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6. RVNRL and Radiation Processing in Thailand

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Abstract

Industrial application of radiation processing in Thailand is gaining wide acceptance. The first private-owned radiation sterilization plant was established in 1984. Commercialization of protective rubber gloves from radiation vulcanized of natural rubber latex (RVNRL) started in 1993. Two new sterilization plants using electron beam accelerator and gamma irradiation were commissioned in 1997 and 1999 respectively. Another gamma sterilization plant is scheduled to operate in the year 2000. Additional electron accelerator is being installed in one operational gamma sterilization plant, for upgrading of gemstones. Research and development at Office of Atomic Energy for Peace (OAEP) and universities has been focused on RVNRL, radiation treatment of sludge, grafting of cassava starch and utilization of irradiated silk protein. Except for RVNRL which has passed to commercial scale, pilot scale of radiation treatment of sludge has achieved its goal to be utilized as new resources for animal feed and fertilizer.

Key words: Radiation vulcanization, Natural rubber latex, Radiation processing

Introduction

The radiation technology program was introduced to Thailand through Office of Atomic Energy for Peace (OAEP) under UNDP/IAEA/RCA projects. There was a spin-off project under close co-operation of OAEP and a private company to establish the first gamma sterilization plant in 1984. Food irradiation, although has passed to market trial for few food items, long before establishment of the gamma sterilization plant, it was not until Thai Irradiation Center (TIC) of OAEP started in 1989 that irradiation service has been in effect for food irradiation and sterilization. R&D and scale-up of radiation vulcanization of natural rubber latex (RVNRL) and radiation treatment of sludge has been also made possible by gamma irradiation at TIC and under UNDP/IAEA/RCA project and partly OAEP-JAERI bilateral agreement project respectively. This paper provides an overview and trends of R&D on radiation processing in Thailand.

Radiation Vulcanization of Natural Rubber Latex (RVNRL)

Research and development of radiation vulcanization of natural rubber latex (RVNRL) started in Thailand in 1981 under the coordination of the International Atomic Energy Agency (IAEA) within the framework of Regional Cooperative Agreement (RCA) industrial projects. National Research Group (NRG) on RVNRL was set up in 1986 comprising of Rubber research Institute of Thailand (RRIT), OAEP, Mahidol University, Chulalongkorn University and Prince Songkhla University. Since then, a number of research work have been conducted trough the research grant from Ministry of Science Technology and Environment (MOSTE). At first, research work was focussed on selection of suitable sources of natural rubber latex, suitable antioxidant and factor affecting properties of RVNRL. Development on scale-up of RVNRL production, industrial scale dipping using RVNRL including heat sensitive dipping with RVNRL was also conducted. Combination of a suitable peroxide vulcanization with radiation vulcanization was investigated in 1996. It was aimed to reduce the irradiation cost for certain rubber products. In parallel to the R&D conducting by governmental research fund, a private surgical glove manufacturing company started its own R&D on large scale RVNRL production and on industrial scale dipping with RVNRL in 1992 and commercializes the first product from RVNRL as protective rubber gloves in 1994. The gloves have been used in Nuclear Power Plant in Japan to eliminate acidic gas and reduce ash on burning. In 1997 Ministry of Science Technology an Environment (MOSTE) by National Metal and Materials Technology Center (MTEC) allocated budget for a small gamma irradiator (10 kCi) to strengthen R&D on RVNRL production. The irradiator was installed at the Department of

Nuclear Technology, Chulalongkorn University. The source and control unit were from Institute of Isotope Co., Ltd., Hungary.

Table 1 shows the net export of natural rubber from 1995 to 1998. These figures show the increasing in net export of natural rubber. From the year 1993 Thailand becomes the largest production of natural rubber in the world. The need to promote R&D on utilization and adding value to the natural rubber is a must. RVNRL is one of the emerging radiation technology that can improve natural rubber product properties. The development of RVNRL is considered to be very fast since R&D has begun. It is hoped that due to the high competition among rubber product producers in the world market, a number of domestic rubber product manufacturers will consider RVNRL for manufacturing of some rubber products of special quality. Table 2 depicts the superior properties of RVNRL and possible potential products from RVNRL.

Table 1. Production, export and consumption of natural rubber in Thailand

Year	Production (Metric tons)	Export		Consumption (Metric tons)
		Metric tons	Millions of Baht	
1995	1,804,786	1,635,533	59,567.26	153,156
1996	1,970,265	1,762,989	61,301.07	173,671
1997	2,032,714	1,837,148	55,550.57	182,020
1998	2,075,950	1,839,396	55,015.13	186,379

Table 2. Superior properties of RVNRL and possible potential products from RVNRL

Properties	Potential products
Nitrosamine free	Baby teats, baby soothers, toy balloons, urinal condoms gloves for dentist, toy products, breast shield protector pezons
Non-cytotoxic	Catheters, endoscope, medical tubing
Low modulus	Surgical gloves, examination gloves, condom
High transparency	Laser balloon, endoscope
Non inhibition of dental impression material	Gloves for dentist
Low toxic gas and low ash content on burning	Protective gloves for radiation contamination
Non protein allergy (Type IV)	Surgical gloves, examination gloves

In 1998, among other aspects, the need to improve inferior mechanical properties especially tear property of RV NR films has been put forward to IAEA. Financial supports are provided to Thai, Japanese and Indonesian research groups under Coordinated Research Program (CRP) to solve the problem including the problems of rubber film tackiness and allergenic rubber protein. Fumed silica and hydroxy apatite with active ZnO are added in small quantity in RVNRL. It is found that tear strength of the film increases markedly to the level that can be accepted for manufacturing of dental rubber dams. As for the problem of allergenic protein, it becomes more serious after U.S. FDA announced the new regulation on 30 July 1999 to limit the water soluble latex protein to 1,200 μg per piece of medical glove. In this regard, it has been found that both fumed silica and hydroxy apatite can immobilize latex protein and prevent migration of the protein to the surface of rubber films. Thus it can reduce the water soluble protein to less than 500 μg per piece of glove. In the future, in stead of setting the limit for protein content, U.S. FDA may put the regulation on the limit of allergen. In this case no allergenic latex protein can contain in the glove at all. To prepare for this forthcoming regulation, radiation vulcanization of deproteinized rubber latex should be considered. This can solve both Allergen Type IV (delay hypersensitive, caused by accelerator in sulfur vulcanization) and Allergen Type I (immediate hypersensitive, caused by latex protein).

Radiation Sterilization of Medical Products

After several years of research work on radiation sterilization carried out by scientists at the OAEP, the result of the work draw attention and interest of a private investor. A feasibility study of medical product sterilization was conducted in 1982. The first private-owned radiation sterilization plant: Gammatron Co., Ltd. was established in 1984 under the supervision of the OAEP personal in technical operations and quality of the products. The capital investment of the plant was around US$3.2 million comprising a Co-60 gamma irradiation of 150 kCi initial loading capacity, a dry source storage, loading facility, and a manufacturing complex to produce disposal medical devices and supplies. The company sterilizes its own manufactured medical products and also gives services to customers. The production of medical products serves 25 per cent of the domestic demand and the remaining are exported to the Middle East countries and Australia. Due to the success of the company and its expanding markets, the company incorporated the Kendall Ltd., in the United States and become Kendall Gammatron Ltd., in early 1998. A 410 kCi of the Co-60 source was shortly added to the existing irradiation facility in order to produce similar products for export to the United States.

At present, there are over 80 manufactures of disposal medical devices in Thailand, about half of them have there own sterilization facilities by conventional methods. Although the sterilization of gamma radiation has proved to be far more effective than conventional methods, there exists only one manufacture with gamma sterilization plant. In 1989 another 450 kCi Co-60 irradiator of Thai Irradiation Center (TIC) belongs to OAEP started for servicing. Due to the lack of the nation regulations of the control of production and import of medical devices and the on going process to set up a Thai Pharmacopoeia, the Food and Drug Administration (FDA) Office suggests that the production of medical products should conform to the formulation describe in U.S. Pharmacopoeia, the British Pharmacopoeia, National Formulary British Pharmacopoeia Codex, British Veterinary Codex and International Pharmacopoeia. The Department of Medical Sciences, Ministry of Public Health is responsible for routine inspection of medical products in Thai market and certifying the product as requested by manufacturers. Even though, the hygienic condition of the plants and in -line-products are being taken into consideration, sterility test is still focussed on the assurance of safety and quality of finished products. To reduce the bioburden of medical products prior to sterilization the OAEP is working hard to convince the manufacturers to take serious precaution in every production step. In addition, the OAEP advise and approaches the FDA to include GMP and/or regulations on sterilization of medical devices. Most importantly, the OAEP suggests the FDA to introduce a section of "Radiation sterilization" under the "Sterilization" section in the Thai Pharmacopoeia.

In Thailand, radiation sterilization seems to prevail other applications and recently, there is a growth in number of radiation sterilization plant as shown in Table 3. One reason among others for growing number of radiation technology related plants is the new policy of Thai Board of Investment (BOI). It started from 1993 which focuses on inviting investors to set up industries in the country with attractive incentives, foreign direct investment reached US $ 6.9 billion in 1998, jumping from $ 4.7 billion in 1997. Industrial development in Thailand thus has brought radiation processing technology to the country faster than expected.

Table 3. Radiation processing facilities in Thailand

Commercial Gamma Plant (Sterilization and other purpose)	150 kCi	1984	Kendall Gammatron Co.,Ltd. Nakornprathom
Gamma Plant for Food Irradiation, Sterilization and other purposes (Research and services)	450 kCi	1993	Thai Irradiation Center(TIC), OAEP, Prathumthani
Electron accelerator (Sterilization of doctor gown, etc)	1.8-2.4 MeV 10 kW	1997	Thai Klinipro Co.,Ltd. Samutprakarn
Commercial Gamma Plant (Sterilization, Food irradiation, etc)	1 MCi (Max 3 MCi)	1999	SteriGenics(Thailand)Ltd. Rayong
Commercial Gamma Plant (Sterilization and other purposes)	1 MCi (Max 6 MCi)	2000	GAMMASTER (Thailand) Ltd. Samutprakarn
Electron accelerator (Gemstone irradiation)	13 MeV, ? kW	2000	SteriGenics(Thailand)Ltd. Rayong

Radiation Treatment of Sludge

Research and development in radiation treatment of sewage sludge and waste water has been carried out by OAEP in collaboration with other government agencies. In 1989 bilateral agreement has been made between Japan Atomic Energy Research Institute (JAERI) and OAEP under the title "Sludge Pasteurization and Upgrading by Radiation" starting from 1990 to 1993. An extended agreement between JAERI and OAEP was signed in 1995 under the title of "Upgrading of Sludge and Agriculture Waste by Radiation". Research by OAEP in collaboration with Department of Medical Science and Department of Public Health shows the number of 73 percent salmonella and 56 percent parasite contamination in sludge samples.

The use of gamma radiation to eliminate these pathogens is a promising treatment to prevent the spreading of such pathogens into environment after utilization of sludge. Scale up of radiation of sludge from food processing factories (10 ton/batch) was done by OAEP during 1996-1997. Successful utilization of irradiated sludge as animal feed and fertilizer has been observed. This research project's leader was awarded an Outstanding Research Award in the field of Biology and Agriculture by National Research Council of Thailand (NRCT) in 1999. Radiation treatment of sludge at pilot scale shows some possibility after complete construction of the central waste water treatment plant in Bangkok Metropolitan.

Radiation Curing

At present the application of curing technology in Thailand is only confined to UV curing. Some printing factories in Thailand are now using UV processing. In 1991, there were 21 units of UV curing machines being used in Thailand and it is expected some increasing in number up to now. The Department of Photographic Science and Printing Technology, Chulalongkorn University is intensively conducting research and development in this area. Since the installation of UV curing machine in 1991, by far, the machine is used as training and research tool for the course of printing. Current utilization of the machine is fussed on paper substrate. The use on plywood coating is underway by the request of Thai Plywood

Company. The main problem of this technology is the supply of chemicals (monomers and additives) which are heavily taxed as high as 40 per cent of the CIF value estimated by the customs. To further enhance local interest on radiation curing application, tax should be reduced and a low energy electron beam should be provided by either government or the assistance of IAEA. Currently the printing industry including printed packages, has a growth rate of 15-20 per cent and it is expected that figure will continue over the next five years. In order to promote the growth of printing industry and its supporting industries such as paper, ink and polymer need to be developed. Almost all the resins and ink materials are imported but after the start up of National Petrochemical Complex (NPC) Industries, it is expected that some necessary raw materials needed for coating manufacturing should be available. Since the use of radiation from electron beam source is important for curing technology, electron beam processing (EBP) should be of great potential to use in industries in Thailand in the future.

Studies on Synthesis of Super absorbents by Radiation Grafting

Research and development on synthesis of super absorbents by radiation grafting has been conducted at Chulalongkorn University since 1992. Saponified cassava starch-g-polyacrylonitrile (PAN) synthesized by radiation was found to obtain product of cleaner and possesses higher water retention than formerly use of Mn (III) as an initiator. Copolymerization of hydrolyzed polyacrylamide (HPAM) and N- vinyl pyrolidone (NVP) by radiation gives product with even higher water retention (950 g/g). The R&D in this topic was funded by MTEC of MOSTE. Further research on radiation grafting of acrylamide (AM)/acrylic acid (AA) on cassava starch gives a very high water retention of 1,150 g/g at monomer-to-starch ratio of 2:1 and radiation dose of only 6 kGy. This topic of study is under CRP of the Agency and is considered to be scale-up soon.

Research and Development on Utilization of Silk Protein by Radiation Processing

Silk waste from hand and machine reeling in Thailand is reported to be about 200 tons per year. Products from silk are considered to be biomaterial, non-allegenic and uses of silk waste in forms of both degraded and crosslinked products are foreseen as potential products for using as base material in cosmetic industry, manufacturing of biodegradable polymer, wound dressing membrane from chitin-chitosan blend with silk protein. A three years program bilateral agreement has been made between JAERI/OAEP in 1998 on Utilization of Silk Protein by Radiation Processing to strengthen R&D on this field. National research group (NRG) has be set up to expand the topics of research work and to invite researchers from other research institutes as well as from universities to join this research program.

Conclusion

Due to the rapid development of the country, high technology, high efficiency and environmentally friendly processes for industrial development are needed for high quality products and green environment. Radiation technology meets these requirements and Thailand will actively continue to put more effort on research and development in this field.

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