Radiation Risk Assessment for the Transport of Radioisotopes using KRI-BGM B(U) type Container

Woon-Kap CHO*

Korea Institute of Nuclear Safety (KINS), Guseong-dong 19, Yuseong, Daejeon, 305-338, Korea.

Abstract. The radiation risks were estimated for the transportation of radioisotopes using KRI-BGM transport container. KRI-BGM container was specially designed for transportation of large amount of radioisotopes for industrial or medical applications. The container can carry maximum 370 TBq of solid Ir-192, 29.6 TBq of liquid Mo-99 and 37 TBq of liquid I-131 respectively. For the radiation risk assessment, it was assumed that maximum design activity of those radioisotopes was transported. Transportation route is from Daejeon where radioisotopes are produced to Seoul where radioisotopes are consumed. Transport distance is 200 km including highway and downtown area from Daejeon to Seoul. As the transportation conveyance, an ordinary cargo truck is used exclusively. Radiation risks were estimated for incident free and accident condition of transportation and RADTRAN 5.6 was used as the risk assessment tool. For the risk assessment of radioisotopes transportation, various parameters such as population density around transport route, weather condition, probability of specific accidents such as impact, fire, etc. were considered. From the results of this study, the exclusive transportation of radioisotopes using KRI-BGM transport container by truck showed low radiological risks with manageable safety and health consequences. This paper discusses the methods and results of the radiation risks assessment for the radioisotopes transportation by an ordinary truck and presents the expected radiation risks in person-Sv and latent cancer fatalities.

KEYWORDS: Radiation risk assessment, transport of radioisotopes, Accident dose risk, latent cancer fatality

1. Introduction

As the applications of radioisotopes to medical and industrial sectors are continuously increasing in Korea, the amount of transport of radioisotopes is also rapidly increasing in recent years. Transports of radioisotopes are usually being carried out through highways using ordinary truck. Truck shipment of large amount of radioisotopes through highways would lead to a radiation dose to the public even if the transport is incident-free, because no shielding material can reduce direct gamma radiation by 100%. As a result, residents, drivers, pedestrians and workers will get a radiation dose, which depends on the recipient's exposure proximity and duration. Even though this radiation dose and the resulting risks are expected to be relatively small, it nevertheless increases the risk to develop cancer. The health and safety risks are frequently characterized in terms of radiation dose to people and human health effects such as latent cancer fatalities.

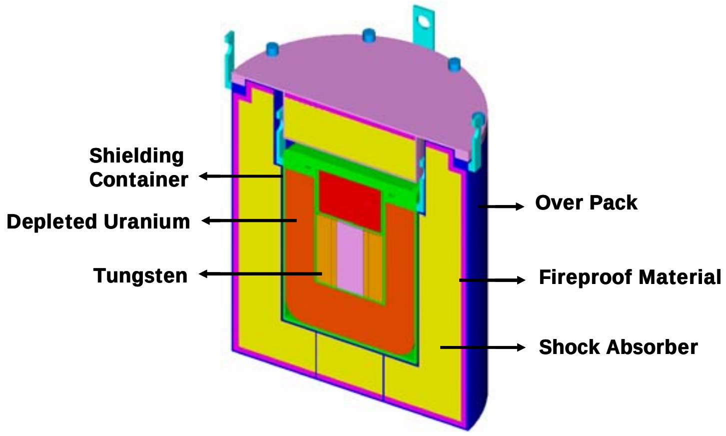
In this study, the radiation risks were estimated for the transportation of large amount of Ir-192, I-131 and Mo-99 radioisotopes. Specially designed transport container, KRI-BGM can carry maximum 370 TBq of solid Ir-192, 29.6 TBq of liquid Mo-99 and 37 TBq of liquid I-131 respectively. It is assumed that transport distance is 200 km including highway and downtown area from Daejeon to Seoul. The RADTRAN 5.6 computer model developed by Sandia National Laboratories was used to calculate the incident-free dose to the maximally exposed individual and accident dose and latent cancer fatalities to the population of affected area as a result of transport of above-mentioned radioisotopes using ordinary cargo truck [1].

2. KRI-BGM B(U) type container

* Presenting author, E-mail : wkcho@kins.re.kr

The KRI-BGM is a B(U) type transportation container intended for transport of large amount of radioisotopes [2]. Type B(U) shipping containers should be designed to withstand all likely accidents that could take place on transport route, such as highways or rail. Containers are presently designed to withstand a 30 mph crash into an unyielding object, and a fire of 800℃ for 30 minutes and physically tested before approval as a B(U) type container to assure that the container meets all safety requirements by the regulations. KRI-BGM container can carry 370 TBq of Ir-192 industrial radiography sources, 37 TBq of I-131 thyroid therapy sources and 30 TBq of Mo-99 sources used for manufacturing of Tc-99m generators respectively. KRI-BGM container is a cylindrical and is fixed with tie-down equipments to the truck during transportation. The overall length and diameter of the container are 475mm and 400 mm respectively. The overall weight of empty container is 170 kg. Main shielding structures are made of depleted uranium and tungsten and main structural materials are carbon and stainless steel. Polyurethane are used as shock absorber and located between shielding container and outer container. Figure 1 shows the outline structure of KRI-BGM transport container.

Figure 1 : KRI-BGM B(U) type transport container



3. Transportation Risk Assessment

3.1 Input Parameters Assumptions

The scenario for transport risk assessment was designed to provide an estimate of human health impacts that are plausible [3]. For the transport risk assessment in this study, important parameters to be considered are transport container, vehicle, radioisotopes, transport route, workers and anticipated accident related information. It is assumed that KRI-BGM container carries maximum design activities of Ir-192, I-131 and Mo-99 and only gamma radiation gives exposure dose to surroundings. Ordinary truck is used exclusively as transport mean and normal speed of truck during transport is around 80 km per hour. Transport route is selected to use mainly highway of 200 km distance from a radioisotope production facility located in Daejeon to application facilities located in Seoul. Only persons living within 800m of the proposed shipment routes are considered. Any dose to the corridor population outside this 800m stretch is neglected. The population density used in the estimation of risks resulting from the truck accident is 2,000 persons per km^2 near highway and around 10,000 persons per km^2 in urban area. Vehicle density on highway is assumed to be 3,000 vehicles per hour and 10,000 vehicles per hour in urban area. The important input parameters used in risk assessment using RADTRAN 5.6 are summarized in table 1.

Table 1: RADTRAN Input Parameters Assumptions

Input Parameters	Assumptions
Transport Container	KRI-BGM, Max. Length(475 mm), Diameter(400mm), weight(170 kg)
Radioisotopes	Ir-192 (solid, 370 TBq(10,000 Ci)), I-131 (liquid, 37 TBq(1,000 Ci)), Mo-99 (liquid, 29.6 TBq(800 Ci)

Transport Vehicle	Truck(exclusive use), speed (< 80 km/hr), one package/vehicle
Transport Route	Land transport (mainly highway), Distance(200 km), Route (Daejeon-Seoul) Population density (persons/km^2) : 2,000 (near highway), 10,000 (city center) Vehicle density(vehicles /hour) : 3,000 (highway), 10,000 (urban area)
Accident Conditions	Accident probability (2.5×10^{-7} /vehicle-km) Fatalities per accident (0.3) Release fraction (0.1 for conditional accident probability)

3.2 Risk Assessments

An analysis of the radiological impacts associated with the transport of high activities of Ir-192, I-131 and Mo-99 was performed under both incident-free and accident conditions. In incident-free conditions, the maximum individual in-transit dose was calculated. For the evaluation of the risks associated with accident conditions, expected values of population risks in person-Sv and latent cancer fatalities were calculated. In case of an accident involving radioisotopes shipment, the dose to individuals and the population will be much higher. In contrast to incident-free transportation, such an accident would cause both acute and long-term exposures, because radioactive particulates would be dispersed in the environment and continue to lead to radiation exposures. A transportation accident leading to a release of radioactive particulates is possible and credible. It could be caused by high impact, long duration of fire or sabotage. Such an accident would lead to high radiation exposure due to inhalation (acute dose) and ground shine (long-term dose). Additional exposure to radiation would arise from ingestion of food, water and soil, even though the dose due to from the ingestion pathway is very small in comparison to the inhalation and ground shine pathways [4].

We considered a crash accident of truck on highway for accident dose risk and health effect risk estimation and assumed that the accident occurrence probability for truck transport is 2.5E-7 as shown in Table 1. As a result of this crash accident of transport truck on highway, it is assumed that release fraction, the fraction of each radionuclide in the cargo that could be released in an accident, is 0.1 for the conditional probabilities of accidents of particular severities. During transportation, as the external dose rate at one meter from the package surface, 14 mrem/hr was used according to the 10CFR Part 71 guidelines. It is conservative assumption considering the actual source term will have lower values and lower external dose rates.

4. Results and Discussion

In incident-free condition of the transport of high activities of Ir-192, I-131 and Mo-99, the maximum individual in-transit dose during the transportation by a truck was calculated to be 4.82E-9 Sv. Expected value of population risk in person-Sv associated with transport of large amount of radioisotopes from Daejeon via truck to Seoul was calculated to be 3.31E-6 person-Sv accounting for ground-shine, cloud-shine, and inhalation. In RADTRAN 5.6, the four pathways are considered in the estimation of transportation risks, i.e., ground-shine, inhalation, resuspension inhalation and cloud-shine. Among the several pathways, the most important pathways during truck transportation are ground-shine and inhalation pathways. The contributions from each possible pathway were 3.26E-6 person-Sv from ground-shine, 1.46E-8 person-Sv from cloud-shine and 3.08E-8 person-Sv from inhalation respectively. These values are very small and it is not expected that any meaningful health effects will occur during the transportation of those amount of radioisotopes considered in this study. The total expected value of population risk in latent cancer fatalities (LCF) for truck transport is 1.65E-7. The contributions from each possible pathway were 1.63E-7 from ground-shine, 7.3E-10 from cloud-shine and 1.54E-9 inhalation respectively. These values are relatively small comparing with the safety goal of nuclear power plant operation of USNRC, which is 5.0E-7. The accident dose risk and the latent cancer fatalities are summarized in Table 2 and 3.

Table 2: Expected values of Population Risk in Person –Sv

Radioisotopes	Ir-192	I-131	Mo-99
Ground shine risk	2.86E-6	2.66E-7	1.33E-7
Cloud shine risk	1.13E-8	2.12E-9	1.16E-9
Inhalation Risk	2.47E-8	4.62E-9	1.40E-9
Resuspension Risk	0	0	0
Total Dose Risk	2.90E-6	2.73E-7	1.35E-7

Table 3: Expected values of Population Risk in latent Cancer Fatalities (LCFs)

Radioisotopes	Ir-192	I-131	Mo-99
Ground shine risk	1.43E-7	1.33E-8	6.63E-9
Cloud shine risk	5.66E-10	1.06E-10	5.80E-11
Inhalation Risk	1.24E-9	2.31E-10	6.99E-11
Resuspension Risk	0	0	0
Total LCFs	1.45E-7	1.37E-8	6.75E-9

5. Conclusions

We estimated and compared the exposure dose risks and health effect risks resulting from the accidents during the transport of the large amount of Ir-192, I-131, and Mo-99 that are broadly used in medical and industrial sectors in Korea. From the results of this study, the transport of radioisotopes using ordinary truck through highway route is a low radiological risk activity with a manageable safety and health consequence. However, there may be a number of social and institutional challenges to the successful transport of high activity radioisotopes through living environment. Type B(U) shipping containers designed to withstand all likely accidents that could take place on transport route should be used for transport of high activity radioisotopes. Detailed and sophisticated transport risk assessment and management must be made for the safe transport of high activity and large amount of radioisotopes. And also, it needs to be emphasized that while it is important to use conservative assumptions in the evaluation of the environmental impacts, it is equally important that the public understand the conservative nature of the results presented in the risk assessment of radioactive material transport.

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