10.4 Feasibility Study on Utilization of Vitrified Radioactive Waste as Radiation Sources

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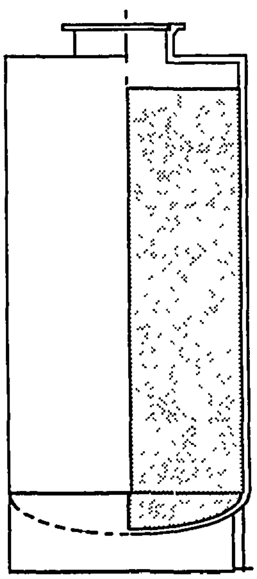
A feasibility study on utilization of vitrified high level radioactive waste (VW) as radiation source has been carried out. Natural rubber latex was radiation vulcanized with VW to demonstrate the feasibility. The dose rate was 0.1 kGy/hr. As a sensitizer, n-butyl acrylate was added. Negligible small activation of natural rubber (NR) latex by neutron from the VW was observed. The residual sensitizer in the irradiated latex and physical properties of film molded from the irradiated latex were the same level with the conventional radiation vulcanization of NR latex with γ-rays from Co-60. Surgical gloves and protective rubber gloves for radioactive contamination were produced from 20 litters of NR latex vulcanized with 2 VWs. The physical properties of both gloves were acceptable. These results suggested that vitrified high level waste can be used as an industrial radiation source.

KEYWORDS
Vitrified high level waste, radiation source, RVNRL

1. VITRIFIED HIGH LEVEL WASTE

Vitrified high level radioactive waste (VW) is solidified liquid high level radioactive waste arisen from reprocessing of spent fuel to immobilize the radionuclides. The VW will be stored for 30 to 50 years to let radioactivity decay. Then the VWs are disposed of deep underground to isolate the waste from the biosphere. Figure 1 shows an example of the canister that will be produced by the Tokai Vitrification Facility (TVF) of the Power Reactor & Nuclear Fuel Development Corporation (PNC) (IAEA, 1992). About 30 VWs are produced as a result of 1GW of nuclear power generation for one year. It is expected that more than 40,000 VWs will be stored in Japan in A.D. 2030 - 2040. The outline of interim storage facility is illustrated in Fig. 2.



Content : Borosilicate glass
Weight : 380 kg incl. Canister weight
Volume : 110 liter

Canister : Vertical cylinder type
Material : Stainless steel

Outer diameter : 430 mm
Height : 1040 mm

Radioactivity : 1.5 X 10^7 GBq
Heat generation : 1.4 kW

Fig. 1 Vitrified high level radioactive waste canister of Tokai Vitrification Facility

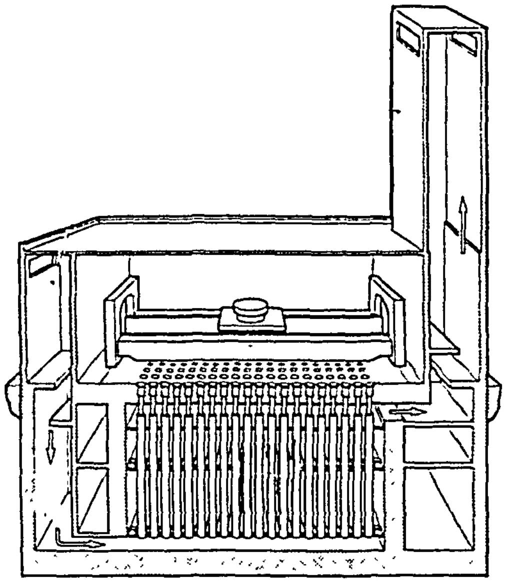


Fig. 2 Interim storage facility

One canister holds more than 10^6 GBq of Cs-137. Utilization of VW as radiation source is an interesting subject for those people who are working in radiation processing. Characteristics of VW as a radiation source are 1) large volume, 2) lower energy and dose rate compared with Co-60, and 3) activation of irradiated materials due to release of neutrons. Therefore there is limitation for utilization of VW as an industrial radiation source. The radiation process that meets the following conditions can utilize VW.

1) low dose rate irradiation
2) irradiation for raw materials (not consumer products)

So far there is no industrial process that meets the above conditions. The radiation vulcanization of NR latex seems to meet the above conditions among the radiation processes under developing.

2. RVNRL

The RVNRL means crosslinking of natural rubbers (cis-1,4- polyisoprene) dispersed in the form of microscopic particles in an aqueous medium. The RVNRL procedure consists of two steps (Makuuchi and Tsushima, 1985): mixing NR latex with sensitizer and irradiating. The resulting radiation vulcanized (RV) NR latex can be used for the manufacture of latex products by the conventional coagulant dipping process. Usually n-butyl acrylate (n-BA) is used as a sensitizer. The irradiation dose for vulcanization can be reduced to 15 kGy from 250 kGy by addition of 5 phr of n-BA. The radiation vulcanized NR latex and products from it have the following advantages over convention sulfur vulcanization (Makuuchi and Markovic, 1991);

1) Absence of N-nitrosamines
2) Very low cytotoxicity
3) Low emission of SO_2 and less formation of ashes
4) Transparency and softness
5) Degradable under the environment

3. RVNRL FACILITY WITH VW

A facility for RVNRL with VW was designed based on the concept of the utilization of interim storage of canisters as an irradiation facility to avoid the construction of irradiation facility for the reduction of vulcanization cost. Irradiation vessel having the same size with the VW canister put into the vertical pit of the storage. The vessel is placed alternately with VW so that one irradiation vessel is surrounded by 6 VWs as shown in Fig. 3. The moving of the canister can be operated automatically. The specifications of the facility are shown in Table 1.

Table 1 Specification of RVNRL facility with VW

Processing rate	1,000 tons/year
Materials of irradiation vessel	Stainless steel
Number of irradiation vessel	36 (112 kg latex/vessel)
Number of VWs	104
Operation days	250 days/year
Operation hours	17 hours/day

The flow sheet of the facility is shown in Fig. 3. The facility will be attached to the interim storage facility of VWs. The NR latex to be irradiated and irradiated NR latex will be transported by tank truck. The capacities of storage tanks of NR latex and irradiated NR latex are $30m^3$.

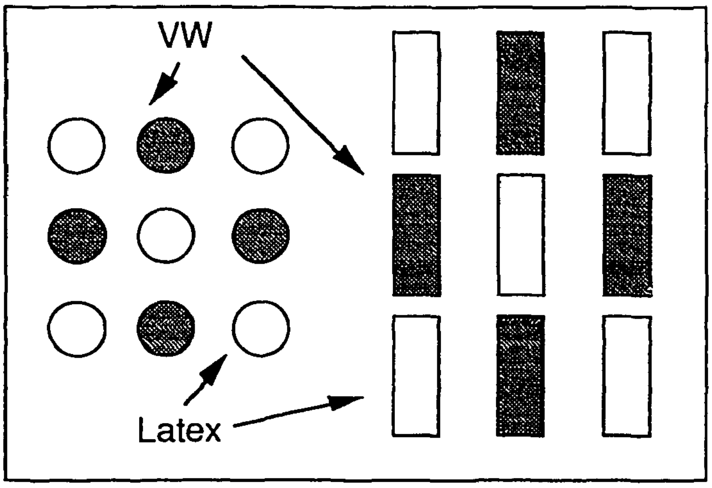
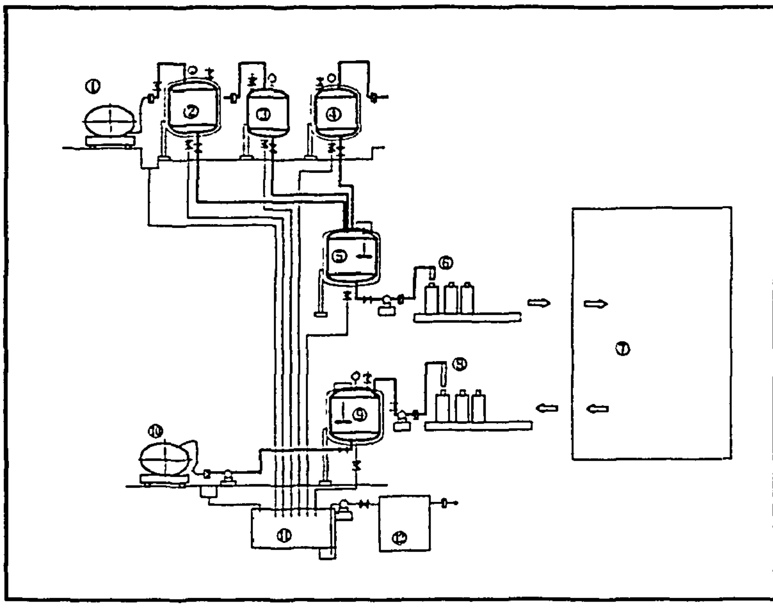


Fig. 3 Configuration of VW canister and irradiation vessel



1. Tank truck
2. NR latex tank
3. Sensitizer tank
4. Distilled water tank
5. Formulation tank
6. Latex charging system
7. VW canister storage area
8. Latex discharging system
9. Irradiated NR latex tank
10. Tank truck
11. Cleaning system
12. Water treatment facility

Fig. 4 Flowsheet of RVNRL with Vitrified High Level Waste

The construction cost and the operation cost of the facility were calculated in view of the respective element by adopting average investment method. The unit processing cost was estimated to be ¥31/kg. It was expected that this value will be acceptable for the latex industry.

4. RVNRL WITH VW

To verify the feasibility of utilization of VW as irradiation source RVNRL was carried out with small VW produced by the Chemical Processing Facility (CPF), PNC. The dimensions of the VW were 76 mm (outer diameter) and 500 mm (height). This VW contains 3.1 kg of glass and 5.9×10^4 Bq of γ-emitters. The dose rate measured with a alanine dosimetry was 0.1 kGy/hr. NR latex was irradiated in a polyethylene bottle having a capacity of 100 ml. The bottle was wrapped with polyvinylchloride. As a sensitizer 5 phr of n-BA was used. Dose was 5-30kGy. Activation of NR latex and bottle were negligible. The residual sensitizer in the irradiated latex was the same level with the conventional RVNRL with γ-rays from Co-60. Figure 5 shows typical example of the relationship between dose and tensile strength (Tb) of

Malaysian NR latex (IOTEX HA). Results obtained with Co-60 irradiation with the same dose is also shown in this figure for comparison. In the case of Co-60 irradiation the maximum Tb was achieved at 15 kGy. While it needed about 25 kGy in the case of VW irradiation in this NR latex. Hence, RVNRL needs more dose than Co-60 does. Probably this is due to lower energy of γ-rays from VW (0.66 MeV from Cs-137). Though VW is slightly inferior to Co-60 in terms of vulcanization dose, physical properties of the obtained rubber meet Japanese Industrial Standard. For example the maximum Tb and elongation at break were 31.5 MPa and 970 %, respectively. Comparison of RVNRL with Co-60 and VW is shown in Table 2. It can be said that VW can be used as an irradiation source for RVNRL.

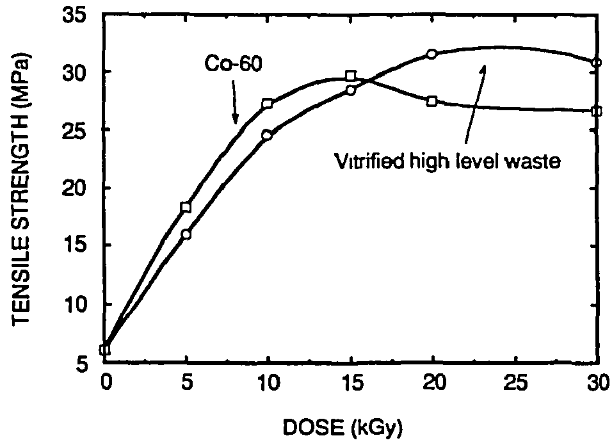


Fig. 5 RVNRL with VW and Co-60

Table 2 Comparison of RVNRL with VW and Co-60

	Irradiation source	
	Vitrified high level waste	Co-60
Vulcanization dose (kGy)	25	15
Tensile strength (MPa)	32	30
Elongation at break (%)	970	930

Test production of surgical gloves and protective rubber gloves for radioactive contamination were carried out successfully. For this purpose 20 liters of NR latex were vulcanized with 2 small VWs. Bottles made of polyethylene terephthalate were used as irradiation vessels. Physical properties such as Tb and elongation at break meet the Japanese Industrial Standards.

5. CONCLUSION

Vitrified high level waste is slightly inferior to Co-60 as radiation source from the point of view of vulcanization dose. However NR latex vulcanized with VW possessed practical physical properties. Vitrified high level waste can be used as a radiation source for RVNRL.

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