Radiation processing of natural rubber latex

New technology has been developed through an IAEA regional programme for Southeast Asia and the Pacific

by K. Makuuchi and V. Markovic

Significant progress has been made in the last 5 years in developing new rubber material using radiation technology that holds important benefits for industries in Southeast Asia and the Pacific. A driving force behind its development has been co-ordinated research through an international programme of the IAEA and United Nations Development Programme (UNDP) known as the Regional Co-operative Agreement (RCA).

The technology is called radiation vulcanization of natural rubber latex, or RVNRL. It uses high-energy gamma radiation (it also can use electron beams) to initiate vulcanization, a process that chemically bonds molecules to produce rubber elasticity and strength. As with other radiation industrial processes, products are not radioactive.

In the RVNRL process, radiation energy replaces the use of a sulphur-based process and produces a material that retains all properties of the conventional product. However, it has some additional remarkable qualities: the absence of carcinogenic nitrosoamines; extremely low cytotoxicity; absence of sulphur and zinc oxide; and high transparency and softness.

These properties are important for many products, particularly catheters, protective gloves, and other medical and hospital supplies. For such uses, it is important that products are free of contaminants, and toxic and carcinogenic components to avoid harmful effects in people. As safety requirements for such products become more stringent, RVNRL can provide a technically and economically viable alternative to the existing vulcanization process.

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Regional co-operation

The potential use of radiation to vulcanize natural rubber latex was recognized very early. In the 1950s, it was studied in several countries, including the United Kingdom, Japan, France, USSR, Poland, India, and Indonesia. In parallel, successful radiation cross-linking applications were developed in the wire and cable industry, among others. Industries were willing to apply radiation technology whenever it could make a superior quality product at acceptable cost.

RVNRL, however, has been slower to get off the ground, so to speak, although the basics of the process were developed long ago. The end products were at least as good as conventional ones, yet the economics of the process were not very attractive to justify investment in new technology.

Interest in this technology was revived in 1982 with the start of the IAEA/UNDP regional project on industrial applications of isotopes and radiation. The use of radiation to vulcanize natural rubber latex was part of the programme from the beginning for two main reasons:

- the region is the world's main supplier of raw natural rubber latex;
- countries of the region have pursued a development policy whereby they export finished or semi-finished products, rather than raw materials only.

Today, the cost of radiation sources and of the irradiation process has decreased significantly compared to 20 or 30 years ago. In a number of industries, radiation technologies have become well established; for example, for the sterilization of medical products, for cross-linking applications, or for radiation curing.

Further, several countries in the region have strong research potential in the production technology for natural rubber latex; they lack only the radiaton technology component.

Toy balloons are among rubber products being produced in tests in Thailand using the technology of radiation vulcanization. (Credit: AECL)

The regional co-operative project pulled together individual capabilities, with the expectation that this would have a beneficial impact on the technology's development as the first step and on its transfer to industry as the next step.

Technology development

In 1983, a pilot plant for RVNRL was installed at the Center for Application of Isotopes and Radiation (CAIR) of the National Atomic Energy Agency, in Jakarta, Indonesia. During the period 1983-86, this plant was used for training of rubber researchers and demonstration of the basics of the technology to industry.

Following this initial phase, in 1986, the IAEA started a comprehensive programme on technology development with the main objectives of reducing the cost of irradiation and improving the quality of final products. This research and development (R&D) work was co-ordinated by the Japan Atomic Energy Research Institute (JAERI), Takasaki Radiation Chemistry Research Establishment (TRCRE). Research groups from China, Indonesia, Malaysia, Sri Lanka, and Thailand participated in the programme. It was carried out in part at national institutions of participating countries and at TRCRE laboratories with research fellows from the same countries. The progress was monitored by regular meetings of scientists involved.

Early work on RVNRL in the 1950s was based on the use of carbon tetrachloride as a radiation sensitizer. The process worked, but had two important disadvantages: 1) high costs of irradiation (there was the need to use absorbed doses of the order of 40 kilogray (kGy), which reduces the efficiency of radiation utilization and consequently increases the cost); and 2) the toxicity of the radiation sensitizer, which necessarily remains as an additive in the final product.

Similarly, today's conventional sulphur process results in remnants of dithiocarbamates, a toxic and potentially harmful additive. Cytotoxicity and the presence of nitrosoamines increasingly are considered as dangerous substances in natural rubber latex products. Several countries have introduced strict regulations on the presence of these substances in certain categories of products, in particular medical devices, and products used by small children, such as rubber nipples and pacifiers. Another concern is the presence of nitrosoamines at the manufacturing site, where it poses potential health hazards to workers.

Natural rubber latex

Natural rubber latex is one important raw material used to manufacture medical products and a number of household and industrial items. It is extracted from the tree species *Hevea Brasiliensis* of the Euphobiacaea family. As the name indicates, the tree originated in Brazilian forests. It has been successfully transplanted into the environment of Southeast Asia and in some parts of Africa. Two countries alone — Malaysia and Indonesia — produce about 85% of the world's total volume of natural rubber latex, or close to a half million tons measured in dry weight.

Natural rubber latex is collected in the fields, then concentrated, stabilized, and shipped to industries for processing. The processing involves vulcanization, in which individual organic molecules are chemically bonded to produce a cross-linked, rubber-like structure that is then shaped into final products by different techniques. One common technique is called "dipping", in which the latex forms around the mold and, after drying at elevated temperature, retains the desired shape and is elastic at room temperatures. At high temperatures, the material disintegrates and at very low temperatures it becomes brittle.

Such "dipped" products consume about 70% of all the natural rubber latex produced. The largest amount of this is used to make gloves (surgical, household, and others), children's toy balloons, condoms, catheters, and other products requiring high standards of hygiene. The largest single item produced from natural rubber latex are gloves uses in medical examinations: about 12 billion pairs are made each year. Growing concern about the safety of medical workers and patients has created an expanding market for these gloves and demand is expected to increase markedly in developing countries.

The first and most important breakthrough achieved by the regional programme was the discovery of a new radiation sensitizer, n-butyl acrylate (NBA). This additive, in small amounts (about 5 parts per 100), reduced the absorbed dose requirement from 30–40 kGy down to about 12 kGy. This had an obvious impact on the process' economy.

Additionally, an analysis of the properties of the starting material identified the best latex for this process. Research also demonstrated that some process elements, like controlled heating and leaching, further improved the properties of the final product.

As expected, the analysis of products made from RVNRL found no evidence for the presence of nitrosoamines and the cytotoxicity was extremely low. The products do not contain any sulphur or zinc oxide. This is important in those cases where eventual disposal of the product by incineration may not be acceptable if sulphur is present.

Applications of RVNRL

Rubber products for medical and hygienic uses are obviously the most promising applications of RVNRL technology because of the absence of carcinogenic and toxic products. These essential requirements are easily met by the radiation technology and, at the moment, by no other alternative. Within the technology development programme, test production of various products such as condoms, gloves, nipples, pacifiers, and toy balloons are now being carried out at different centers participating in the programme. Pilot production of condoms and gloves for medical examinations is done in Indonesia. Products are tested extensively in various field locations.

In Thailand, the Office of Atomic Energy for Peace has started a co-operative project with a local manufacturer for test production of toy balloons using RVNRL technology. Preparation of the natural rubber latex is being done at the Thai Irradiation Centre in Bangkok.

Low-cost irradiators have been specifically designed for vulcanization applications, and the main parameters for estimating production costs and for conducting feasibility studies have been developed.

So far, however, the process has not yet been used on a large scale. This is partly because it is a newly developed technology not well known to industry and because existing regulations in many countries do not yet set strict health and safety standards for some critical latex products. Two commercial applications have been developed in Japan: for protective gloves used in work with radioactive materials and for rubber recepticals used in optical laser endoscope medical examinations.

Technology transfer activities

The transfer of the RVNRL technology to industry is carried out through the regional project.

Related activities have included an international symposium in 1989 that took place in Tokyo and Takasaki; it was organized by JAERI in co-operation with the IAEA. About 60 participants from 15 countries reviewed the technology's status (the proceedings have been published by JAERI in Japan). Additionally, regional and national IAEA-organized seminars and training courses are conducted to promote the exchange of information and transfer of technology.

Future efforts will focus on technical factors of the RVNRL process as well as on fundamental research.

Already established is that the technology is safe for application and minimizes environmental hazards. It is economically acceptable when applied under high-capacity processing conditions. It is also particularly suitable for service contracts, under which one large irradiator can be used by a number of small manufacturers.

Training courses that include demonstrations of the technology of radiation vulcanization are part of IAEA regional activities in Southeast Asia; shown here is a scene from a course in Jakarta.