Isotopes and radiation for modern industry

by S. Machi, H.C. Yuan, and Y.G. Sevastyanov*

Technology based on isotopes and radiation is essential for industrial modernization. Introduction of this technology saves raw materials and energy, improves product quality and the operational safety of plants, and helps protect the environment; all of which leads to social and economic benefits in both developed and developing countries.

The IAEA's international conference on industrial application of isotopes and radiation technology, held in France in 1981, attributed the significant growth in use of such technology during the past decade to the development of new applications and to improvements in the reliability of instruments and equipment. Annual sales of radiation products have reached a level of between US $2 and 3 million. The total activity of Co-60 sources installed for industrial purposes is approximately 70 MCi, and the installed capacity of industrial electron-beam accelerators is more than 14 MW. Radiation technology provides a unique processing tool with the following advantages: temperature independence; low-temperature capability; ease of control; freedom from catalyst; capability in solid substrates; and high speed reaction.

Table 1 contains a listing of major industrial radiation products. They cover a wide field of applications and uses, necessary for everyday life. In many cases, radiation processing has been recognized to have superior characteristics including energy saving, less pollution, simplicity of process, and unique products.

To develop new applications of radiation chemistry and processing, the International Atomic Energy Agency is implementing two co-ordinated research programmes. One is on the use of radiation technology for the immobilization of bioactive materials, such as enzymes, antibodies, antigens, tissue cells, and drugs. With radiation processing, the biocomponent is not de-activated and not contaminated because the immobilization is carried out at low temperatures and without using catalysts. There is a wide spectrum of potential applications of immobilized bioactive materials in the chemical and food industries as well as in medicine. The other programme is to develop new materials such as separation membranes (to be used, for example, in desalination) and biocompatible materials using radiation grafting techniques.

* Mr Machi is Head, Industrial Applications and Chemistry Section in the Agency's Division of Research and Laboratories. Mr Yuan and Mr Sevastyanov are staff members in the Industrial Applications and Chemistry Section.

Table 1. Industrial applications of radiation technology

Products	Uses	Radiation sources
Cross-linking of insulation of wires and cables	Heat-resistant wire and cable	Accelerator
Polyethylene foam	Thermal insulation, backing, mats, sports clothing, etc.	Accelerator
Curing of surface-coating	Wood panel, steel, ceramic tiles, plastic film, paper, etc.	Accelerator
Heat-shrinkable tubing and sheets	Electrical insulation, corrosion protection of pipelines, food packaging	Accelerator
Wood/plastic composite	Flooring, furniture, sporting goods, etc.	Co-60
Acrylic-acid grafted polyethylene	Lamination on metal foil	Accelerator
Degradation of PTFE	Solid lubricants	Co-60, accelerator
Polymer flocculant	Treatment of waste water	Co-60
Synthesis of chemicals	Synthetic detergent, chlorinated paraffin, etc.	Co-60, accelerator
Super absorbant products	Disposable diapers, air freshener, etc.	Accelerator
Pre-vulcanized rubber	Automobile tyres	Accelerator
Conservation of historical works	Wooden and stone works	Co-60
Sterilization of medical supplies	Needles, syringes, sutures, blades, dialyser, bandages, etc.	Co-60, accelerator
Food irradiation	Potatoes, onions, shrimps, etc.	Co-60

A large demonstration project on radiation technology is being implemented in Indonesia by the IAEA and the United Nations Development Programme (UNDP) under the Regional Co-operative Agreement (RCA)*, for the transfer of technology to developing Member States. Three technologies are being transferred under this project: radiation vulcanization of natural rubber; electron-beam curing of surface-coating on wood products; and cross-linking of wire insulation. Semi-commercial scale demonstration plants for rubber vulcanization using a Co-60 source, and for surface-coating using electron-beam accelerators, will be commissioned in 1983. These plants will provide on-the-job training and market development in thirteen RCA Member States. Another large project on electron-beam applications in industry is being implemented in Egypt, funded by UNDP.

Sterilization of medical supplies

Sterility is the chief criterion of quality for many medical supplies. In a radiosterilization facility, hermetically sealed supplies, packed in cardboard boxes, are made to pass several times before a Co-60 source via a conveyor system. Radiation emitted by the Co-60 penetrates the packing material, destroying microbial pathogens in the product, thus rendering it sterile. Compared with conventional techniques, radiosterilization has the following advantages: continuous operation of the irradiation facility with a minimum of maintenance and attendance; high operational reliability; high degree of sterility assurance; no toxic chemicals are used; and capability in many single-use items made of plastic materials.

At the present time, nearly 70 plants are operating in all parts of the world, offering extensive irradiation services on a routine basis. Some have a capacity as large as 4 to 6 MCi of Co-60. As a result, single-use medical supplies of high quality have become widely available, and this has contributed greatly to improving public health.

Since 1970 the IAEA, with the assistance of UNDP, has successfully promoted radiation sterilization in developing Member States, notably Egypt, Hungary, India, the Republic of Korea, and Yugoslavia. The IAEA and UNDP's assistance to these projects went beyond the mere demonstration of techniques and the provision of equipment; the emphasis was on establishing commercial irradiation services and on demonstrating economic viability. The plants constructed in the above five countries were all designed to accommodate a Co-60 source of up to one megacurie. Recently, the Islamic Republic of Iran has also received assistance from the IAEA and UNDP to launch a radiosterilization project in a similar manner. Under the regular technical co-operation programme, the Agency has provided support to Bangladesh, Ghana, the Philippines, and Portugal in establishing pilot-scale irradiation facilities for radiosterilization. Under the RCA, three training courses on radiation sterilization will be held in India and in the Republic of Korea in 1983, 1984, and 1985.

The Agency's efforts have brought technical and economic benefits in these radiation sterilization projects. The essential points are as follows: transfer of technical know-how for the construction and operation of facilities; improvement of radiation efficiency and dose uniformity for megacurie Co-60 irradiators; and availability of sterilized single-use disposable medical supplies by stimulating local manufacturers to use irradiation services and to diversify into new products or exports.

Non-destructive testing by radiography

Industry has placed increasing emphasis on improving the reliability and safety of machines and systems because such improvements have prevented serious accidents or breakdowns in production lines. Isotope radiography based on iridium-192, caesium-137, cobalt-60, etc., has been used extensively in the quality control of weldings and castings for machinery, pipelines, and boilers. The importance of industrial radiography has been fully demonstrated in big construction projects for nuclear and fossil-fuel power plants, petroleum refining, petrochemical plants, and cross-country pipelines transporting natural gas and other petroleum products.

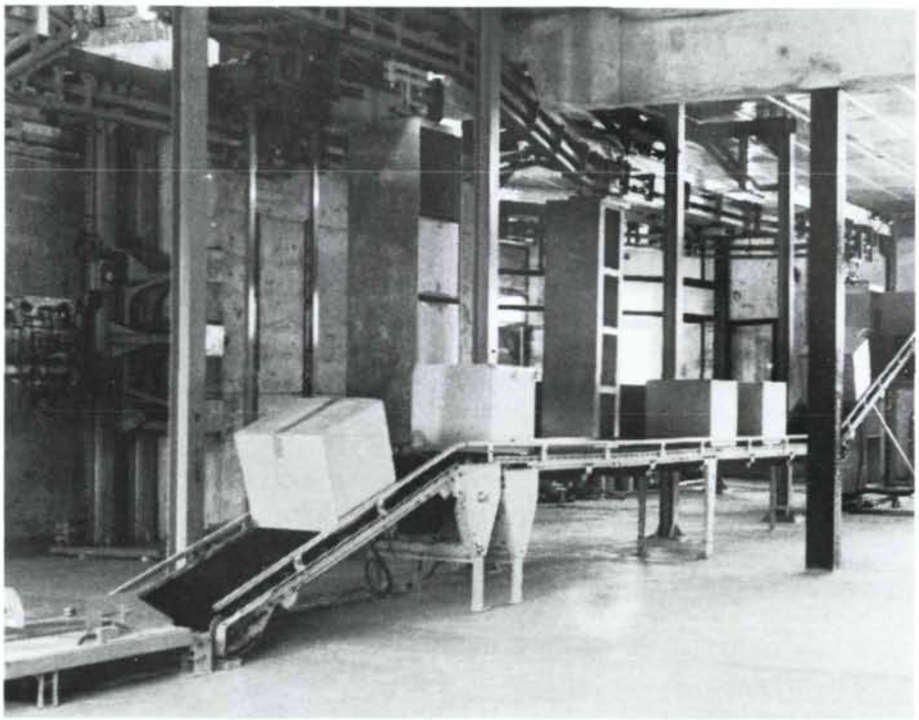
In the early 1970s, the IAEA implemented a UNDP large-scale project on non-destructive testing in Argentina to develop the necessary skills for machine industries and nuclear power projects. The implementation of this project has recently been extended to a Latin American regional project for the provision of quality assurance personnel in Latin American countries. Through the provision of equipment, experts, and fellowships, the IAEA has helped Ecuador, Egypt, Malaysia, Pakistan, Singapore, Sri Lanka, and Tunisia to apply industrial radiography in plant and pipeline construction. Under the RCA programme, with the assistance of UNDP, three extensive training courses on radiographic and ultrasonic inspection will be conducted between now and 1987.

Wear and corrosion studies

Manufacturers could operate much more effectively if they could decrease the corrosion of processing equipment and the wear of pumps and compressors. Materials suitable for construction have to be tested before final selection and the rates of loss due to wear or corrosion during operation of critical components have to be monitored. The development of thin-layer activation as a tool for investigation has helped solve these problems.

The test material is activated with particles containing a few microcuries of radioactivity on a thin surface layer about 25 to 300 μm in depth, and 1 cm^2 in area. The

* The Regional Co-operative Agreement for research, development, and training related to nuclear science and technology involves 13 countries in Asia and the Pacific Region.



A plant for sterilization of medical supplies using radiation from Co-60 constructed in Yugoslavia with the assistance of the IAEA and UNDP. The shielding and conveyor are designed for maximum loading of 1 MCi of Co-60.

activity level is very low and does not disturb plant operations, thus allowing the irradiated components to be installed in the plants under actual working conditions. By monitoring the changes of radioactivity levels, the rates of wear or corrosion can be followed in field tests. In IAEA co-ordinated research programmes, good results have been obtained in studies of engine and machine tool wear implemented in Hungary and Yugoslavia.

On-line controls

In plant operations, on-line measurements of process parameters or control of product specifications can be carried out with nucleonic gauges. Gauging operations are used in the level detection of liquids or solids in storage, density readings of fluids and slurries, thickness measurement of sheet materials, and determination of moisture content. The scope ranges from civil construction — as in controlling the density and moisture in concrete and soils — to the control of thickness in the high-speed production of paper, plastic films, and metal sheets in fully automated plants. In the latter case the thickness can be measured and precisely controlled without any physical contact with the materials, whether they be hot, damp, soft, or plastic. The development of microprocessor technology has revolutionized the design of such gauges.

The IAEA is promoting a large demonstration project, funded by UNDP, on the technology transfer of nucleonic control systems used in the paper and steel industries in Thailand and in India, within the framework of the RCA. The training of personnel and the demonstration of this technology and its benefits are major objects of the project. The first year of operation of the demonstration plant at the Siam Kraft Paper Company has shown that the nucleonic control system can pay for itself in less than one year, mainly as a result of resource and energy savings.

Tracer technology in industry

In industry tracers are used to investigate material transport in processing systems where the flow and mixing patterns are of keen interest in both design and operation. The industrial acceptance of tracer methods in plant operations is a clear indication that economic benefits can be derived both at the stage of commissioning a plant and in the improvement of equipment performance. In the 500 000 t/year cracking plant at Wilton, UK, radioisotopes contributed significantly to the successful commissioning programme. Three training courses and three workshop-demonstrations on tracer technology will be organized by the IAEA and UNDP under RCA from 1984 to 1986, in India and Singapore.

Exploration and recovery of minerals

Mining is one of man's fundamental activities — along with farming, fishing, hunting, lumbering — and it is the only one of these which is not renewable. Mineral resources will not last forever; some have already been depleted. It is therefore vitally important that every effort be made now to find new deposits, and to extract and process important minerals as efficiently as possible. In the exploration and subsequent recovery of mineral resources, nuclear techniques play a significant role.

The oil and coal industries have readily accepted nuclear techniques which help towards greater efficiency and lower costs, at all stages from well-drilling to production and refining, and are probably among the largest users of radioisotope methods today. In the special case of uranium, new borehole-logging techniques that measure uranium directly are being introduced into routine operation. Nuclear techniques are now gaining wider application in the exploration for, and exploitation of, more conventional mineral resources, such as aluminium and bauxite, copper, cobalt, nickel, lead, zinc, iron, manganese, etc.

The transfer of these techniques to developing Member States which have not yet explored their resources to the fullest is an important task for the IAEA. The IAEA held a very successful regional training course on the use of nuclear techniques in the mineral industry in Australia in 1980, and an international seminar on the same subject was conducted in Canada in 1982, for the development of trained manpower in this field.

By means of its co-ordinated research programmes, the IAEA is helping develop new nuclear techniques for mineral exploration, mining, and processing. For example, a new technique based on radioisotope-excited X-ray fluorescence has been developed for on-line measurement of zinc concentration in zinc-ore slurries. Within the framework of the RCA, nuclear techniques developed in Australia for the measurement of copper concentration in slurries will be transferred to the Philippines and other countries in Asia as a part of an IAEA/UNDP project.

Economic benefits

An IAEA conference held in 1981 highlighted significant economic benefits in nucleonic control systems and tracer technology in industry (Table 2) mainly due to savings in material, energy, and labour.

Table 2. Cost-to-benefit ratio in nucleonic control system and tracer technology

Applications	Cost-to-benefit ratio
Paper thickness and moisture-content control	1–9
Zinc-coating control	1–30
Sulfur in oil gauge at desulfurization	1–10
Leak-detection in domestic central heating systems by radiotracer	1–7

During the same conference, case studies were presented by several industrial participants on the economics of radiation processing. For example, in case of radiation cross-linking of 6.6 kV cable insulation by electron accelerators, it was announced that the total processing cost was lower for the radiation method at a larger production rate (600 km/month) but it is almost the same as for the chemical method at lower production rates (300 km/month). This is a general rule in cost comparison between the radiation method and the chemical method, because of the larger capital investment for radiation facilities, but lower cost for materials and energy.