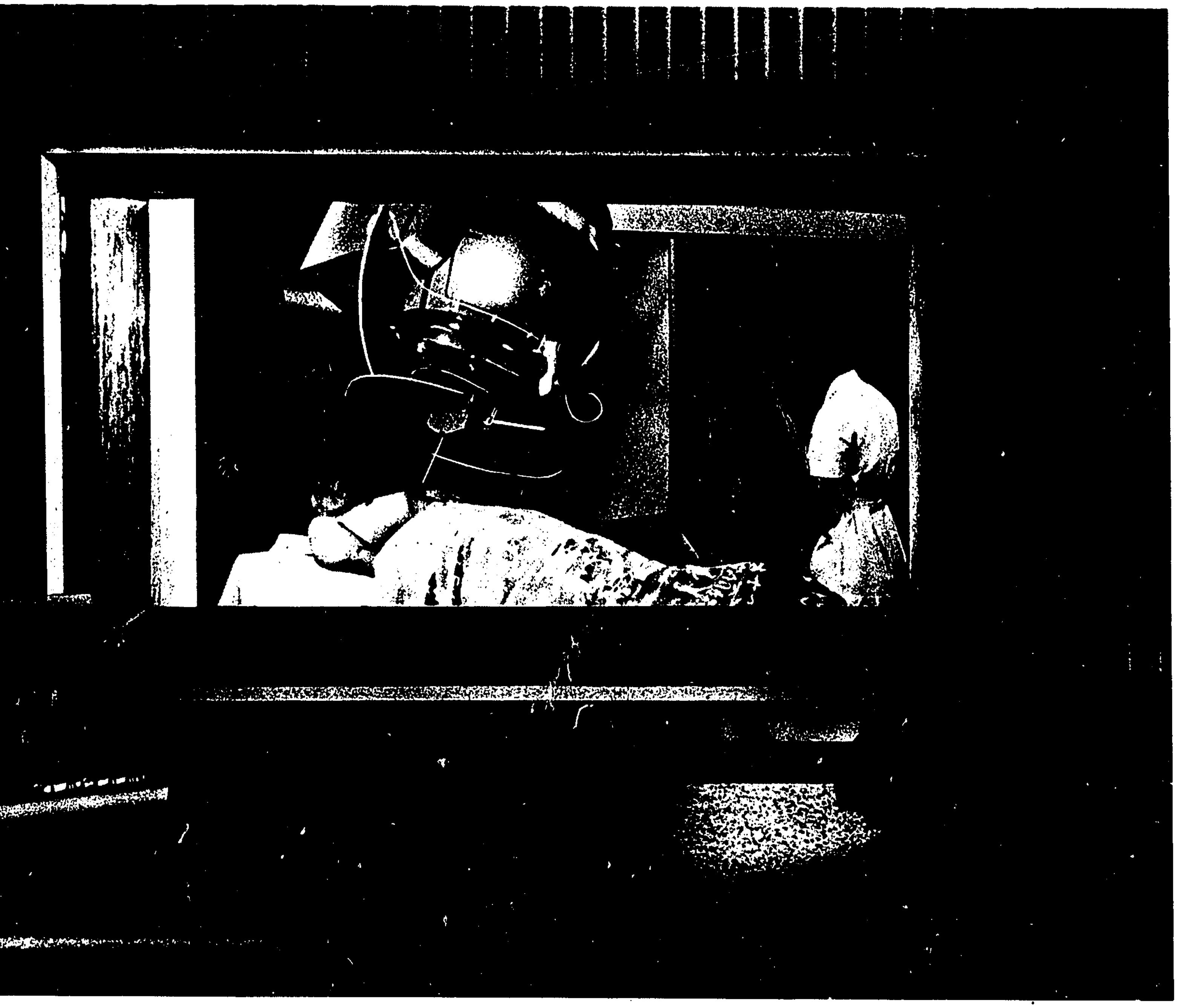
MEDICAL RESEARCH

Tracer studies have revolutionized many branches of the medical field, particularly endocrinology, immunology, biochemistry and nutritional studies. Radioisotopes induced the detection of a second thyroid hormone. To understand nutritional disorders, radioactively labelled foodstuffs have been used to study the absorption and metabolism of important nutrients. Life cycles of certain disease-causing parasites have been more clearly understood through tracer techniques. Nuclear techniques have substantially contributed to the understanding of complex metabolic processes.

STERILIZATION OF MEDICAL PRODUCTS

The sterilization of medical products, equipment, devices and pharmaceuticals is essential to prevent infection. The ability of ionizing radiation to destroy microorganisms has been found useful in many instances where other procedures are not applicable. Any substance may be sterilized in this manner so that materials that are heat sensitive such as some plastics can be treated.

A patient receiving a cobalt - 60 treatment for cancer



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Hunger and malnutrition affect 2/3 of mankind. This problem could be brought under control in a matter of years. Nuclear techniques are helping in this effort in a variety of ways:

Insect control
- Sterile-male technique
- Mode of action of insecticides and other agricultural chemicals
- Ecology of insect pests

Irrigation
- Efficiency of water use
- Water balance
- Source and quantity of water supply

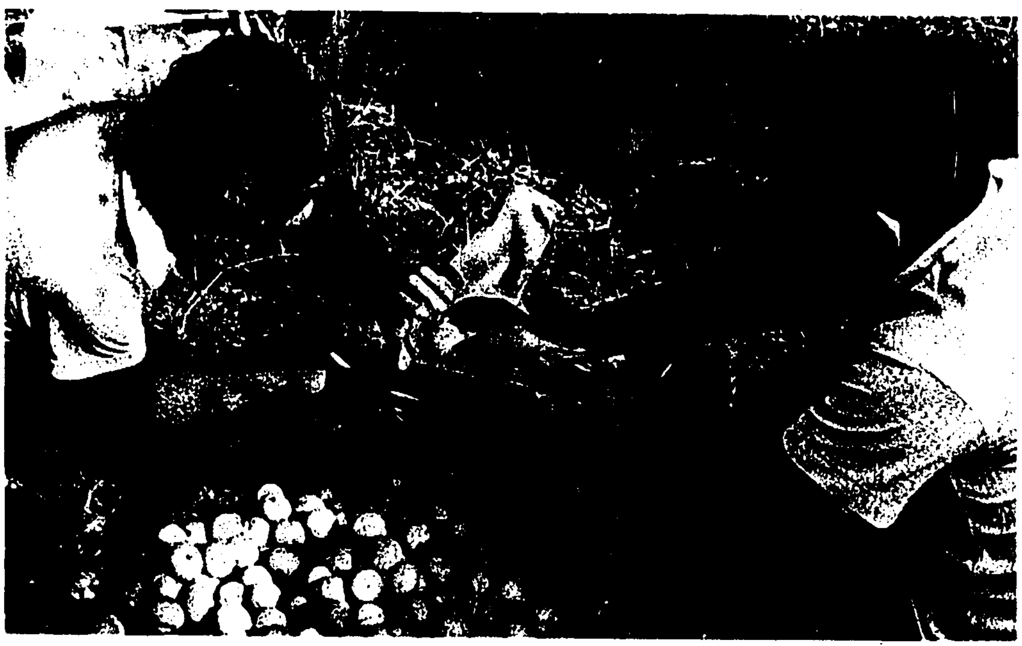
Soil fertility, plant nutrition
- Efficiency of fertilizer use including nutrient losses, when, where, and what form of fertilizer
- Nutritional problems of unknown origin
- Nutrient interactions

Food & environment contamination
- Detection of pesticide residues
- Metabolic studies of pesticides
- Monitoring of food contamination from fallout.

Plant breeding
- For higher yields
- For disease resistance
- For improved quality
- For growth under unfavourable environmental conditions

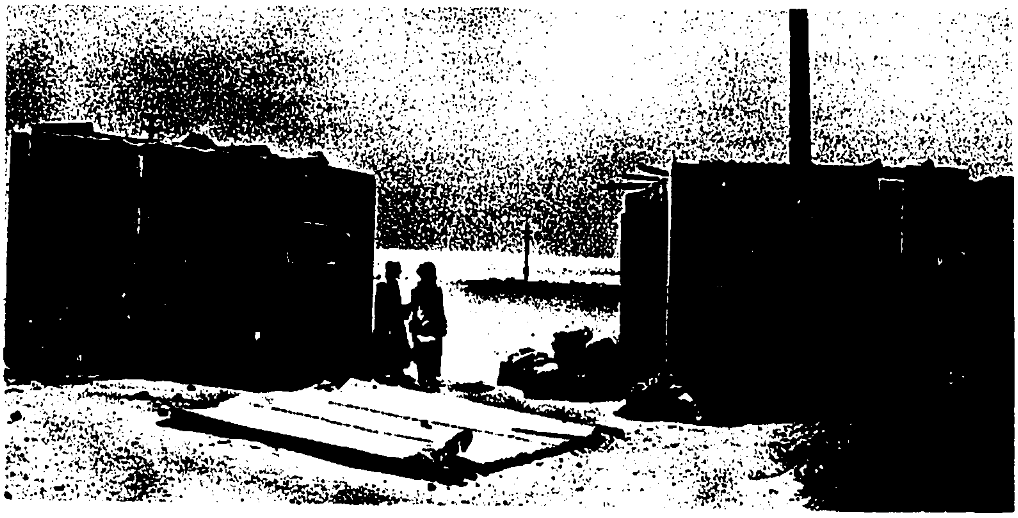
Animal production and health
- Efficiency of protein and milk production
- Nutrient deficiencies
- Parasite control (vaccines)

Food preservation
- Prevention of sprouting and disinfestation
- Extension of shelf life
- Elimination of harmful organisms
- Production of infinitely stable (sterile) products



INSECT CONTROL

An estimated 12% of the preharvest global agricultural production is lost due to insect pests each year. The sterile-male technique is a control method that helps to avoid undesirable pesticide residues which contaminate the environment.
Researchers examine fruit from an area in which sterile flies were released for any evidence of infestation.



IRRIGATION

The universal use of proper water techniques would allow for an increase in the world's irrigated area of 50% or more, using the same amount of water. The IAEA assists in studies of water resources using isotope techniques in some 20 countries. One of these investigations is being carried out in the Great Sahara. The photo shows concrete blocks that house boreholes from which scientists take samples of tritium-labelled water.

SOIL FERTILITY, PLANT NUTRITION

Radioisotopes make it possible to determine the uptake and fate of applied nutrients and thus determine optimum modes of application and the effectiveness of various fertilizers. In an experiment in Ceylon, radioactive isotopes in solution were used to ascertain uptake of fertilizer at varying distances and depths from a coconut palm.

It is estimated that about 33% of the global agricultural plant production is lost due to pests and disease each year (insect pests-12%, weeds-10%, plant diseases-12%). This amounts to $70,000 million pre-harvest loss per year.

FOOD AND ENVIRONMENT CONTAMINATION

Radioisotope methods are powerful tools for studying the fate and significance of pesticide residues and other chemical and radioactive contaminants of food and the agricultural environment. The IAEA is sponsoring a programme to study these problems at Makerere University, Kampala, Uganda. In combating the tsetse fly, radioactively-labelled insecticides are sprayed under different conditions and their fate in the environment is determined over the next weeks and months. Here bark samples are collected for study.

PLANT BREEDING

Irradiation of seeds results in creating genetic variability of crop plants, which through breeding increase food production in tarms of quantity and quality. The picture shows two types of barley growing in an experimental field. On the right is the normal variety, on the left is the mutant variety, which can make better use of nitrogen fertilizer to increase yield.

ANIMAL PRODUCTION AND HEALTH

Using a radiation-attenuated vaccine against the sheep lung worm in India, the average difference in meat weight between treated and untreated animals was 2.8 kg per animal over a six month period.

FOOD PRESERVATION

"It is probably fair to state that the process of radiation treatment of foods has been more thoroughly tested for safety of consumption than has any other food preservation technique."
Kenneth F. MacQueen

IRRADIATED FOOD PRODUCTS CLEARED FOR HUMAN CONSUMPTION (AUGUST 1971)

Country	Product	Purpose of Irradiation	Radiation Source	Dose (permissible range)(Krad)	Date of approval
Canada	potatoes	sprout inhibition	Cobalt 60	10 max. 15 max.	9 November 1960 14 June 1963
	onions	sprout inhibition	Cobalt 60	15 max.	25 March 1965
	wheat and wheat products	insect disinfestation	Cobalt 60	75 max.	28 February 1969
Denmark	potatoes	sprout inhibition	10 MeV Electrons	15 max.	27 January 1970
Hungary	potatoes (experimental batches)	sprout inhibition	Cobalt 60	10	23 December 1969
Israel	potatoes	sprout inhibition	Cobalt 60	15 max.	5 July 1967
	onions	sprout inhibition	Cobalt 60	10 max.	25 July 1968
Netherlands	asparagus (experimental batches)	radurization	Cobalt 60	200 max.	7 May 1969
	cacaobeans (experimental batches)	disinfestation	Cobalt 60 4 MeV Electrons	70 max.	7 May 1969
	strawberries (experimental batches)	radurization	Cobalt 60 4 MeV Electrons	250 max.	7 May 1969
	mushrooms	radurization	Cobalt 60 4 MeV Electrons	250 max.	23 October 1969
	potatoes	sprout inhibition	Cobalt 60 4 MeV Electrons	15 max.	23 March 1970
	shrimps (experimental batches)	radurization	Cobalt 60 4 MeV Electrons	50 - 100	13 November 1970
	spices (experimental batches)	radicidation	Cobalt 60 4 MeV Electrons	800 - 1000	1970
	onions (experimental batches)	sprout inhibition	Cobalt 60 4 MeV Electrons	15 max.	5 February 1971
Spain	potatoes	sprout inhibition	Cobalt 60	5 - 15	4 November 1969
United States of America	wheat and wheat flour	insect disinfestation	Cobalt 60 Cesium 137 5 MeV Electrons	20 - 50 20 - 50 20 - 50	21 August 1963 2 October 1964 26 February 1966
	white potatoes	sprout inhibition	Cobalt 60 Cesium 137 Cobalt 60 + ^{137}Cs	5 - 10 5 - 10 5 - 15	30 June 1964 2 October 1964 1 November 1965
Union of Soviet Socialist Republics	potatoes	sprout inhibition	Cobalt 60	10	14 March 1958
	grain	insect disinfestation	Cobalt 60	30	1959
	dried fruits	insect disinfestation	Cobalt 60	100	15 February 1966
	dry food concentrates	insect disinfestation	Cobalt 60	70	6 June 1966
	fresh fruits & vegetables (experimental batches)	radurization (extension of market-life)	Cobalt 60	200 - 400	11 July 1964
	semi-prepared raw beef, pork & rabbit products, in plastic bags (experimental batches)	radurization	Cobalt 60	600 - 800	11 July 1964
	poultry eviscorated, in plastic bags (experimental batches)	radurization	Cobalt 60	600	4 July 1966
	culinary prepared meat products (fried meat, entrecôte), in plastic bags (experimental batches)	radurization	Cobalt 60	800	1 February 1967
	onions (experimental batches)	sprout inhibition	Cobalt 60	6	25 February 1967

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Insect-Pest Management and Control, National Academy of Sciences, Washington, D.C., 1969

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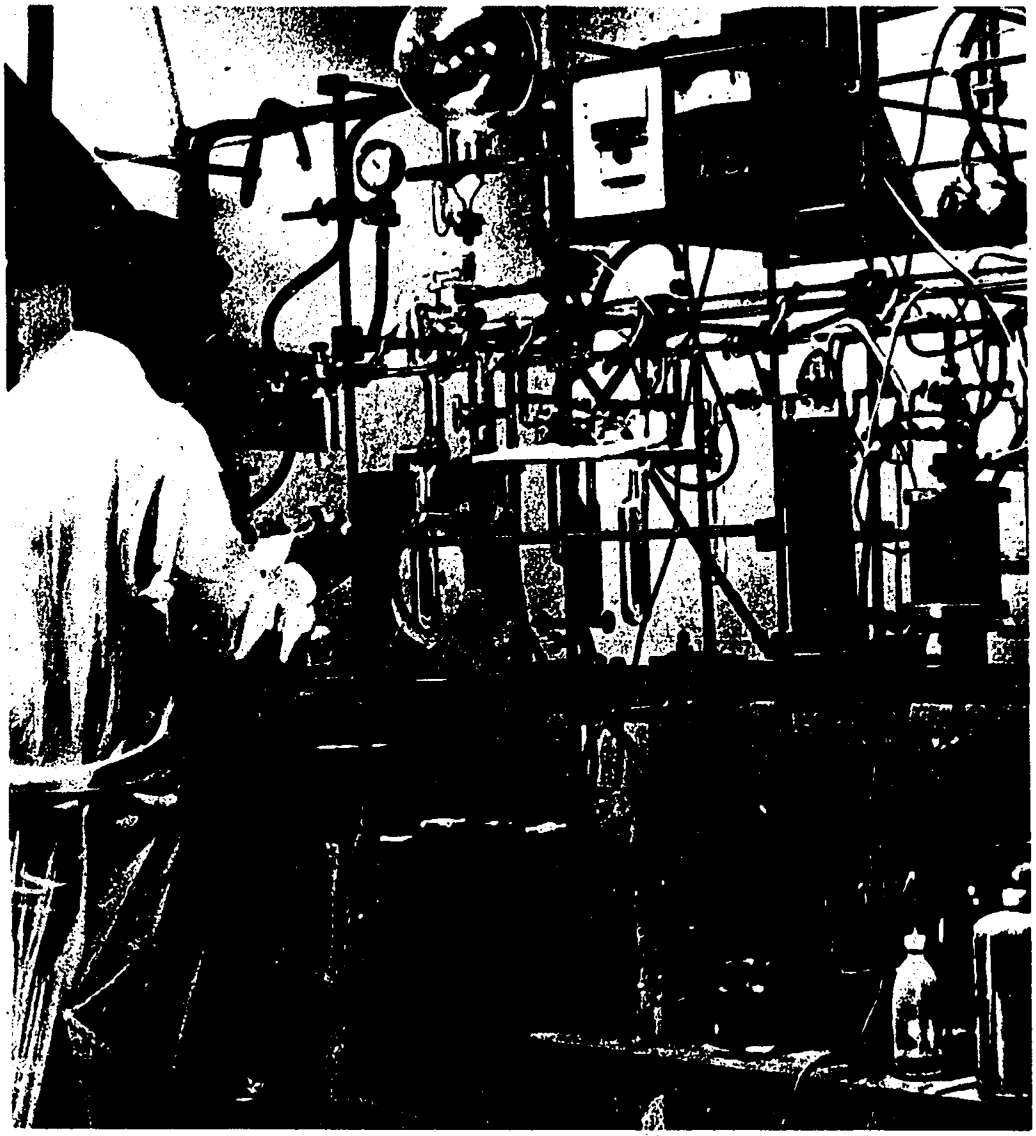
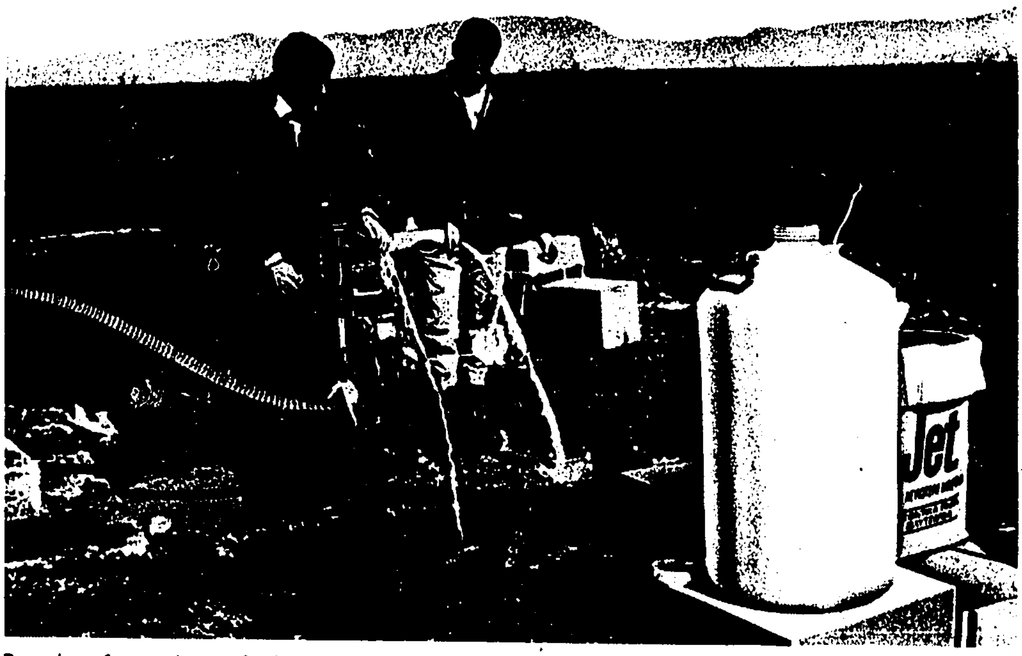


Some of the laboratory equipment used to prepare water samples for analysis

Water is one of the basic elements for survival. A sup~~ply of adequate water for~~ various uses, sufficient in quantity and adequate in quality, is a basic need for every community regardless of its size and its stage of development.

Progressively increasing demands for water require careful appraisal of water resources in order to achieve the most efficient and beneficial uses of available resources. Although there is a continuous circulation of water in nature, which is called the hydrologic cycle, usable water resources in any given region are limited. Thus, we must learn everything about water: how much is available, its location, and how to use it beneficially and without spoiling its quality.



Pumping of groundwater for isotope analysis

The movement of water in the hydrologic cycle is erratic in time and space. It takes both engineers and hydrologists to search for methods and tools to solve the difficult problems associated with the origin, the distribution and properties of water. Nuclear techniques are among the most modern means for studying hydrology and can be effectively used along with other hydrologic methods in order to have a comprehensive knowledge and understanding of the available water resources. For certain types of hydrologic information, nuclear methods are the only possible means.

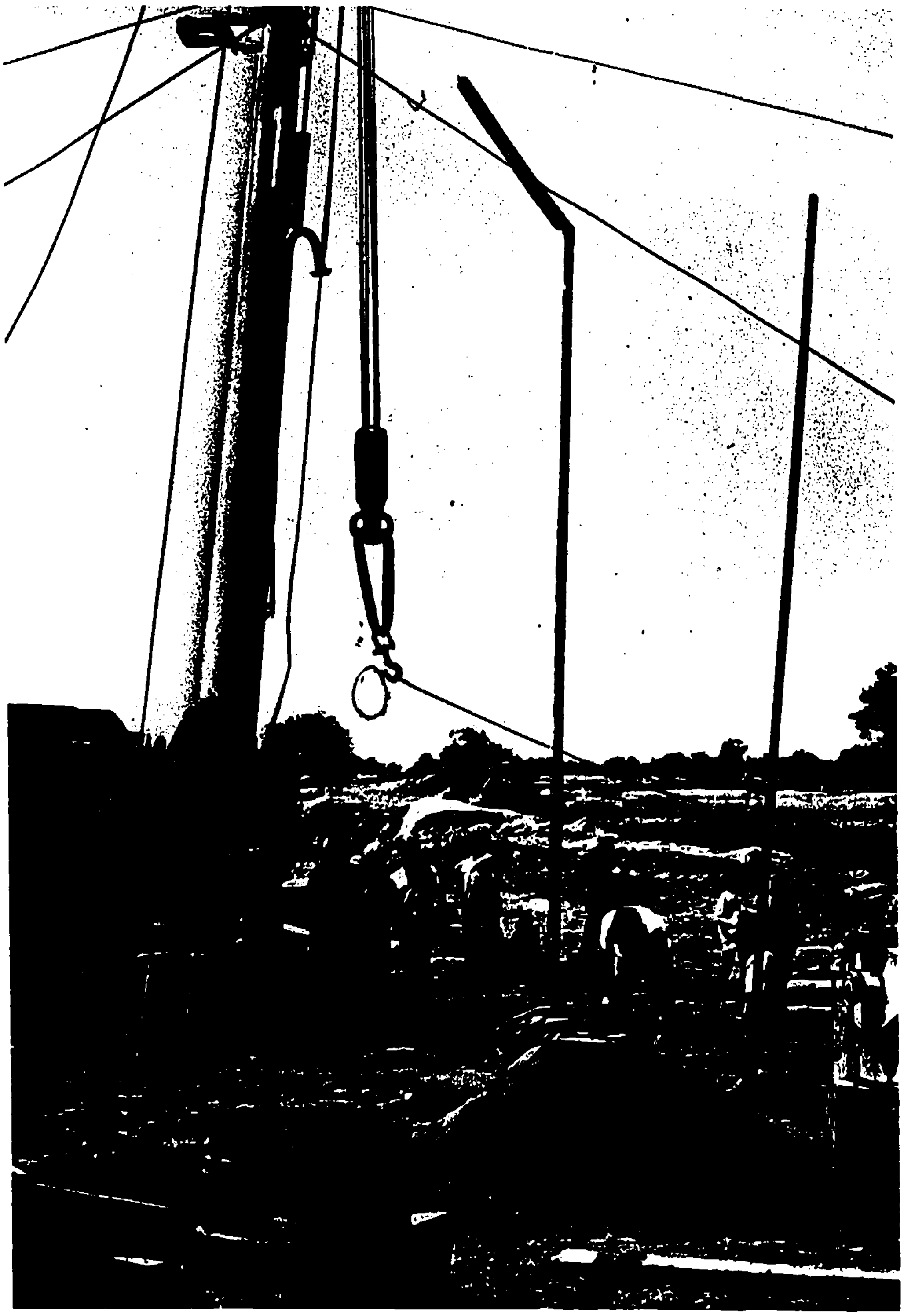
Isotopes are used as tracers to identify water movement and related characteristics through various phases of the hydrological cycle:

- Measurement of streamflows
- Measurement of snow cover and its water equivalent
- Measurement of suspended sediment carried by rivers
- Determination of aquifer characteristics such as porosity and transmissivity
- Determination of direction and velocity of groundwater flows
- Study of dynamics of lakes
- Study of leakage from lakes and reservoirs
- Study of groundwater systems on a regional basis, in order to determine their recharge areas, the amount of recharge and their interconnections with different water bodies.

Once the water distribution and movement is identified, water can be tapped more effectively and efficiently both for agricultural and domestic uses.

IAEA is actively involved in the application of nuclear techniques in water resources development projects in various countries in collaboration with other UN agencies, such as FAO, WHO and UNESCO. It also participates in the work of the International Hydrological Decade (IHD) organized by UNESCO and in the ACC Sub-Committee on Water Resources Development.

Drilling operations in search of groundwater



ARID ZONES AND AREAS FACING WATER PROBLEMS

Arid and semi-arid zones (darker areas) cover more than 1/3 of the world's exposed land surface.

TO KNOW MORE

Primenenie radioacktivngh izotopov v gidrotehniceskom stroitel'stve, (by) M.P. Belikov, V.A. Emel'janov, V.E. Nesterov, Moscow, Goddtrojizdat, 1961

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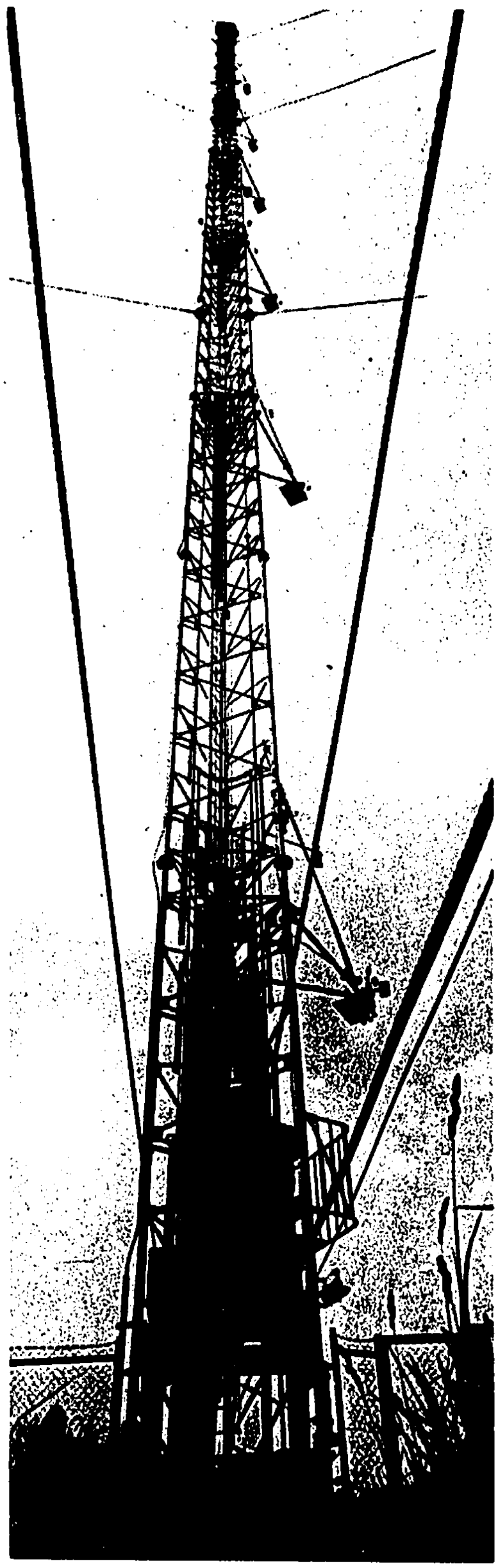
Isotope Hydrology 1970, Proceedings of a Symposium, Vienna, IAEA, 1970

Nuclear Techniques in Environmental Pollution, Proceedings of a Symposium, Salzburg, IAEA, Vienna, 1971

Where does this pollution originate? Is it affecting your environment?



Little is known about the quantitative behaviour of air pollutants, although more than 200 million tons are released into the atmosphere each year in the United States alone.
To identify and map these pollutants, two nuclear techniques are used:

- tracers
- activation analysis

● TRACERS

As a rule, information on the behaviour, dispersion and fate of air pollutants after they leave their place of origin is difficult to interpret if there is a variety of sources. Isotopic tracers are a means of readily acquiring this information. Generally, activable tracers and isotopic ratio techniques give the best results, especially in large-scale field studies. The two stable isotopes of sulphur make it easy to follow sulphur oxides as they are emitted from fossil fuel plants and are converted into sulphur dioxides in the atmosphere. The stack that is releasing the pollutant can then be identified.

● ACTIVATION ANALYSIS

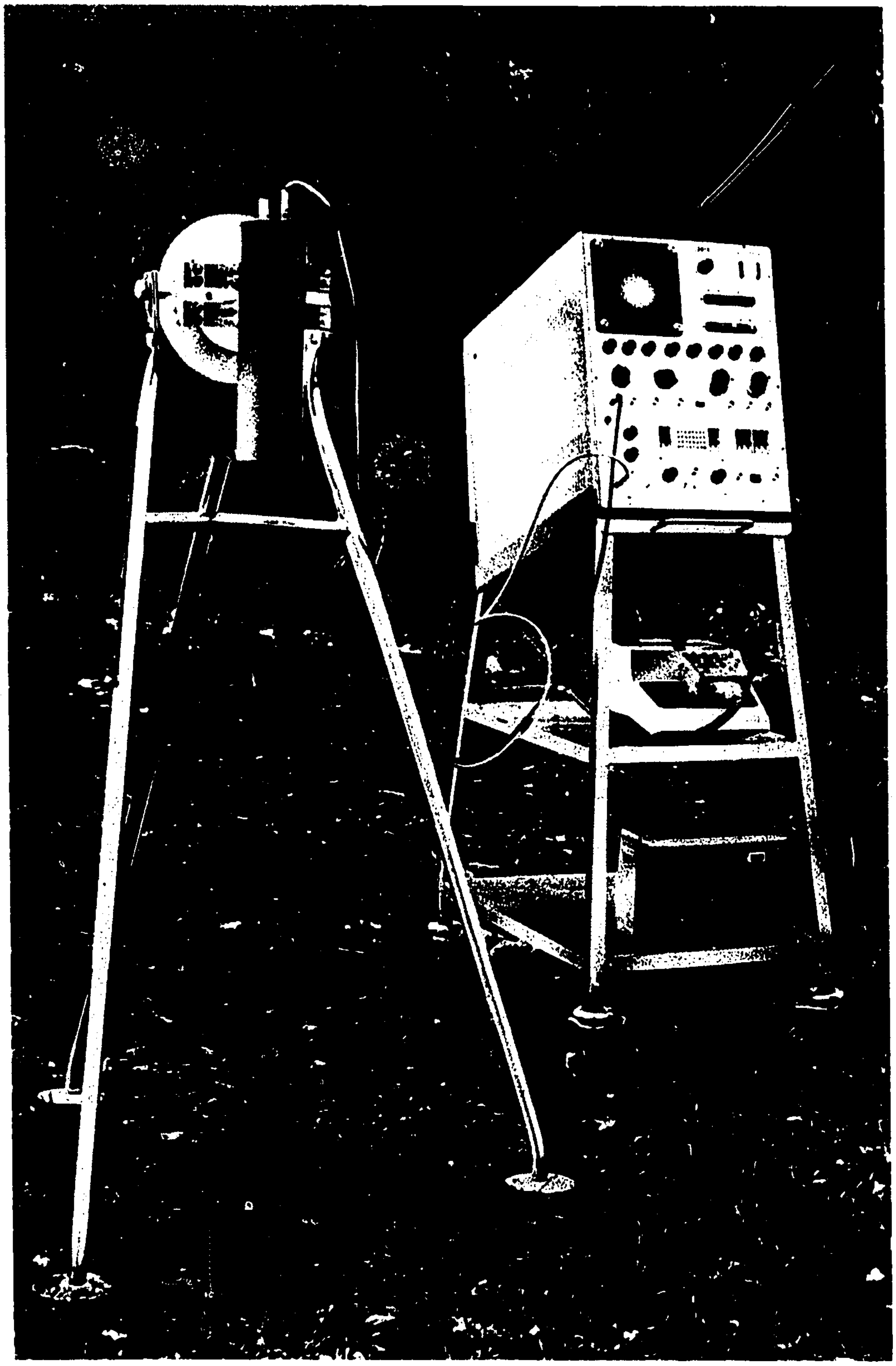
Using neutron activation analysis, researchers are able to distinguish the elemental composition of particles in the air. Local dilution and dispersion of the pollutant from its source and transport and removal of the pollutant to land and sea surfaces by atmospheric processes can be studied when several samples are taken from different places. It is also possible to use the elemental ratios (such as F/Cl) to define whether a pollutant is of natural origin or due to pollution.

ENVIRONMENTAL MONITORING

An environmental monitoring system is used to measure radiation levels in the atmospheric environment. This system measures background radiation and can immediately note any significant changes that might occur. Checks are made around nuclear facilities to insure that normal levels are maintained.

⇦ Tracers can be dispersed from this tower to be followed through the atmosphere.
The tower is also equipped to take readings at different heights to measure radiation or tracers.

Equipment Used in Environmental Monitoring ⇨



TO KNOW MORE

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48