Dose Evaluation by the Q system for LLW Bitumen Packages in Fire Environment

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1. Introduction

Large amounts of waste classified as "combustible solids" such as asphalt packages and plastic packages, are included in the waste generated by nuclear power plants and reprocessing plants throughout the world. Therefore, it is necessary to confirm transportation safety standards, especially fire situations encountered during sea and land transport, by evaluating beforehand the following items.

① What is the nature of the burning?
② How much of the contained nuclide is discharged?
③ What is the exposure dose imposed on the general public and workers?

This evaluation discusses the appropriateness of the Q system concept and the radioactive limiting value during transportation, which calculates the exposure dose to the general public and workers by using the "Q system" (IAEA Safety Series No. 7, 1985) shown in the IAEA Transport Regulations. Calculations are based on data related to nuclide discharge rate obtained from thermal tests of asphalt packages contained in 200ℓ drums, (watabe et all 1992) as performed at the Central Research Institute of the Electric Power Industry.

2. Evaluation

Figure 1 shows the evaluation flow of exposure dose calculations in this research. As Figure 1 shows, calculations of both the external and internal exposure doses are based on new ICR recommendations (Pub. 26, 30, 51) using the exposure routes and conditions established by the Q system in the IAEA Transport Regulations. In order to assess the evaluation of the Q system, we calculated the exposure dose in accident situations where radioactive material is discharged into the atmosphere from asphalt packages.

3. Q System Exposure Dose Evaluation

Using the Q system, we calculated the exposure dose from radioactive material discharged from asphalt packages as a result of accident conditions.

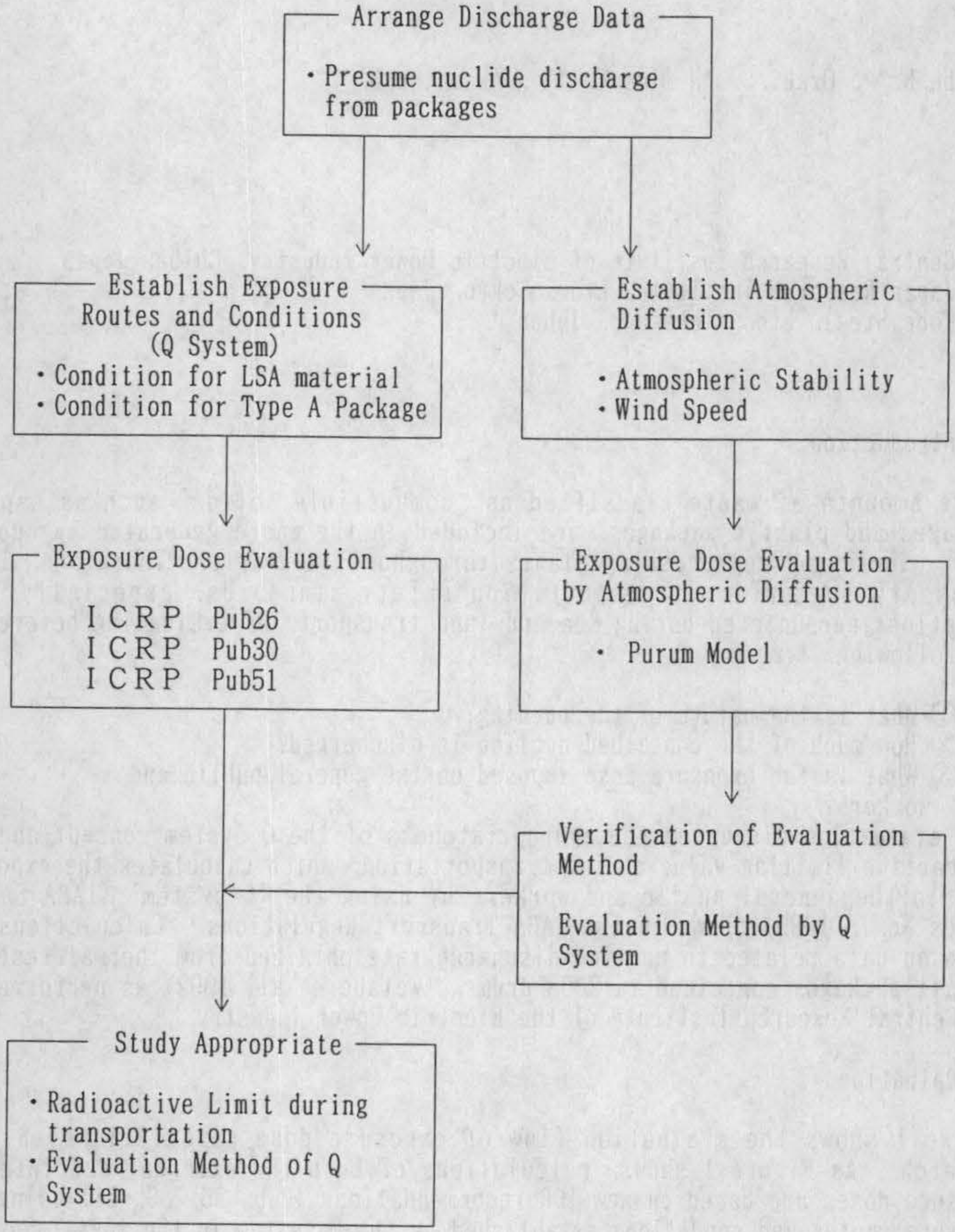


Fig.1 Flow Chart of Dose rate

3.1 Summary of Nuclide Discharge Data

We made assumptions concerning the nuclide discharge dose from actual package during fire accident, based on the results of fire tests of simulated asphalt package that were conducted at the Central Research Institute of the Electric Power Industry. With regard to the nuclide discharge from actual package we made assumptions as to the size of the discharge dose and A_2 value of nuclide of high importance from the characteristic chemical similarities of simulated nuclide.

C_s :1.5×10^{-2} W%

Nuclide other than C_s :5.0×10^{-3}W%

Table 1 Simulated Nuclide Discharge Rate

Nuclide	Discharge Rate (W%)
C_o S_r E_u	$4.4\times10^{-3}\sim3.6\times10^{-4}$
C_s	$1.5\times10^{-2}\sim4.7\times10^{-3}$

3.2 Establishment of Exposure Routes and Conditions

Exposure routes and conditions are the same as those in the Q system. As there are 3 evaluation conditions, comparison evaluations are conducted in all 3 cases.

- Conditions to determine a contained radioactive dose (A_1, A_2 value for Type A packages.)
- Conditions to determine LSA material concentrations.

(1) Conditions to determine a contained radioactive dose for Type A packages

The conditions for determining a contained radioactive dose for Type A packages are what we call the Q system. The Q system takes 5 exposure routes: Qa, Qb, Qc, Qd, Qe into consideration, and gives the exposure condition for each. Among these, Qc matches the exposure evaluation during the fire of asphalt package (internal exposure). Qc exposure conditions are as follows.

- exposure limit: 50 mSv (5 rem)
  Intake for 1 ALI.
- intake rate: $10^{-4}\sim10^{-3}$
- discharge rate: $10^{-2}\sim10^{-3}$

The net intake rate, including the above intake rate, for the content amount of the package is 10^{-6}. In this discussion, an evaluation is made through the discharge rate and the volatile rate obtained during the fire test.

(2) Conditions for determining LSA material concentrations

The conditions for determining LSA material concentrations are also given in the Q system. Exposure conditions when determining LSA material concentrations are as follows.

- exposure limit: 50 mSv (5 rem) ·
  Intake for 1 ALI.-
- intake rate: 10mg LSA material. This is the LSA material intake rate for a person with a 2 m^3/h respiratory coefficient who stays 30 minutes in a space where 10mg (LSA)/m^3 particles are suspended.
- discharge rate: not defined

When asphalt package encounters fire, it is not supposed to create a space filled with 10mg (LSA)/m^3 particles, therefore, it is necessary to establish a substitute space concentration. In order to establish this, the following scenario which matches the scenario in the Q system should be assumed and evaluation should be made using a volatile rate obtained from fire tests.

① Space used to determine Q_c and the ordinary leakage limit for Type B packages- space capacity: $50m^3$ (assume the space of a cargo truck)

- number of emissions: 10 times/hour (weakened at e^{-10t})
- average concentration rate for 30 minutes for the initial concentration:

  $0.199 = e^{-10t}\ dt/t_0$ (t_0=0.5Hr)

- average concentration rate for 30 minutes for the initial discharge dose (1):

  $3.98 \times 10^{-3} / m^3$

② Space used to determine Q_E

- space capacity: 300 m^3(space of 10m ×10m ×3m, assume storage and cargo handling area)
- number of air changes: 4 times/hour (weakened at e^{-4t})
- average concentration rate for 30 minutes for the initial concentration:

  $0.432 = e^{-4t}\ dt/t_0$ (t_0=0.5Hr)

- average concentration rate for 30 minutes for the initial discharge dose (1):

  $1.44 \times 10^{-3} / m^3$

In comparing the above two spaces, the concentration that should be considered is ①. As it is the more severe condition, evaluation should be made using this space.

3.3 Exposure Dose Evaluation

(1) Conditions for determining a contained radioactive dose for Type A packages

Evaluation is based on the following conditions.

- initial radioactive dose: $100A_2$
- nuclide:combination of C_s and nuclide other then C_s (C_o, M_n , P_u , and others)
- volatile rate during fire: C_s : 1.5×10^{-2} W%

  Nuclide other than C_s : 5.0×1.0^{-3} W%

- intake rate: $10^{-4} \sim 10^{-3}$

table 2 shows the evaluation results.

Table 2. Exposure Dose during Fire (Conditions for determining a Type A Package Radioactive Dose)

Intake Rate	Combination of Nuclide			Remarks
	C_s 100%	C_s 50%	C_s 10%	
10^{-4}	75mSv ($1.5\times10^{-6}A_2$)	50mSv ($1.0\times10^{-6}A_2$)	30mSv ($0.6\times10^{-6}A_2$)	
10^{-3}	750mSv ($1.5\times10^{-5}A_2$)	500mSv ($1.0\times10^{-5}A_2$)	300mSv ($0.6\times10^{-5}A_2$)	

(2) Conditions for determining LSA material concentrations
The evaluation conditions when determining LSA materials concentrations are as follows.

- initial radioactive dose: $100A_2$
- nuclide:combination of C_s and nuclide other then C_s (C_o, M_n, P_u, and others)
- volatile rate during fire: C_s :1.5×10^{-2}W%
  Nuclide other than C_s :5.0×10^{-3}W%
- average concentration rate for 30 minutes for the initial discharge dose (1):
  $3.98\times10^{-3}/\ m^3$
- intake rate: $1m^3$ space (breathing)

table 3 shows the evaluation results.

Table 3. Exposed Dose during Fire (Conditions for Determining LSA Material Concentrations)

Combination of Nuclide			Remarks
C_s 100%	C_s 50%	C_s 10%	
300mSv ($6.0\times10^{-5}A_2$)	200mSv ($4.0\times10^{-5}A_2$)	200mSv ($2.4\times10^{-5}A_2$)	

4. Exposure Dose Evaluation by Atmospheric Diffusion
We calculated the concentration distribution and exposure dose from the Purum model as an atmospheric diffusion model for situations where radioactive material is discharged into the atmosphere from asphalt consolidation as a result of a Purum model accident.

4.1 Evaluation Conditions
Evaluation conditions are as follows.

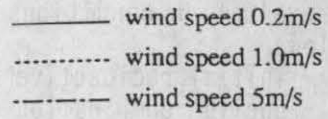
① Discharge height
Land discharge

② Weather conditions
- wind speed ... 0.2, 1.0, 5.0 m/sec
- atmospheric stability...A, C, F

③ Evaluation point
10 points up to 100 meters with 10 meter intervals from the discharge point.

④ Radioactive material discharge conditions
1 Bq/sec

4.2 Evaluation Results
Figure 2 shows the distribution obtained from results of the diffusion calculations by the Purum model. Figure 3 shows the exposure dose.
Using these results, the exposure dose is calculated in cases where $100A_2$ of Cs is discharged. Figure 4 shows the calculated exposure dose.



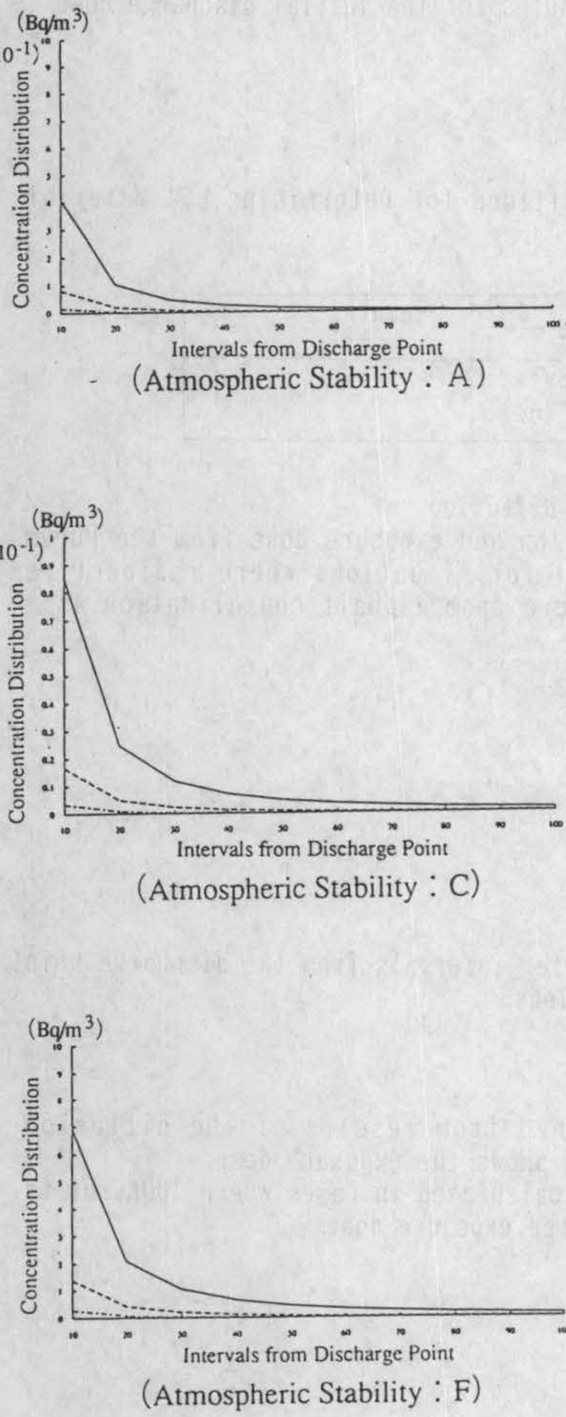


Fig.2 Consentration Distribution

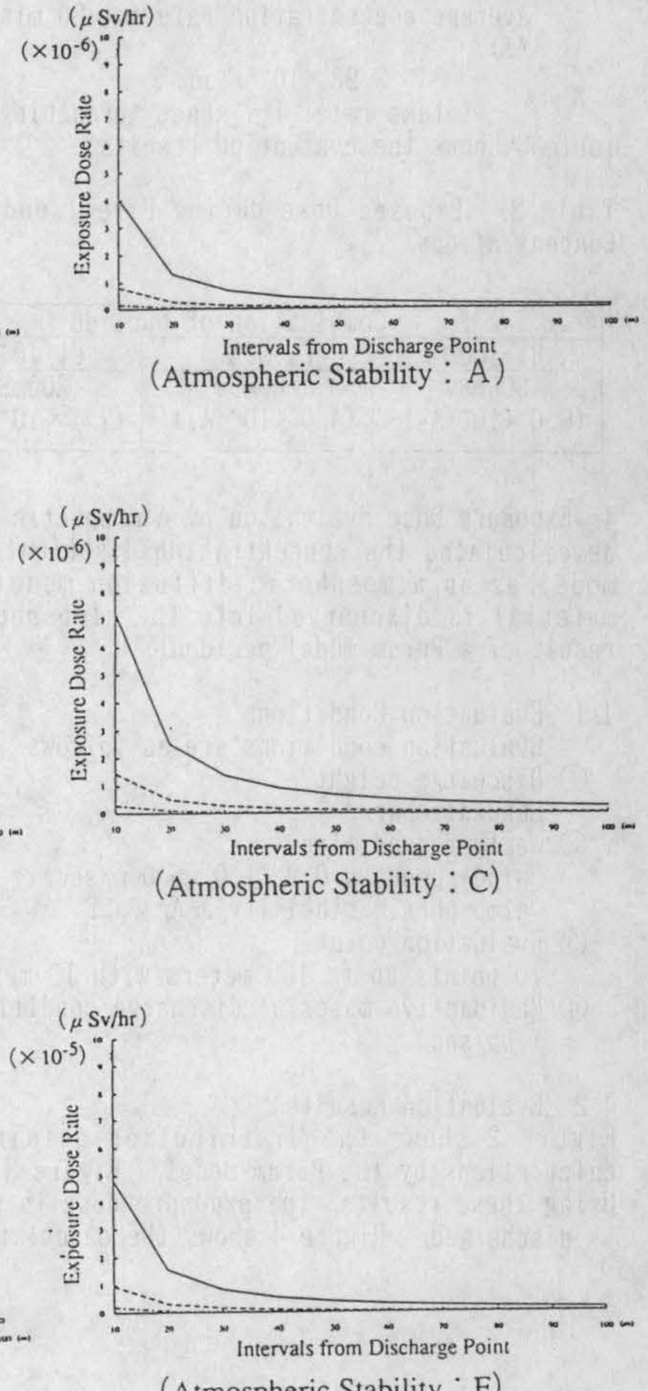


Fig.3 Exposure Dose Rate

5. Conclusion

The exposure dose based on the above-mentioned exposure evaluation is as follows.

Evaluation by Q system: $10^2 \sim 10^3$mSv

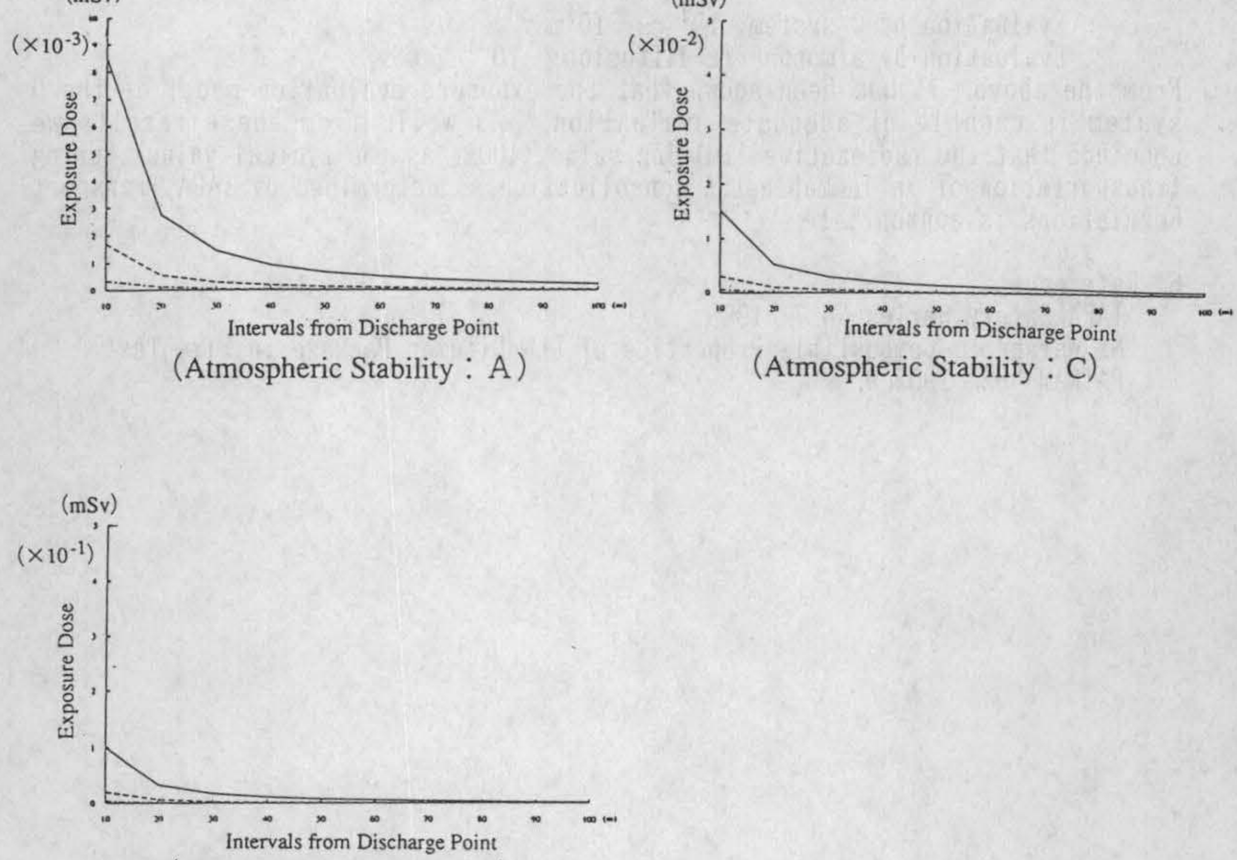
Evaluation by atmospheric diffusion: 10^{-1} mSv

From the above, it has been shown that the exposure evaluation model of the Q system is capable of adequate evaluation. As well, from these results we conclude that the radioactive limiting value ($100A_2$ as the typical value) during transportation of inflammable LSA consolidation as determined by IAEA Transport Regulations is appropriate.

6. Reference

IAEA Safety Series No.7, 1985

N. Watabe : "Combustible Properties of LLW Bitumen Package in Fire Test", PATRAM '92, 1992.9.



(Atmospheric Stability : A)

(Atmospheric Stability : C)

(Atmospheric Stability : F)

Fig.4 Exposure Dose