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PRESENT STATUS ON DEVELOPMENT OF INDUSTRIAL RADIATION PROCESS PLANTS IN BRAZIL

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ABSTRACT

Nowadays there is a big effort from industry and agribusiness community to aggregate value to the products manufactured in the country in order to become competitive in the international market. The irradiation processing have being extensively applied as effective and reliable technique for the sterilization for medical care products and the reduction of bioburden in food ingredients. For other materials and process production this technique already is competitive and environmentally friendly. Works are being concentrated by the research institutes driving the efforts on becoming available and spreading the results of their investigations and developing irradiation facilities approaching the industry and agribusiness to include the irradiation process in production chain.
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1. INTRODUCTION

Many peaceful nuclear technologies today stand firmly established. They are being widely applied and accepted around the world in such fields as nuclear medicine, health care products, food production, manufacturing, electricity generation and environmental protection. Nuclear science and technology is making important contributions to meeting basic human needs and raising standards of living in the developing world.

The main applications of Non-Power Nuclear Energy using radioisotopes or radiation technology are in the area of Nuclear Medicine: diagnostics and therapy of diseases, radioactive macro-imaging and tracer medical technologies, direct internal and external medical radiation technologies (radiotherapy), biomedical research and pharmaceutical drug testing and manufacturing radioactive materials (nuclear batteries) and irradiation of blood components. In the food processing and agricultural area the developing and main applications are in food irradiation, controlling insect pests, minimizing the use of fertilizer.

In the area of industrial applications there are consolidated techniques such as: tracers for process and manufacturing quality control and optimizations, radiation detection for measurement (level gauges, thickness of metal or non-metal pieces) and irradiation of materials to enhance physical and chemical properties. For environment protection the nuclear techniques are applied in these fields: water resource studies (isotope hydrology, desalination, radiation technology to disinfect and treat drinking water, wastewater, industrial effluents and sludge), marine environment, flue-gases from coal-fired plants using electron

beam, studies for the detection of abandoned landmines using neutron and characterization of water, soil and air using nuclear analytical techniques (neutron activation analysis).

Applications of radiation process technologies contribute for increasing industrial process efficiency, energy conservation, and environmental protection and add value to products. Radiation processing technologies play an important role during manufacturing of many products such as wire and cable, automobile tires, plastic films and surface treatment of materials.

Brazil started the use of radiation technology in the seventies on crosslinking polyethylene for insulation of wire and electronic cables and sterilization of medical care devices. The present status of industrial applications of radiation shows that the use of this technology is increasing according to the economical development and the necessity to become the products manufactured in the local industries competitive in quality and price for internal and external market.

In many countries the main problems that have a critical pressure are food preservation, public health and environmental protection. Radiation technology, for instance in sterilization of medical devices, food irradiation, wastewater treatment, advanced curing and polymer processing, can be an effective contribution for the alleviation of such pressure.

2. RADIATION PROCESSING

Radiation Processing refers the use of radiation as a source of energy for industrial processing and comprises the application of ionizing radiation on physics, chemistry, biology and microbiology fields.

The main applications of radiation processing technology are classified considering their developments stage are:

- Established Technologies:
    1. Radiation sterilization
    2. Materials modification: a) Radiation crosslinking and b) Radiation curing
- Emerging Technologies:
    1. Electron beam process treatment of flue gases;
    2. Radiation processing of industrial , municipal and hospital wastes;
    3. Treatment of drinking water, wastewater and industrial effluents;
    4. Food irradiation;
    5. Radiation vulcanization of natural rubber latex.
    6. Treatment of fresh-cut flowers
- New Developments:
    1. Radiation immobilization
    2. Biocompatible materials (hydrogel wound dressing membranes)
    3. Homeland security

The consolidated applications of radiation process in Brazil are:

2.1. Radiation sterilization

Radiation sterilization is a well-established technique and has the purpose to improve hygienic quality of medical and pharmaceuticals products, raw materials and biological tissues. Commercial radiation sterilization started 30 years ago in Brazil with the growth of the disposable medical products market. Today, four industrial gamma irradiators concentrated their activities on sterilization of disposable medical products. One of this irradiators was designed and constructed using national technology by the researchers of IPEN (Instituto de Pesquisas Energéticas e Nucleares) . This large facility is in operation since 1999 and has a capacity of 185 PBq(5 millions Curies) of the ^{60}Co.

Currently, more than 50% of disposable medical products manufactured in North America, Europe, Japan and Australia are radiation-sterilized and worldwide, over 200 gamma irradiators are being operated for a variety purposes in 55 countries, with a combined inventory of about 220 million curies. An increasing number of electron accelerators are also being used. (Morrisey, R.F. *et. al*., 2002). In Brazil and worldwide the radiation process activities have been maintaining for many years an increasing market of 10% per year.

2.2. Materials modification

The crosslinking in polymeric materials predominates on materials modification when using radiation processing, where the purpose of radiation is to improve the mechanical and thermal properties and chemical, environmental and radiation stability of preformed parts as well as bulk materials. Both polymer crosslinking and chain scission occur during the treatment, but one or the other of these effects may be predominant in some materials.

The main applications in Brazil are: wire and cable insulation crosslinking used in electric home appliances, computers, cars, motors, communication cables, heat shrinkable products (tubing, film, tape, sheet), polyethylene foam, pre-vulcanization of rubber tires components. There are eleven industrial electron beam set up in the country with accelerating voltage raging from 300keV to 1,5MeV. Most of this machines are imported from USA.

Irradiation treatment is the process of using high energy particles or electromagnetic waves to alter the color of gem material, enhancing its appearance and value. Brazil is one of greatest gem stone producer but this irradiation process application is incipient due to the lack of dedicated irradiation facilities.

2.3. Food treatment

Studies about foodstuff and medicinal herb irradiation are being done for more than 40 years. The electron beam and cobalt-60 gamma irradiation effects on food, its nutrients, shelf life and sensorial properties are subjects of these studies. The irradiated food detection methodologies development laboratory was implemented to control the processes.

The consolidation of the use of ionizing radiation process in Brazil has many entries in the food production chain. It is being extensively used in food ingredients for microorganism decontamination such as spice, dehydrated fruits and grains, and for insect disinfestation mainly in cereal flour.

The international market also claims for infestation free fresh fruits, without the use of hazardous chemical products. Brazil has a great potential to supply the fresh fruit market and the irradiation techniques is one of the best choices to replace fumigation techniques, which leaves harmful residual chemicals or hot water treatments that decrease the taste quality. For this reason, the use of the new irradiation technique to improve the fresh fruits and juices quality can become a key activity for internal and international commerce. In this direction, the Brazilian Government studies to set up an irradiation facility in the main fruit production region of the country.

2.4. Agribusiness improvements

The Brazilian agricultural grains productivity are increasing, so the Nitrogen consumed by plants increases too, but varies greatly from one species to another. Therefore is important to reduce dependence on chemical fertilizers through Biological Nitrogen Fixation (BNF), because nitrogen use a large amount of oil to be produced, the Rhizobium bacteria and the peat as carrier of this microorganism.

In the case of soybean crop, that demands a high quantity of Nitrogen, the high costs of nitrogenous fertilizers is becoming prohibitive so BNF have been emphasized for sustained and increased productivity. The beneficial effect of Rhizobium on the soybeans yield appears only when a large numbers of inoculated rhizobia are inoculated to get high Nitrogen Fixation in the absence of competitive microorganism. The use of inoculation technology represents to economy of Brazil a value with a magnitude of 2.5 billion of American Dollars.

The objective of peat flour sterilization is to eliminate competitive and undesired microbial cells prior to Rhizobium inoculation, this procedure do not significantly alter the chemical and physical characteristics of peat materials. Now a days the existing gamma irradiation facilities(contract service), that also deal with sterilization of medical care products, can not process the internal demand and the national peat are being replaced by gel solutions that are imported.

In the same direction the radiation processing of sugar cane must reduce the initial bacterial population, with consequent improvement in the yield of the ethanolic fermentation avoiding the necessity of decontaminating the must with antimicrobial products. According to present Brazilian production of alcohol, that is close to 5 billions of liters per year with the perspective to up grade to 15 billions in the next 10 years, the application of this technology is quite promissory. The researches are concentrated on development of electron beam irradiation devices to process large volumes.

3. RADIATION SOURCES

Two types of radiation sources are routinely used in radiation processing technology: gamma radiation from artificially produced radioactive isotope Cobalt-60 and high energy electrons produced by accelerators, in the energy range of 0.3 up to 10MeV. The choice of one or the other depends on the process and on economic considerations and both satisfy the main industrial requirements: availability in design and specifications to match industrial

throughput, acceptable investment cost, high safety standards for operation and simple process control.

The main differences between gamma rays from Cobalt-60 sources and electron beams (EB) are dose rate and penetration of radiation. In general gamma irradiators are used for the irradiation of high-density and large-volume materials while electron beams are suitable for the irradiation of thin materials such as plastic films and surface coatings. (Makuuchi, K. 1992).

In the worldwide there are approximately 190 Cobalt-60 gamma irradiators and the number of electron beam accelerators for radiation processing being close to 1,200. They are used in different fields of applications, predominating the use of gamma irradiators for sterilization of disposable medical products and food stuff treatment. While the EB have the main applications concentrated on polymers modification., The Table 1 shows the present status of gamma and electron beam facilities in Brazil, South America, Japan, USA, World.

Table 1. Status of gamma and electron beam facilities in the worldwide

Facilities	South America	Brazil	Japan	USA	World
Gamma Irradiators (100kCi-10MCi)	11	$7^{(*)}$	8	30	> 190
EB Accelerators (300keV-10MeV)	13	11	>280	> 300	> 1200

(*) Including the research irradiators

3.1 Development of Irradiation Facilities in Brazil

Concerning to radiation processing technology until 1999 all the applications in the country were pending of imported equipment that are very expensive. The break-through was obtained with design and construction of a large gamma irradiator by the IPEN's researchers working as consultant to a private company. This irradiator is very reliable, working more than 8200 hours with, the cost of this machine was the half the price and with a performance similar to the imported ones.

In 2003 with financial support from FAPESP it was started the construction of new gamma irradiator that incorporated the "compact" tendency. This new small size gamma irradiator was set up at *Instituto de Pesquisas Energeticas e Nucleares (IPEN-CNEN/SP)*, Brazil, with a revolutionary design. The national developed technology for this facility consists of continuous tote box transport system, comprising a single concrete vault, where the automated transport system of products inside and outside of the irradiator utilizes a rotate door, integrated with the shielding, avoiding the traditional maze configuration. Covering $76m^2$ of floor area, the irradiator design is product overlap sources and the maximum capacity of Cobalt-60 wet sources is 37PBq (1MCi). It has being used as a demonstration facility for manufacturers, who need an economic and logistic in house irradiation system alternative. Also supporting the local scientific community on development of products and process using gamma radiation, assisting the traditional and potential users on process

validation, training and qualification of operators and radioprotection officers. The Figure 1 shows the compact gamma irradiator set up at IPEN.

Fig. 1. Multi application gamma irradiator – IPEN - Brazil

The on going development activities using EB are concentrated on:

Environmental protection: the studies performed to demonstrate the efficiency of EB radiation technology (electron beam) to treat drinking water, wastewater, industrial effluents and sludge using real samples from Municipal plant and industries. (Duarte, C.L., *et al*., 2004 and Borrely, S.I., *et al*., 2000). These positive results guided to concentrate the efforts on development of efficient irradiation devices and conception of a movable facility to be set up on a truck trailer.

This facility will use an electron beam accelerator (500keV), that now is being refurbished with International Atomic Energy Agency technical support, will be used as a movable demonstration facility, will incorporated a hidraulic irradiation device to demonstrate *in situ* the performance on treating effluents and sugar cane must . It will be also fitted with a fluid bed irradiation device for grain and products decontamination. The Fig. 2 shows a sketch of the movable electron beam with the configuration to treat liquids.

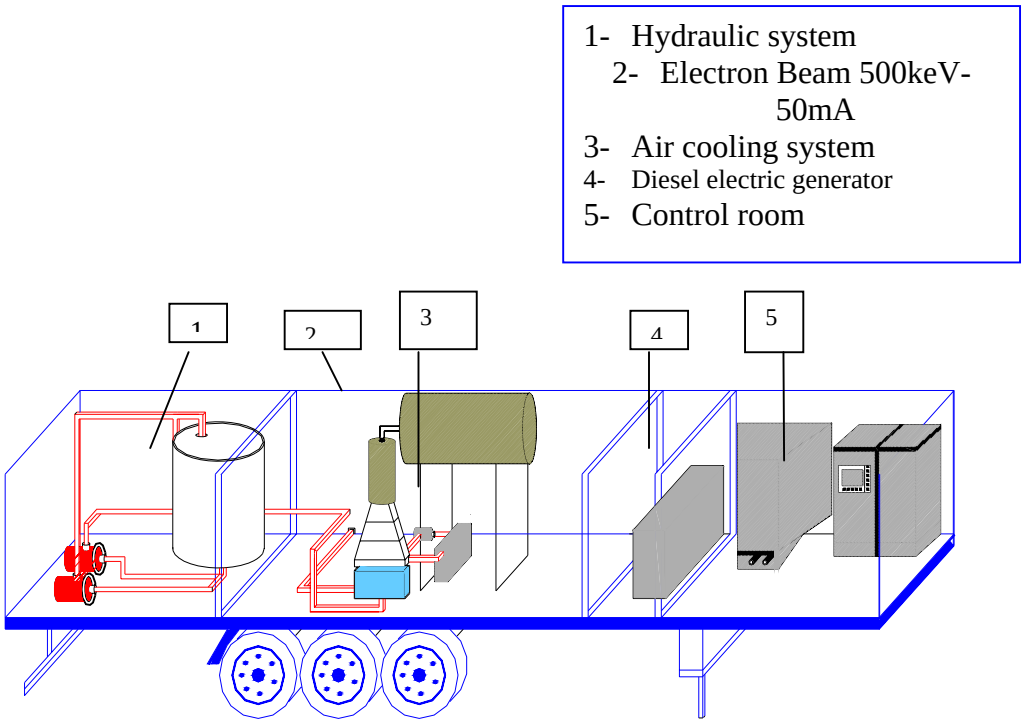

Fig. 2. Mobile electron beam wastewater treatment facility

4- CONCLUSION

It is observed through the Table 1 that there is a big potential in Brazil to increase the activities on radiation processing and some applications such fruit disinfestation, peat flour sterilization and sugar cane must decontamination claim for reliable and not expensive irradiation facilities in order to become more competitive the internal production, showing that human and financial resources to be invested in this area will have prompt return to the country.

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