Animation of Environmental Assessment at Sinking of Vessel Transporting Radioactive Materials

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Introduction

As an island nation Japan relies heavily on sea transportation, particular for the conveyance of radioactive materials. Demographics in Japan are such that in the event of an accident involving ships carrying radioactive materials many people would be affected. Given such circumstances, it is very important to assess the environmental impact of an accident at sea and to validate the safety of sea transport.

This report evaluated the concentration of radioactive materials in the sea and simulated the behavior of nuclides in the sea. Animation was used to depict the results of the simulation. We considered the hypothetical case of a ship that sank in a Japanese bay while transporting radioactive materials.

Process

This study consists of four process:

(1) Setting Accident Scenarios
In constructing accident scenarios we took into consideration such factors as the extent to which a package was pressure-proof, the ability to salvage a sunken package promptly, the depth and tide in the bay, distance from shore, etc. Then two sinking locations were chosen (see Fig.-1).

Location A: the entrance to the bay
Location B: a channel

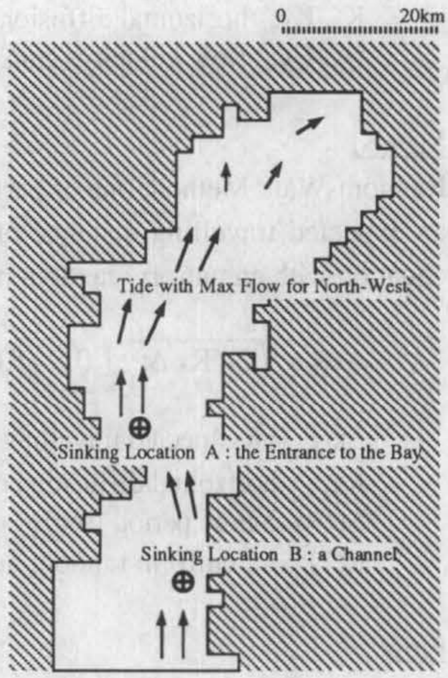


Fig.-1 Sinking Locations and Tide in the Bay

(2) Assumptions made about Radioactive Leakage
The extent to which packages are pressure-proof

was examined and the sea depth required to rupture the packages was estimated. Two possible leakage scenarios were considered. In one case the sinking location was shallower than the rapture depth such that it would take several decades to corrode the seal. In the other case the sinking location was deeper than the rapture depth such that radioactive leakage would begin immediately after sinking.

In this simulation all radioactive materials were assumed to leak the moment after sinking. This assumption seems to be the severest condition judging from half-life periods of these nuclides.

(3) Calculation of the Concentration of Radioactive Materials

The concentration in the sea was calculated by using a numerical simulation model. This model can take geographical features and current or tide flow into consideration.

Equation

Two dimensional equation of diffusion and flow was used.

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(K_x \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial C}{\partial y} \right) + U_x \frac{\partial C}{\partial x} + U_y \frac{\partial C}{\partial y}$$

- C: concentration (Bq/cm^3)
- t: time (sec)
- x, y: coordinates (cm)
- K_x, K_y: horizontal diffusion coefficient (cm^2/sec)
- U_x, U_y: flow velocity (cm/sec)

Method

Random-Walk Method, one of particle diffusion methods, was adopted. Using this method an expected travelling distance of a particle due to diffusion, Δx_D, is given as the next equation with an uniform random number, R(1).

$$\Delta x_D = \sqrt{24\, K_x\, \Delta t}\ \{ 0.5 - R(1) \}$$

- Δx_D: an expected travelling distance of a particle due to diffusion (cm)
- K_x: horizontal diffusion coefficient (cm^2/sec)
- Δt: a time period (sec)
- $R(1)$: an uniform random number from 0.0 to 1.0

Flow

In the bay there is complicated tide flow which changes periodically in a day. In this simulation two cases of flow condition were chosen in consideration with actual surveyed data of tide in the bay. One case assumed that there was maximum flow for north-west. This condition should be severest on the environmental impact, because nuclides would be carried abundantly into the internal bay on the flow. The other case assumed a lack of flow whereby the mass-flow balance remained constant (see Fig.-1).

Horizontal Diffusion Coefficient

Because the diffusion coefficient of the bay was unknown, three values, 1e+5, 5e+5 and 1e+7 cm2/sec, were set for parametric study.

Depth of the bay

In this simulation a two-dimensional equation was used and the depth was set at a constant of 10 m, one of the most shallow areas in the bay.

Evaluated Time Period

Because flow patterns in the bay change over the course of a day, the behavior of nuclides was evaluated for 24 hours after the accident.

(4) Animation of Results indicating Radioactive Concentration in Sea

The results of radioactive concentration study were translated into animated graphics using EWS (Titan). The animation was created by piecing together hundreds of pictures taken over the course of 24 hours.

Case Scenarios for the Evaluation Process

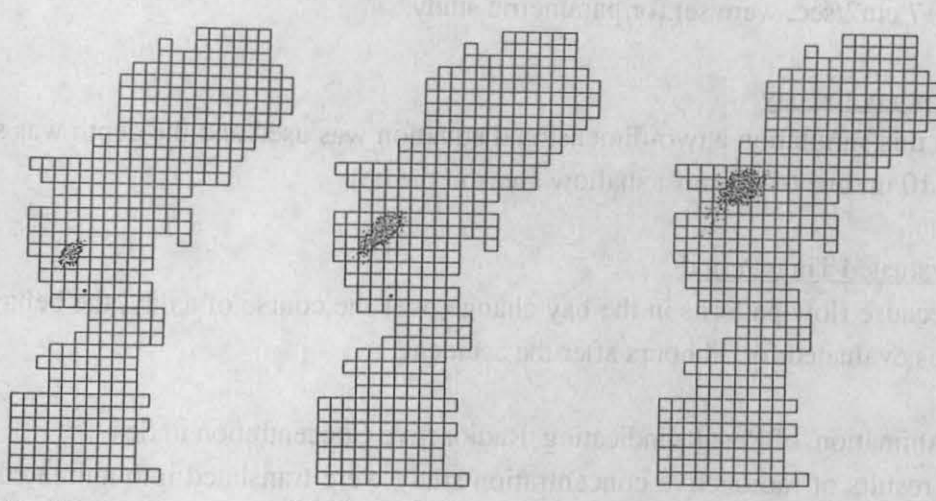
Based on the aforementioned assumptions, six possible case scenarios for the evaluation process were constructed as shown in Table-1.

Table-1 Cases for Evaluation

CASE	Sinking Location	Flow (Tide)	Diffusion Coefficient cm^2/s
CASE A-1	At the Entrance to the Bay	Max Flow for North-West	1e+5
CASE A-2			5e+5
CASE A-3			1e+7
CASE A-4		Nothing	5e+3
CASE B-1	At a Channel	Max Flow for North-West	5e+3
CASE B-2		Nothing	5e+3

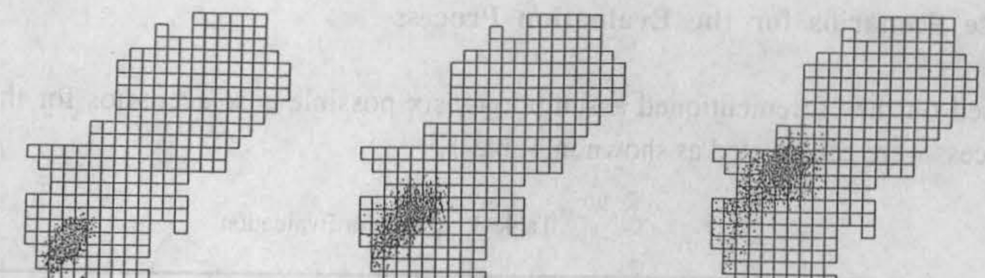
Results

Radioactive concentrations in each case are shown as particles on the maps shown on Fig.-2. Each case consists of three maps depicting concentration levels at 6, 12, 24 hours after the accident. Each map clearly indicates the diffusion of nuclides carried by the tide.



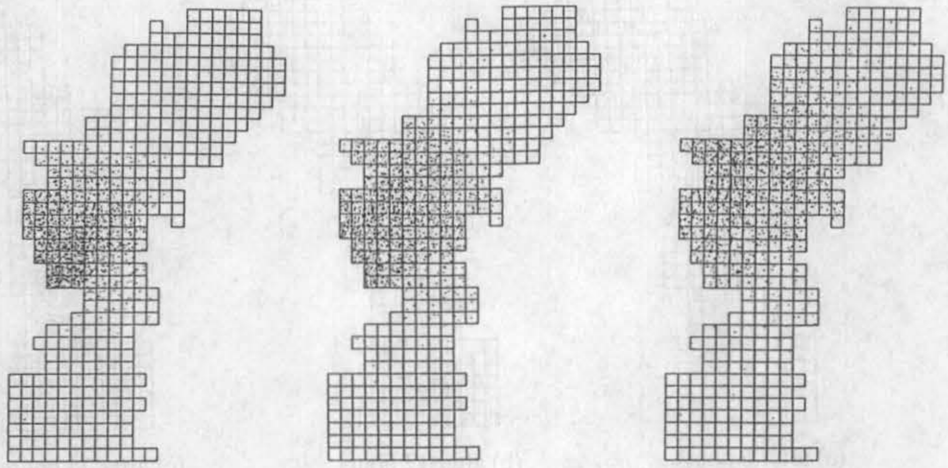
(a) after 6 hours (b) after 12 hours (c) after 24 hours

Fig.-2 Particle Map of Radioactive Concentration ; CASE A-1



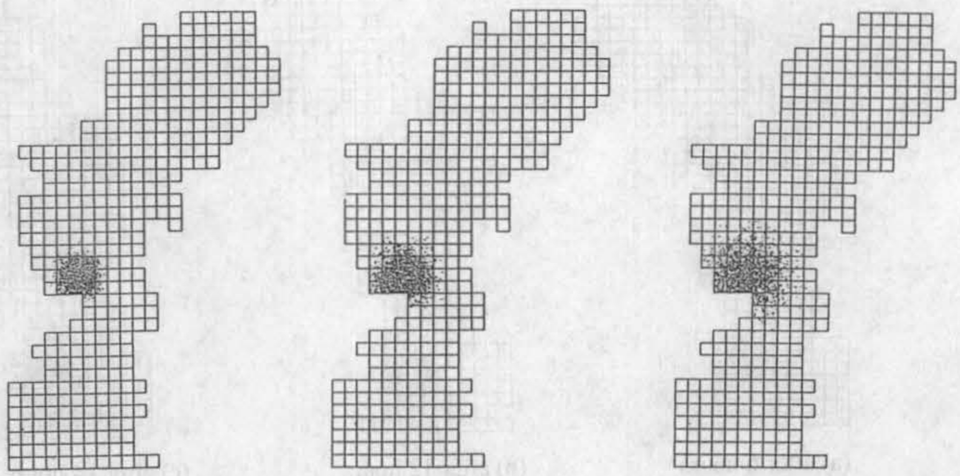
(a) after 6 hours (b) after 12 hours (c) after 24 hours

Fig.-2 Particle Map of Radioactive Concentration ; CASE A-2



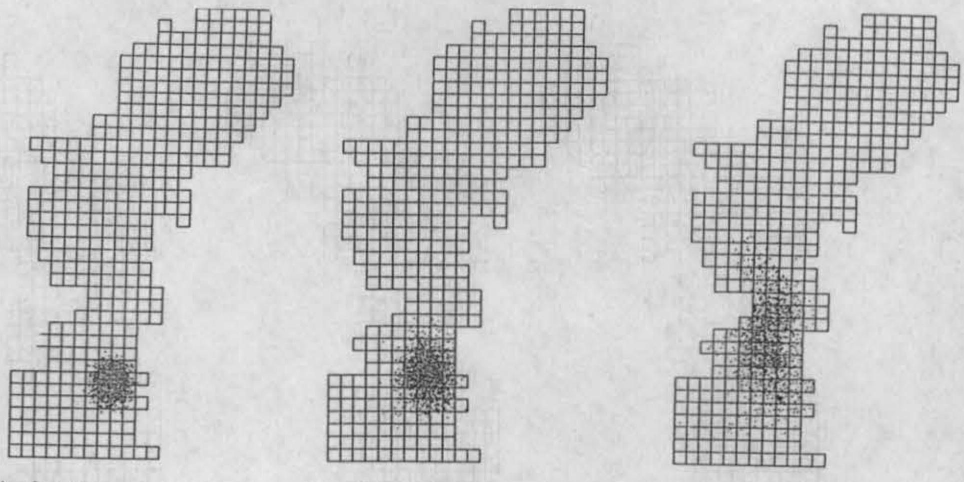
(a) after 6 hours (b) after 12 hours (c) after 24 hours

Fig.-2 Particle Map of Radioactive Concentration ; CASE A-3



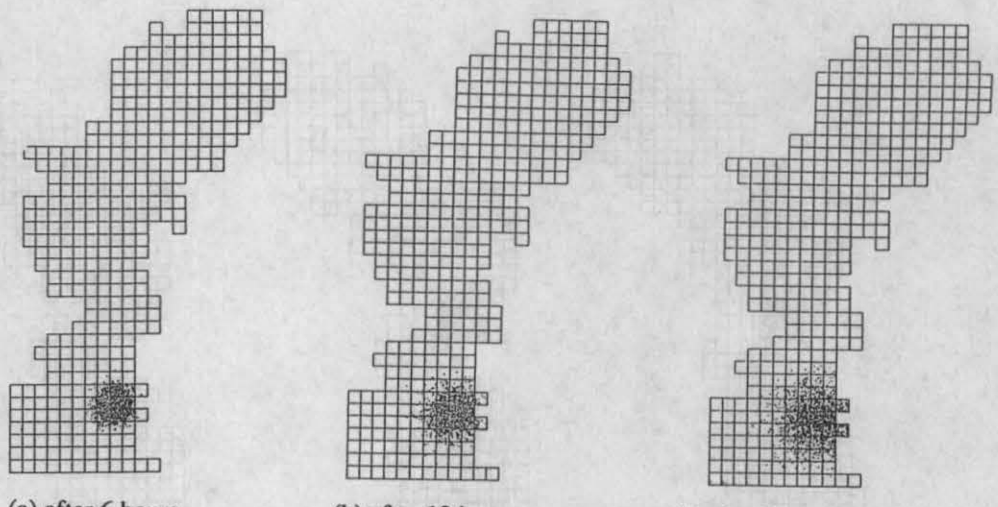
(a) after 6 hours (b) after 12 hours (c) after 24 hours

Fig.-2 Particle Map of Radioactive Concentration ; CASE A-4



(a) after 6 hours (b) after 12 hours (c) after 24 hours

Fig.-2 Particle Map of Radioactive Concentration ; CASE B-1



(a) after 6 hours (b) after 12 hours (c) after 24 hours

Fig.-2 Particle Map of Radioactive Concentration ; CASE B-2

Postscript

Video animation will be used at the 'poster' session of this symposium to describe the results of our study. This animation provides a visual demonstration of the radioactive concentrations in the bay. It offers a concrete image of both the movement of radioactive materials and the environmental impact of an accident at sea.

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(In Alphabetical Order)