EVALUATION OF THE RADIOLOGICAL IMPACT FROM

RADWASTE TRANSPORTATION IN TAIWAN BY USING CODE RADSHIP-2

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ABSTRACT

RADSHIP-2 is a computer code developed under the support of Radwaste Administration of Atomic Energy Council, Republic of China to evaluate the radiological impact to the environment from the radwaste transportation in Taiwan area. RADSHIP-2 was basically based on RADTRAN code but allowing more exposure pathways to be considered especially through the sea transport. Falling-off factors to take account for the dose decreasing away from the transport package were provided by using QAD-CG code and built into RADSHIP-2 code for the population dose assessment during truck shipment. The physical dispersive process of radwaste released in a bay and coastal water were also modelled for pier operation and sea shipment contaminated accidents. The results calculated for Taipower's radwaste transportation in Taiwan were compared with those from RADTRAN. It can be found that even considering more exposure pathways specific in Taiwan area, the resulted annual doses to the general population under normal condition is 0.8763 man-rem and the expected number of annual latent cancer fatalities under accident conditions is only 4.885×10^{-5}.

INTRODUCTION

In Taiwan, there are currently three twin-unit nuclear power stations (4 BWRs and 2 PWRs) in commercial operation, from which thousands of solid radwaste drums (55-gallon drum) will be produced per year as shown in Figure 1. Under the consideration of storing solid radwaste on off-shore island, the National Lan-Yu Storage Site located at the southeastern tip of the Lan-Yu island was selected as the interim storage site. All of the solid radwaste drums are carefully stored for 2-3 years in nuclear power plants before shipped to Lan-Yu. And during each shipment truck transportation, pier operation and sea shipment are included. Although the records relating to transportation of radioactive materials in Taiwan area is good, public concern about the radiological impact resulted from solid radwaste transportation is continuously expressed.

To provide the evaluation of radiological impact from radwaste transportation in Taiwan, the RADTRAN[1] code developed by Sandia Lab was employed during the past. However, concerning the actual transportation situation in Taiwan, RADTRAN can not be well adapted in following aspects:

(1) As the transport mode being employed in Taiwan, more exposure pathways should be considered.
(2) The local population distribution condition is quite different from that described in RADTRAN.
(3) The evaluation of possible accident during pier operation is not included in RADTRAN.
(4) RADTRAN does not include the physical dispersive process for radwaste released in a bay and coastal water under possible accident as sea shipment should be considered in Taiwan.

Based on the above requirement and basic model in RADTRAN, Institute of Nuclear Energy Research developed the code RADSHIP-2[2] specifically for the radioactive material transportation analysis in Taiwan under a contracted program with ROCAEC and Taiwan Power Company. This code can fullfill the requirement for analysis of the radiological impact under the transportation condition in Taiwan. Also the falling-off factor to take account for the dose decreasing away from the transport package were provided by using QAD-CG code and built into RADSHIP-2 code for the population dose assessment during truck transportation.

RADSHIP-2 is written in FORTRAN-IV and successfully operational on the FACOM-M200 computer system since May 1985.

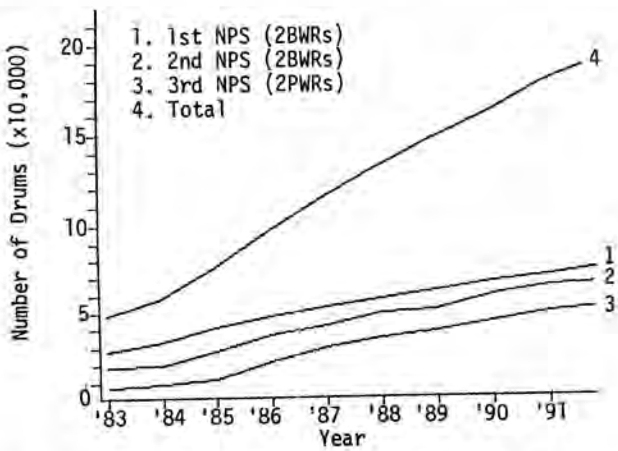

Fig. 1. Expected Quantities of Radwaste Drums in Taiwan

THE RADSHIP-2 MODEL

The development of RADSHIP-2 code was based on RADTRAN code but allowing more exposure pathways to be analyzed as shown in Table I. The analyzed radiological impact includes those from the normal transportation and those from vehicular, ship and handling accidents involving release of radioactive materials. The physical dispersive process of radwaste released in a bay and coastal water, were modelled to be continuous point release as described in IAEA series[3] with the consequential dose calculation following USNRC Regulatory Guide 1.109[4]. The dose falling-off factors to account for the dose decreasing away from the transport package were pre-calculated by using QAD-CG[5] code and built into RADSHIP-2 code. RADSHIP-2 also has the capability to perform the population dose integration depending on the input of closest distance from the shipment centerline for each population zone. Besides, RADSHIP-2 was written using FIDO system to allow the input data preparation more convenient and flexible.

A. Shipment Model

RADSHIP-2 analyzes two type of radwaste containers currently being employed in Taiwan, the standard container without shield installed for 36 drums and the specially designed container with shield installed for 48 drums. The number of radioisotopes to be handled can be up to 20 with type of nuclide, activity, packaging type and transport distance to be identified by the users.

B. Transportation Model

The transportation model used in RADSHIP-2 is subdivided into three parts: the accident rate, traffic pattern and shipment information. The accident rate part specifies the rate of occurence according to the severity of the accident and for different population density zone. The traffic pattern part include the fraction of travel on different type of road and population density zones. The shipment information part specifies the work person in different transportation stages, people on vehicle, dose conversion factor, distance between container and exposed person, handling and stop time.

C. Population Distribution Model

Three kinds of population density zone can be specified and the population density in special area such as pier, emergency anchoring port or the regions that accident might occur can be identified.

D. Radiological Impact under Normal Transportation

The code combines the population model, traffic pattern model and transportation model to calculate the annual dose rate according to the categories in Table II. The dose is expressed in terms of expected latent cancer fatalities.

TABLE I

Exposure Pathways

Transport Mode	Condition	Exposure Pathways
Land Transport (Truck)	1. Normal Transportation	Resident, People on Link, People on Guided Vehicle, Driver, Traffic Control Patrol, Toll Station Personnel.
	2. Scheduled Stop	Resident, People on Guided Vehicle, Driver, Traffic Control Patrol.
	3. Non-Scheduled Stop	Resident, People on Link, People on Guided Vehicle, Driver, Traffic Control Patrol.
	4. Accident	Resident, Worker.
Pier Operation (Loading and Unloading)	1. Normal Operation	Resident, Handler, Worker, Supervisor.
	2. Non-Contaminated Accident	
	. Cargo Fall on Ground or Ship	Handler, HP.
	. Cargo Fall into the Sea	Handler, HP, Diver.
	3. Contaminated Accident	Resident.
Sea Transport (Ship)	1. Normal Transportation	Crew, HP.
	2. Accident	
	. Sinking (Typhoon, Vessel Collision, Aground)	Resident.
	. Accident on Ship (Aground, Small Accident)	Crew
	. Non-Scheduled Anchoring	Resident, Crew.

TABLE II

Results of the RADSHIP-2 and RADTRAN Codes

	Annual Dose (man-rem)	
	RADSHIP-2	RADTRAN
1. Land Normal Transportation		
. Resident	0.2612	0.276
. People on Guided Vehicle	0.4182	----*
. Driver	0.5117	0.3996
. Traffic Control Patrol	0.0011	----
. Toll Station Personnel	0.0	----
. People on Link	0.0600	0.031
Subtotal	1.2532	0.7066
2. Truck Scheduled Stop		
. Resident	0.0	0.0
. People on Guided Vehicle	0.0	----
. Driver	0.0	----
. Traffic Control Patrol	0.0	----
Subtotal	0.0	0.0
3. Truck Non-Scheduled Stop		
. Resident	0.0357	----
. People on Guided Vehicle	0.0251	----
. Driver	0.0307	----
. Traffic Control Patrol	0.0334	----
. People on Link	0.0639	
Subtotal	0.1888	----
4. Pier Operation		
. Normal Operation		
--- Resident	0.0687	----
--- Handler	6.3087	3.9
--- Crew	13.3041	----
--- Supervisor	2.2329	----
. Cargo Fall on Ground or Ship		
--- Handler	2.86×10^{-5}	----
. Cargo Fall into the Sea		
--- Handler	2.86×10^{-6}	----
--- Diver	2.50×10^{-14}	----
Subtotal	21.9144	3.9
5. Sea Transportation		
. Normal Condition		
--- Crew	28.22	30.4
. Aground		
--- Crew	3.48×10^{-3}	----
. Small Accident		
--- Crew	7.26×10^{-3}	----
. Non-Scheduled Anchoring		
--- Crew	1.7416	----
--- Resident	0.3868	----
Subtotal	30.3599	30.4
6. Truck Contaminated Accident		
. Resident	5.791×10^{-6}**	5.791×10^{-6}**
7. Pier Contaminated Accident		
. Resident	4.306×10^{-5}**	----
8. Ship Contaminated Accident		
. Resident	2.501×10^{-11}**	----

* '---' means this exposure pathway is not included in the code.

** Unit in (Latent Cancer Fatalities/yr)

E. Accident Severity and Package Release Model

The accident severity model divides all accidents into eight severity categories depending on the fire, crush, impact, puncture forces or user specified condition encountered in the accident. The accident severity categorization determines the fraction of radionuclides released from different kinds of package type. The package release model combines the user specified radionuclide release fraction, radionuclide aerosolized fraction and the fraction of the radionuclides will enter human body through inhalation. These results are then combined with the accident rates for each severity category, transport distance and annual transport times to determine the expected annual release of each radionuclides in each population zone.

F. Meterological Dispersion Model

Gaussian plume model can be used to describe the diffusion of the cloud of aerosolized debris released at the site of accident. The dispersion calculation, are not performed by RADSHIP-2. Instead the dispersion factors are provided separately and used as input to RADSHIP-2.

G. Health Effects Model

The health effects model in RADSHIP-2 is similar to that in code RADTRAN and is based on U.S. NRC Reactor Safety Study report WASH-1400[6]. The relative toxicity of the material shipped is analyzed in terms of potential for producing early fatalities and latent cancer fatalities. The analysis is based on the computed dose received by the various organs of interest.

H. Radiological Impact due to Accidents

This section of RADSHIP-2 combines the probabilistic occurrences of accidents of varying severity in various population zones with the meteorological diffusion to compute the expected number of latent cancer fatalities due to shipments during that year and the probability of a given number of early fatalities due to accidents during the given year.

I. Dispersion Model in Sea

As the container dropped into sea and cause water pollution, the sea water dispersion model is based on IAEA Safety Series No. 5 report 'Radioactive Waste Disposal into the Sea'. The dose calculation model is based on U.S. NRC Regulatory Guide 1.109.

RADSHIP-2 APPLICATION

Table II shows the dose calculated by RADSHIP-2 code for Taipower's radwaste transportation in Taiwan. On the average, 15000 solidified radwaste drums are shipped to Lan-Yu per year. Some of the transport conditions are shown in Table III. Based on the same transport condition, analysis has also been performed by using RADTRAN code with results also being included in Table II for comparison. It can be found that RADTRAN code provides only part of exposure pathways as provided by RADSHIP-2 code. The resident dose under normal truck transportation calculated by RADSHIP-2 is smaller than by RADTRAN, that is because the falling-off factor used in RADSHIP-2. And the different exposure situation assumed in these two code during transportation cause a little different results of dose received by driver, people on link, and crew. Besides, the handler doses are also different from both code, for different approach method been used.

TABLE III

Typical Data Used in RADSHIP-2

Parameter	Value
Transport Index (mrem/hr)	13
Distance per Shipment (km), land	20
sea	350
Package per Shipment	6
Shipment per Year	50
Velocity (km/hr), land	30
sea	15
Curie per Package (Ci)	4.64
Nuclide	Co-60
Population Density (people/km²),	
High	10,000
Medium	1,000
Low	100
Fraction Travel, High	0.2
Medium	0.3
Low	0.5
Traffic Count (car/hr); High	700
Medium	60
Low	10

From this analysis, it reveals that the annual doses to the general population is 0.8763 man-rem, average dose per person is about 0.024 mrem which is much smaller than the average annual natural background of 100 mrem in Taiwan area. And the expected number of annual latent cancer fatalities caused by probable contaminated accidents is only 4.885×10^{-5}. Hence, the radiological impact from Taipower's radwaste transportation to the environment in Taiwan is very low and can be neglected.

REFERENCES

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5. V. R. Cain,. "QAD-CG: The Combinatorial Geometry Version of the QAD-P5A Point Kernel Shielding Code," CCC-307, Oak Ridge National Laboratory (1977).

6. "Calculation of Reactor Accident Consequences," Appendix VI to the Reactor Safety (WASH 1400), USNRC, Oct. 1975.