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# Calculations of safe distance from the point of a severe accident during transportation of a package containing spent nuclear fuels*

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## Abstract

This paper shows our calculations with a diffusion calculation code, HotSpot, on the effects of a radiological release of fission products by assuming a severe accident in transportation of spent nuclear fuel. Two main conclusions of the calculations were:

1. By assuming that 5% of spent PWR fuel rods contained in a transport package TN12 were damaged and entire gaseous fission products were released in to the air, a French paper derived the safe distance as 450 m, whereas our calculations to replicate it estimated the safe distance of 33 m. The large discrepancies were ascribed to differences in source terms.
2. *Nuclear emergency preparedness and response for nuclear facilities (May 2000)* suggested a safe distance of 15 m with an assumption of a release rate of $A_2$ value per week for 10 hours. Our calculations to replicate the description showed a consistent result with it.

## Introduction

As Japan is one of the natural disaster-prone countries, its citizens have experienced various natural disasters, such as earthquakes, typhoons, and accident disasters. [1]. For emergency response and preparedness, compound disasters like a huge earthquake, and associated tsunami and nuclear disaster should take into account. This paper deals with a study in line with the considerations: our calculations on the effects of a radiological release by assuming a severe accident in nuclear material transportation which might be occurred by a compound disaster.

Efforts of the former Nuclear Safety Commission (NSC), which would become Nuclear Regulation Authority (NRA) in September 2012 [2], to prepare for and response against nuclear disasters that are listed in Table 1. It focuses on our history of lessons learned from two major accidents, i.e., Three Miles Island (TMI) nuclear accident in 1979 and JCO nuclear criticality accident in 1999 [3].

* A part of this work was carried out by the Japan Atomic Energy Agency (JAEA) under entrustment by the former Nuclear Safety Committee of the Cabinet Office.

**Table 1 Efforts of former Nuclear Safety Commission (NSC) of Japan to prepare for and to response against nuclear disasters**

| Month Year | Occurrence |
|---|---|
| March 1979 | A nuclear accident occurred at TMI nuclear power plant in the USA. |
| June 1980 | The former NSC issued the guidelines for *Nuclear emergency preparedness and response for off-site of a nuclear power plant* [4]. |
| September 1999 | A nuclear criticality accident occurred at a uranium fuel fabrication plant of JCO in Tokai village, Japan. |
| December 1999 | *Act on special measures concerning nuclear emergency preparedness* [5] was established. |
| May 2000 | The former NSC revised the guidelines for *Nuclear emergency preparedness and response for nuclear facilities* [6]**. |

** Public radiation doses were evaluated for a hypothetical transport accident in preparing the revision.

The former NSC decided to issue the guidelines for Nuclear e*mergency preparedness and response for off-site of a nuclear power plant* [4] in June 1980 following the nuclear accident occurred in 1979 at the TMI nuclear power plant.

A nuclear criticality accident happened at a uranium fuel fabrication plant of JCO, a Japanese nuclear fuel cycle company, in Tokai village, Ibaraki prefecture, Japan, in September 1999 [3]. Fission-born neutrons were emitted and reached beyond site boundary. Following the accident, the former NSC issued the revised EPR guidelines, named the *Nuclear emergency preparedness and response for nuclear facilitie*s [6] as a revision of Ref. 4 to prepare for potential nuclear accidents at nuclear facilities and in transportation of nuclear materials. Public radiation doses were evaluated for a hypothetical transport accident in preparing the revision, and safe distance obtained by the evaluation was included in an appendix of the *guideline*.

International efforts to be mentioned would be those led by the International Atomic Energy Agency (IAEA). A Safety Guide, TS-G-1.2 [7], was issued in 2002, and its revision, *DS469*, was initiated in discussion recently [8].

For safe distances in case of accident, French experts reviewed and presented it at PATRAM2004 [9]. Their paper was a good milestone for us to follow.

The purpose of the present paper is to calculate the safe distance from the point of a severe accident during transportation of a package containing spent nuclear fuels. The former NSC suggested it as 15 m, however, there were no detailed descriptions in Ref 6.

## Calculations

Calculations to replicate French paper

HotSpot is a computer code that provides a first-order approximation of radiation effects associated with the atmospheric release of radioactive materials. It was developed by Lawrence Livermore National Laboratory [10] and evaluated by US-DOE [11,12]. For a purpose of getting accustomed to the code, the authors tried to follow a case of the calculations published in the French paper [9]. The case assumed that 5% of spent nuclear fuel rods contained in a spent nuclear fuel transportation cask TN12 were broken following mechanical impact prior to a fire, and entire gaseous fission products were released into the environment under a very severe weather condition. In Ref 9, the amount of released $^{3}$H was given as 2.42x$10^{15}$ Bq, and the safe distance was calculated to be 450m.

By adopting the same assumption, we first calculated the source term by using ORIGEN 2 [13], a computer code for use in simulating nuclear fuel cycles and calculating the nuclide compositions and characteristics of materials contained therein. The calculated amount of released $^{3}$H was found as approximately 9x$10^{12}$ Bq. As this amount more than two orders smaller than described in Ref. 9, one of the authors, FW, asked the discrepancies to Mr. Sert, the top author of the Ref. 9. The authors checked their calculations, and admitted that there had been confusion between fission gases per fuel rod and per fuel assembly (=264 rods in an assembly) in their calculations. Table 2 shows reconfirmed source term that is divided original source term in Ref. 9 by 264.

**Table 2 Reconfirmed Source term for TN12 cask calculations**

| Nuclide | Release quantity (Bq) | Assumption |
|---|---|---|
| $^{3}$H | 9.20x$10^{12}$ | the entire gaseous fission products of 5% fuels contained in the cask, 55,000MWD/tU, 180days cooled |
| $^{85}$Kr | 1.46x$10^{14}$ | |
| $^{129}$I | 5.42x$10^{8}$ | |

We performed a dispersion calculation by use of HotSpot in assuming a release height of 2 m with a wind speed of 2 m/s. When the maximum allowable dose is set to 10 mSv, as was pointed out in Ref 9, the calculated safe distance became 33 m for stability class F (see Figure 1).

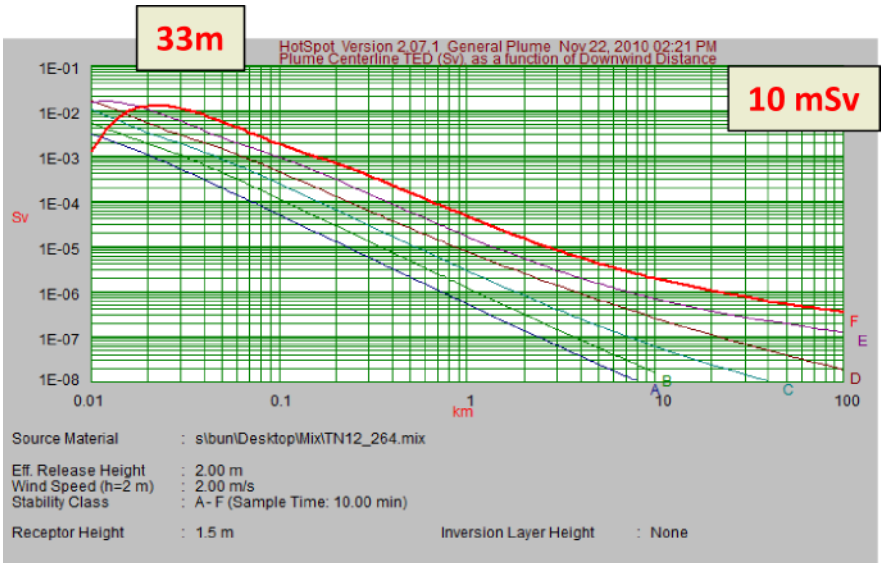


**Figure 1 Calculation results of effective doses by a release of radioactive nuclides from a transportation cask TN12 containing spent nuclear fuels from a light water reactor; assumed a release from a 2 m height with a 2 m/s wind speed**

<u>Calculations for NFT-14P</u>

As similar to the TN12 case, the safe distance was calculated for another transport cask NFT-14P. It was a popular type B package for transporting spent PWR fuels in Japan. By assuming 5% of fuel rods contained in NFT-14P were broken following mechanical impact prior to a fire; entire gaseous fission products of broken rods were released into the environment under a very severe weather condition. Table 3 shows source term of this assumption. The calculation results in assuming a release height of 2 m with a wind speed of 2 m/s are shown in Figure 2. The calculated safe distance becomes 29 m for stability class F.

**Table 3 Source term for NFT-14P cask calculations**

| Nuclide | Assumed release quantity (Bq) | Assumption |
|---|---|---|
| $^{3}H$ | $8.00 \times 10^{12}$ | the entire gaseous fission products[14] of 5% fuels contained in the cask |
| $^{85}Kr$ | $1.33 \times 10^{14}$ | |

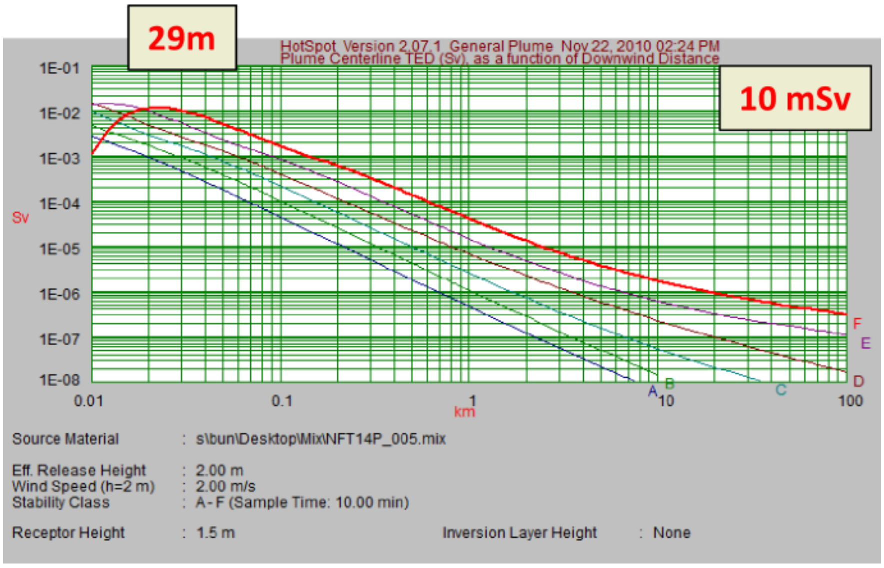


**Figure 2 Calculation results of effective doses by a release of radioactive nuclides from a transportation cask NFT-14P containing spent nuclear fuels from a light water reactor; assumed a release from a 2 m height with a 2 m/s wind speed**

Calculations to replicate the EPR guidelines

Appendix 3 of the *EPR guidelines* [6] was entitled *An evaluation of hypothetical accidents in transportation of nuclear materials*. It described that the effect onto the public by a leakage of radioactive materials from a type B package was no larger than 5 mSv at a distance of 15 m from the source. The leak of radioactive materials from the source assumed $A_2$-value per week, which was the permitted value under the special test conditions, continued for 10 hours.

**Table 4 Source term for hypothetical accident on Type B package**

| Nuclide | Assumed release quantity (Bq) | Assumption |
|---|---|---|
| $^{3}H$ | $2.38x10^{12}$ | $A_2$/week, continued for 10 hours |
| $^{85}Kr$ | $5.95x10^{12}$ | $10xA_2$/week, continued for 10 hours |

Our calculations confirmed that the radiation exposure at 15 m and beyond from the accident point was smaller than 5 mSv for any stability classes from A to F, as shown in Figure 3.

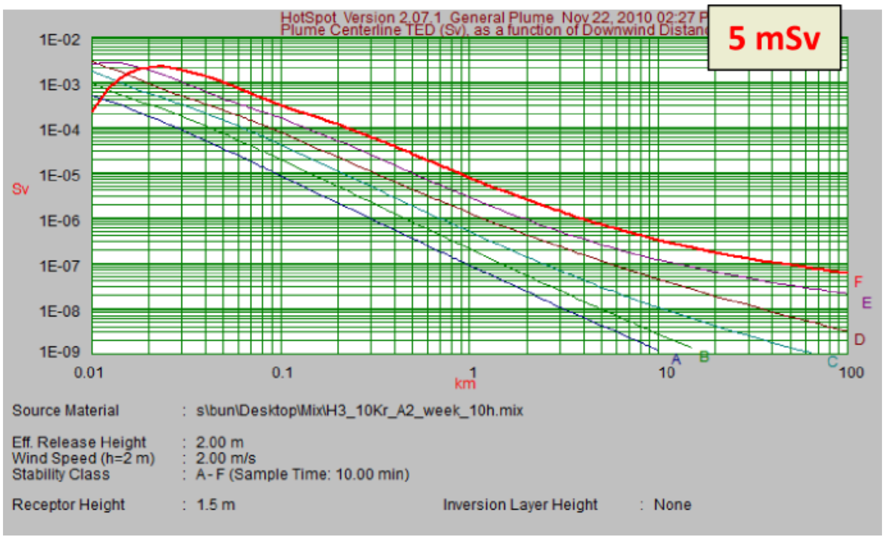


**Figure 3 Calculation results of effective doses by a release of rate of $A_2$ value per week for 10 hours; assumed a release from a 2 m height with a 2 m/s wind speed**

<u>Comparison calculations using HotSpot and using EyesAct</u>

*EPR guidelines* [6] referred to *Environmental radiation monitoring guidelines* [15] for environmental radiation monitoring in emergency. A computer program EyesAct [16], which calculates dispersion of radioactive nuclides, essentially accorded to the *Meteorological guideline on the safety analysis* [17] and was programed in reference to JAERI-M90-206 report [18] published in 1990. Therefore, in order to check the consistency in the *EPR guidelines*, we have made comparative calculations using both HotSpot and EyesAct for the cases shown in Table 5.

**Table 5 Comparison calculations using HotSpot and using EyesAct**

| Item | Value(s) |
|---|---|
| Released radionuclide | $^{3}H$ |
| Concentration dose conversion coefficient (inhalation + skin) | $2.75 \times 10^{-11}$ Sv/Bq |
| Released quantity | $4 \times 10^{13}$ Bq ($A_2$ value) |
| Wind speed and atmospheric instability | 5m/s and D; 2m/s and F |
| Released height | 2m, 10m |

The results of calculations were summarized as follows:

1. Both programs produced almost the same results for cases of wind speed 5 m/s and atmospheric instability D.
2. The calculated dose by EyesAct overestimated the one by HotSpot near the source point for the case of wind speed 2 m/s and atmospheric instability F. This may attribute to the differences in

diffusion parameters used in EyesAct and HotSpot. The former adopted Pusquill equations [17] whereas the latter adopted Briggs equations for standard terrain [10].

## Conclusions

1. By assuming that 5% of spent PWR fuel rods contained in a transport package TN12 were damaged and entire gaseous fission products were released in to the air, a French paper derived the safe distance as 450 m, whereas our calculations to replicate it gave the safe distance of 33 m. The large discrepancies were ascribed to differences in these source terms.
2. The safe distance was calculated for NFT-14P with an assumption of 5% of fuels contained in NFT-14P were broken and the calculated safe distance became 29 m.
3. *EPR guidelines (2000)* suggested a safe distance of 15 m with an assumption of a release rate of $A_2$ value per week for 10 hours. Our calculations to replicate the description showed a consistent result with it.
4. In considering the comparison results using EyesAct with those using HotSpot, the safe distance derived by EyesAct which accorded to Ref. 17, might be shorter than that derived by HotSpot.

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