New Challenges with Nuclear Techniques

- For Advanced Industrial Development and for a Cleaner Environment-

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1. Introduction

In the past 30 years, the RCA has been successful in transfer of nuclear technology to the Member State in the various fields of applications. In the history RCA, excellent contribution of the Member States to the RCA projects should be commended. The UNDP Industrial Project has also been supporting the RCA since its first phase started in 1980.

Priority areas of RCA activities have been changing in the order of food/agriculture, medical application, industry and environment protection to meet changing needs of the Member States. Currently the RCA has balanced activities among different applications.

Nuclear technology for both power and non-power application has been contributing to sustainable development and human welfare in terms of environmental protection, human health, clean energy and food security. Innovative nuclear technologies are being developed leading to a new horizon of nuclear applications.

2. Radiation Technology Serves Environmental Protection

(1) Cleaning flue gases from coal and oil burning power stations

The emission of SO_2 and NO_x into the atmosphere from coal and oil burning power plants and industrial plants is one of the major sources of environmental pollution. These pollutants cause "acid rain" and also increase to the "greenhouse effect".

Innovative technology using electron beams to simultaneously remove SO_2 and NO_x by irradiation was first developed in Japan and further adapted by research groups in, Germany, Poland, China and Brazil. As shown in Figure 1, the flue gas is exposed to electron beams while it passes through an irradiation chamber. A small fraction of gaseous ammonia is injected into the chamber. As a consequence of reactions induced by radiation, SO_2 and NO_x are converted into a mixture of ammonium sulphate and nitrate particulates which can be separated from cleaned gases by standard techniques of electrostatic precipitators being used as a fertilizer for

agriculture.

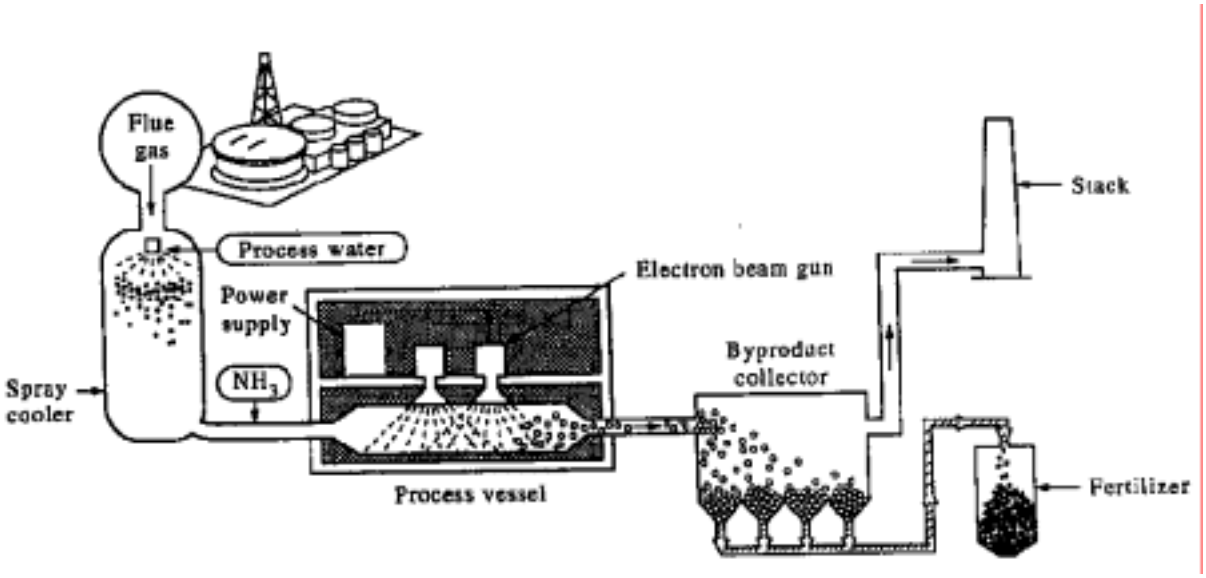

Figure 1. Flow diagram of electron beam process for flue gas treatment.

The advantages of this technology over conventional processes for treating flue gases are:

- It is the only process to simultaneously remove SO_2 and NO_x.
- The by-product of the process can be used as agricultural fertilizer.
- The process does not require large amounts of water.
- It can meet the stringent requirements for removal efficiency of SO_2 and NO_x.

A large pilot plant with the capacity to clean 20,000 Nm^3/hour of coal burning flue gases has been in operation in Poland under an IAEA/Poland Technical Co-operation project. It has been shown by continuous operation that more than 90% of SO_2 and 85% of NO_x can be removed from the flue gases treated by the irradiation of about 10kGy. In Japan, large pilot scale plants were also successfully operated for cleaning treatment of flue gases from oil burning power plant.

An industrial demonstration plant using this technology to clean flue gases of 270,000 Nm^3/hour from a power station in Poland has started operation in December 2000 with the Agency assistance. Also in China an industrial demonstration plant to remove SO_2 in flue gas from a coal burning power station has been in operation for 2 years and the 2nd plant is under construction. In Japan a demonstration plant to clean heavy oil burning flue gas of power station of 220MWe is about to start operation in Chubu Power Co. as shown in Figure2.

Economic feasibility studies of this electron beam process by the IAEA and Japanese experts have shown that this technology is more cost effective than the conventional process in terms of both initial investment and operational cost. It should be noted that the conventional process, which involves the combination of catalytic reduction of NO_x and neutralization of SO_2

Figure 2 EB Plant to Clean Flue Gas of Heavy Oil Burning Power Plant of Chubu Electric Power Corporation

by lime-stone process, produces gypsum as a by-product, which is not useful in some countries. By contrast, the by-product of the electron beam process is a valuable fertilizer.

In 2001 the Japan Atomic Energy Research Institute (JAERI) has started operation of pilot plant to remove dioxin from flue gas of municipal incineration plant. On 14th of February 2002, it was officially announced that 90% of dioxin can be removed from the gas at 15kGy. The scheme of the process is shown in Fig.3, and picture of the facility in Fig.4. An accelerator of 0.3 MeV•40mA is used to treat flue gas 1,000 N m^3/h from the incineration plant of City of Takasaki containing 1-5 ng/ m^3 of dioxin.

(2) Cleaning industrial waste water

In Korea a commercial company has been extensively studying treatment of wastewater from dye factories using pilot plant. An electron accelerator of 1.0 MeV•40mA is used to treat wastewater of 1,000m^3/day. Based on positive results of feasibility study, an industrial scale plant of 10,000 m^3/day has been proposed by EB Tech. Co. to the Korean Government and IAEA for support.

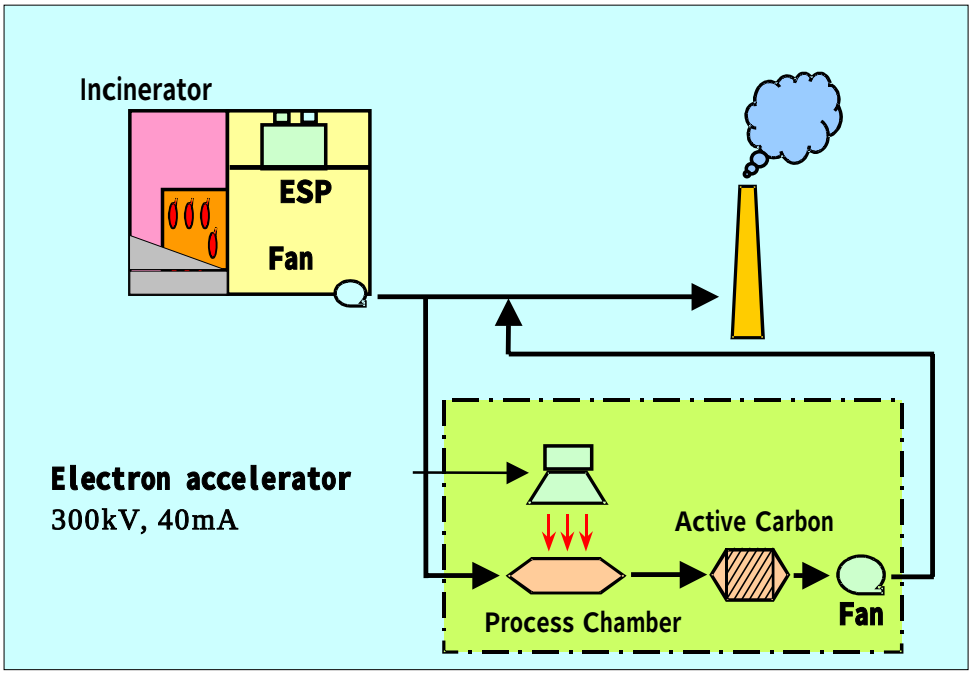

Figure 3 Pilot plant of cleaning flue gas from incineration plant

Figure 4 Flow sheet of electron beam process for removal of dioxin

3. Efficient Industrial Process and Unique Products

Use of radioisotopes and radiation in modern industry is of great importance for process improvements, and product quality control, and brings about energy and material saving leading environmental conservation. The major areas of application of isotopes and radiation in industry are shown in Table 1.

Table 1. Application of isotopes and radiation in industry

1.	Radiation processing for manufacturing
2.	Non-destructive testing by radiography for quality control
3.	Nucleonic control systems for process control and optimization
4.	Tracer technology for process optimization and trouble-shooting

(1) Radiation cross-linked polymers having excellent heat and chemical resistance

Radiation can induce desired chemical reactions without using catalyst at room temperature. One of the advantages of radiation processing is savings in energy consumption. Some plastics cross-linked by radiation can be tailored to shrink when heated which is a desirable property in packaging, wire insulation and corrosion protection of pipeline welds. Wire industries make extensive use of electron-beam to produce heat resistant insulation for wire.

By the radiation cross-linking properties of plastics such as polyethylene, polyvinylchloride and rubber is improved in thermal resistance, chemical resistance and mechanical strength. Examples of commercial products manufactured by radiation cross-linking are shown in Table 2.

Table 2. Commercially produced radiation cross-linked polymers

Products	Applications
Cross-linked polyethylene and PVC	Wire insulation resistant to heat and chemicals, pipes for heating systems
Foamed polyethylene	Insulation, packing, floating materials
Heat shrinkable tubings and sheets	Food packaging, insulation, protection against corrosion
Cross-linked rubber sheets	Automobile tires (high quality), roof protection sheets (weather resistant)
Cross-linked polyurethane (Japan)	Cable insulation for antilock brake sensor
Cross-linked nylon (Japan)	Automobile parts resistant to heat and chemicals
Super heat resistant SiC fibre (Japan)	Metal and ceramic composites, semi-commercial plant
Vulcanized natural rubber latex (Malaysia)	Surgical gloves, condoms

Cross-linked polymer insulated wire are used in the automobile industry, telecommunications, the aerospace industry and in home electrical appliances. In the automobile tire industry, radiation processing is used to cross-link rubber molecules to improve physical

properties for the production of radial tires, in Japan, France, USA, Brazil, Korea, and recently in Indonesia.

(2) Clean surface coating

Another environmentally friendly application of radiation processing is the curing of surface coatings different products, such as wood panels, adhesive tapes, surface coats for printing, floppy discs, and decorative steel plates. A major advantage of electron beam curing is that no organic solvent is emitted into the environment by evaporation. Therefore, this process does not pollute the environment. The excellent quality of surface cured by electron beam has been proven. More than 400 low cost and low energy electron accelerators for surface coating are used for industrial purpose in the world.

(3) New applications

New applications of radiation processing of polymers are (1) hydrogel crosslinked by radiation being used for wound dressing, (2) adding values on natural polymers such as carrageenan, chitosane, alginates and silk, (3) crosslinking of PTFE at high temperature to improve mechanical properties such as abrasion resistance (4) absorbent production by radiation grafting for selective absorption of uranium for its recovery from sea water.

Figure 5 Preparation of hydrogels by radiation crosslinking in Indonesia

(4) Electron Accelerator - simple operation and better public acceptance

Accelerators which generate high energy electrons and Co-60 sources are major radiation sources for industrial applications. Figure 6 shows the rapid increase in the number of electron accelerators used in Japan. Some 60 accelerators are used for research and development aiming at new commercial applications. There are approximately 200 Co-60 gamma irradiators and 1,000 electron beam accelerators used mainly for industrial purposes throughout the world.

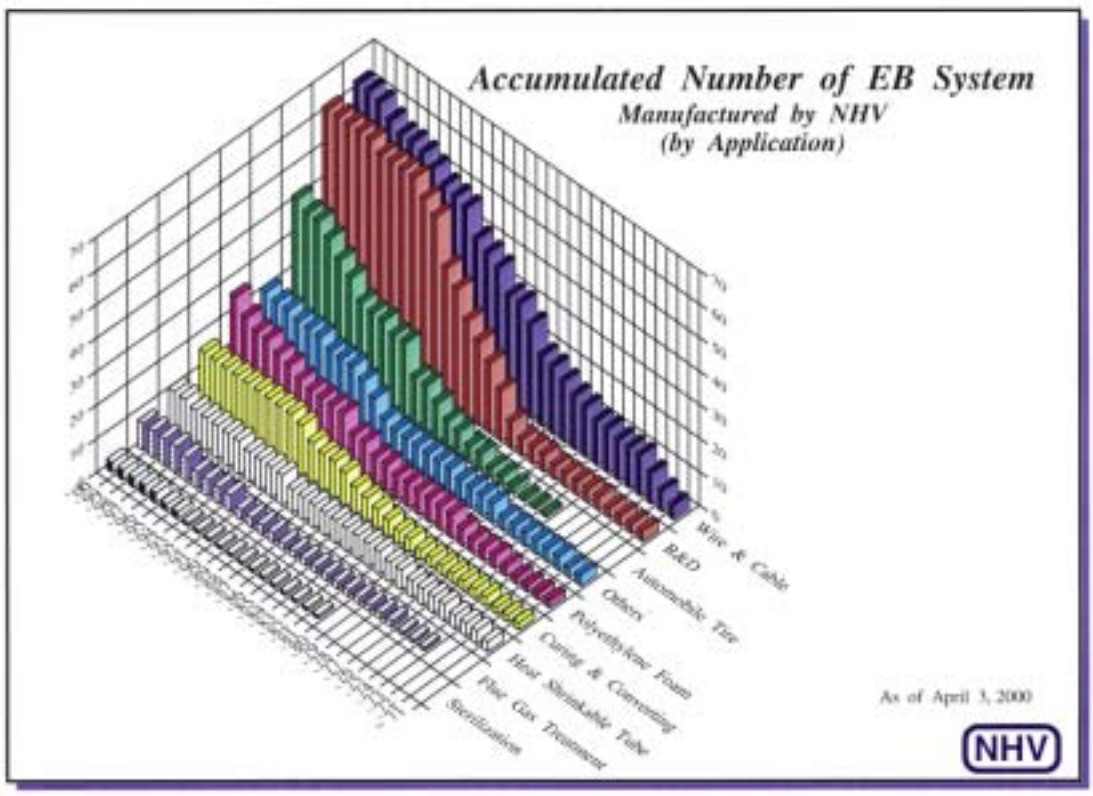

Figure 6. Increase in the number of electron beam accelerators in Japan

3. Environmentally Friendly Agriculture

"Food for all" was the stated goal of the November 1996 Declaration of the World Food Summit. Eight hundred million people are chronically undernourished throughout the world. The world population of 6.2 billion is still growing particularly in Asian region. Therefore, securing food for the increasing population is an important challenge. Nuclear applications encompass mutation breeding, soil fertility and crop production, animal production, food safety, insect pest control, which contribute to sustainable agriculture.

(1) Plant mutation breeding

Irradiation of plant materials such as seeds, buds and plantlets with gamma rays or

neutrons can introduce changes in DNA sequences and rearrangement of parts of chromosomes. These changes have resulted in a large number of improved mutant crops demonstrating;

- disease resistance,
- early maturity,
- drought tolerance,
- better yield,

Over the past 60 years, 1,800 new mutant plant varieties induced by radiation have been officially released and are now growing on millions of hectares of land.

In Japan more than 10 years ago a mutant variety of a pear "Nijisseiki" developed by low dose-rate irradiation method. This variety has an excellent resistance against "black spot disease". Amount of pesticide for the protection from disease has been decreased to one fifth, which brings about environmental benefit and economical profit. This is a success demonstrating nuclear technique for "environmentally friendly agriculture".

By the FAO / IAEA Laboratories and Member States such as Indonesia and Malaysia, mutant varieties of banana which are more resistant to plant disease (Fuzarium) and higher yield are being developed by radiation mutation in combination with tissue culture techniques.

The low dose-rate irradiation of plants using so-called "γ-field" shows potentiality of new mutants. Malaysia and Korea are, therefore, about to install a small "γ-field" for mutation breeding program.

Other new technique is using heavy particle such as ions irradiation which induces mutant not available by γ-ray because of its high LET (linear energy transfer).

Examples of significant achievements of improved varieties by mutation are shown in Table 3.

Table 3. Examples of mutant varieties bringing large economic benefits

Diamant barley is a mutant variety which, together with derived varieties, is the basis for beer production in Central Europe.
NIAB 78 is a gamma ray induced mutant of cotton, developed and released in Pakistan. It has significantly increased national production of this crop.
Zhefu 802, one of many successful rice mutant varieties is grown on at least 1.4 million hectares in China.

(2) Food irradiation saving environment

Irradiation reduces spoilage, improves food hygiene and extends shelf life.

Radiation can kill insect pest of fruits and vegetable, without using methyl bromide

fumigation which pollutes environment. Under the Montreal Protocol, chemicals which deplete the ozone layer, such as methyl bromide, must be phased out in the future. Food irradiation can replace such chemical treatment to protect environment.

In the United States, food derived pathogenic bacteria such as Salmonella, E.Coli, Listeria, Campylobacter, Vibrios, Trichinella and other parasites claim estimated 5,000 lives annually and between 24 and 81 million cases of diarrhea of various kinds. The related economic losses are estimated between $7.7 billion and $23 billion in the USA alone. Food irradiation is increasingly recognized by health authorities as a means of countering this health problem. Currently 250 supermarkets in the USA are selling irradiated ground beef for hamburgers. Irradiated foods, in particular 60,000 tons of species, have been on the commercial market in 35 countries.

In Vietnam with the assistance of IAEA, recently an irradiator of 400kCi Co-60 started operation being fully utilized for irradiation of frozen shrimp and other foods.

(3) Sterile insect technique (SIT) using radiation for control of insect pests replacing pesticide

Conservative estimates indicate that insect pests reduce world food production by 25% to 35%, in spite of enormous amounts of pesticide applications of about US$ 25 billion annually. This heavy reliance on pesticides brings about serious environmental pollution. To replace insecticide a nuclear technique, so-called sterile insect technique (SIT), has been used against major insect pests in several countries.

Radiation can sexually sterilize insects. When mass-reared and sterilized male insects are released into the wild population, the female insects mate with sterilized males not to produce offspring. The Substantial reduction of fertile matings causes a fall in populations that eventually leads to eradication.

The SIT has proved highly effective against several key insect pests such as, fruit flies, new world screwworm fly, tsetse flies, and lepidoptera. The SIT is excellent technique to reduce the amount of pesticides to be used which pollute environment and damage biodiversity. With advice and assistance from IAEA/FAO the SIT has been used successfully to eradicate or control medfly in several countries such as Mexico, Guatemala, U.S.A., Chile and Peru and brings about substantial economic and environmental benefits.

The IAEA has completed eradication of the tsetse fly from Zanzibar in Tanzania. Tsetse flies transmit trypanosomiasis, a disease which debilitates animals and causes sleeping sickness in humans. This disease is a major limiting factor in agriculture development for many

African countries. A larger project of tsetse fly control and eradication is in progress for Ethiopia.

5. New Techniques Challenging Cancer

Nuclear technologies play an important role in medical care in particular for radiotherapy of cancer and nuclear medicine for diagnosis.

(1) Teletherapy - efficient treatment by heavy particles

Teletherapy is widely used radiation therapy technique. The teletherapy has tended towards the use of linear accelerators generating electrons and X-ray up to 25MeV, capable of reaching deep seated tumours. About 2000 Co-60 machine and 6000 accelerators are in use worldwide.

Table 4. Number of centres and teletherapy machines by region

Region	Population 1998 (millions)	Radio-therapy centres	Cobalt-60 units	Clinical accelerators	Teletherapy machines (total)	Machines per million population
North America	300.9	1903	207	2251	2458	8.2
Western Europe	387	1027	410	1109	1519	3.9
Northern Africa	138.2	59	54	41	95	0.7
Central Africa	358.6	22	25	2	27	0.1
South Asia	1245.1	221	286	46	332	0.3

New technique challenging cancer is particle therapy using proton and heavy ion which can avoid bad side-effect by focusing beam in tumor and give efficient damage to it. Heavy particle beam can be focused in area and depth and have high linear energy transfer (LET) and biological effects. In fact treatment by heavy ion beam such as C-14 has shown excellent recovering rate for about 1,000 clinical tests demonstrating benefits for patients of bone, liver and lung cancer at the National Institute of Radiological Sciences in Japan.

(2) Brachytherapy - using micro source

Brachytherapy has recently advanced rapidly. By using new micro-size(1mm in diameter) high dose rate Ir-192 sources with high specific activity, radiation source can be invasively inserted into tumors and treatment time have been reduced to only 10-20 minutes instead of 10-20 hours. Procedures for insertion are easier and new sites such as bronchi of the lungs, bile ducts and small heart vessels are accessible.

Table 4 shows large difference in number of teletherapy machines by the regions. In developing countries number of machines and the human resources are extremely insufficient.

6. Conclusion - Combating malaria and anthrax

Nuclear technology for mankind should be well understood by public and further enhanced in its applications. The IAEA has initiated the R&D on the SIT application for the control or eradication of mosquitoes transmitting malaria. Research and development of the technology to mass-rear steriled male mosquitoes by automated processes will be carried out at the IAEA/FAO Lab. in Seibersdorf. A city in northern Sudan is under examination for a model area of the first trial eradication.

Anthrax-tainted letters and parcels are threatening citizens in Asia. Radiation can eliminate pathogenic bacteria including "anthrax". Now US officials are applying the use of accelerator to irradiate postal mails to eliminate "Anthrax" from letters and parcels. Eight accelerators will be installed in the post office in US.

Nuclear technology have demonstrated excellent results in various fields of application, and further research and development is being carried out for new applications.

(February 28, 2002)