COMPARISON BETWEEN A REAL ACCIDENT INVOLVING A HAZCHEM AND A POSTULATED ACCIDENT INVOLVING RADIOACTIVE MATERIAL

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ABSTRACT

A tanker which was transporting ten metric tons of liquefied petroleum gas enriched with propylene overturned on an urban fly-over and started leaking. Because of the heavy initial leak, the tanker could not be approached though experts reached the scene with all necessary protective gear within an hour of the accident. The situation could be brought under control many hours after the accident occurred. The gas is highly inflammable. Persons living as far away as ten kilometers complained of the odour. Public living within a radius of three kilometers were directed not to light matches or operate electric switches. Traffic over three major roads leading to the accident spot and over a suburban railway route was closed for over 24 hours. This accident is compared with a postulated accident involving an identical tanker transporting 10 tons of a radioactive liquid of the maximum activity that could be permitted to be transported in the tanker. The paper demonstrates on the basis of calculated values of the radiation dose that the counter measures warranted under identical accident conditions are simpler for the radioactive consignment than the hazchem consignment..

INTRODUCTION

Activities relating to nuclear power production and the applications of radioisotopes in medicine, industry, agriculture and research warrant transport of radioactive material through public domain. Radioactive material is transported in conformity with the applicable regulations . In India, the relevant regulatory requirements are prescribed by the Atomic Energy Regulatory Board in the Safety Code on Safe Transport of Radioactive Materials issued [(1)]. This Safety Code is based on the IAEA Regulations for the Safe Transport of Radioactive Material, 1986 [(2)]. The Code which is undergoing extensive revision would be in conformity with IAEA Regulations, 2000 [(3)]. Frequently apprehensions are expressed as to the adequacy of the safety standards which are built into the regulatory system. It is against this background that the study reported in this paper, was undertaken. The objective of this study was to compare the counter measures required for an accident involving a radioactive shipment with those required for a shipment of a hazardous chemical, under comparable accident conditions.

PREMISES

The premises on which this study was undertaken are as follows:

1. The safety standards applied for transport of a hazardous chemical are not more stringent than those for radioactive material in terms of what is perceived as "acceptable risk".

2. The design criteria for the packaging are commensurate with the hazard associated with the contents both for hazardous chemicals and for radioactive material; that is, the failure of a package with the maximum permitted contents following an accident would entail comparable health hazard whether the consignment is one of radioactive material or a hazardous chemical.

For the purpose of this study a real accident involving a hazardous chemical was considered on the basis of which the accident conditions for a comparable radioactive shipment could be "postulated" without loss of generality.

THE INCIDENT

In August 1999, an accident involving a tanker carrying liquefied petroleum gas (LPG) enriched with propylene took place. A tractor-trailer laden with 10 tons of the chemical was going out of the city of Mumbai driving on a State Highway which allows four lane traffic on either side with a divider at the middle of the road. While it was approaching the city limits, it had to negotiate a fly-over, about 8 m wide which allows only the traffic moving away from the city. It had been raining for a few hours and it was an overcast afternoon. Being the monsoon season, there was strong to moderate wind. This weather condition can be characterised as Pasquill's Weather Category C or D which may be described as Slightly unstable to Neutral conditions [(4)].

The vehicle while ascending the fly-over, slipped and the tanker fell on its right side across the fly-over, thereby blocking it. The driver who escaped unhurt noticed that due to the impact, the content of the tanker had started leaking. The content being LPG quickly started evaporating. The strong to moderate wind carried the highly inflammable gas which was enriched in propylene, predominantly towards north-west. There was the possibility of the wind blowing due south and west in brief spells. There were small residential colonies of almost entirely single-storied small houses and shops in the immediate vicinity all around and some multi-storied buildings in the north.

COUNTER MEASURES IMPLEMENTED

Within minutes of the accident, the following counter measures were implemented as directed in the transport emergency instructions, which always accompany all shipments of dangerous goods:

- The relevant competent authority and the response agency were notified.

- The residents of the nearby colonies were advised not to smoke nor light even kitchen stoves.
- In order to eliminate all possibilities of electric fires power supply was cut off in the affected region.
- Traffic approaching the city along this route was directed to take an alternate route which would have resulted in an extra driving distance varying from 15 to 30 km.
- Traffic leaving the city through this route was diverted likewise.
- Suburban train traffic moving parallel to the highway for destinations up to about 25 km beyond the fly-over was stopped.
- The site was guarded by the concerned public functionaries.

These restrictions were in force for nearly twenty four hours until the experts controlled the leak and declared the situation safe. The amount of safety achieved by implementing these counter measures was what the relevant regulations required.

POSTULATED COMPARABLE RADIOACTIVE SHIPMENT ACCIDENT

The following accident was postulated for the purpose of comparison.

Initiating event:	Tanker slides and falls on its right side on the fly-over
Radioactive Shipment:	LSA II transported in an identical tanker – Tritiated water of specific activity 0.8 TBq/kg.
Weather conditions:	Pasquill's Category C or D with enough warmth to cause evaporation of the spilled water.
Consequence:	Loss of containment and release of the entire content and spread of contamination of the run off and dispersal of the evaporated water.

The radioactive material that was selected was based on the fact that it is tritiated water that is generally likely to be transported in a tanker such as the one which was involved in the hazchem accident. The package in which HTO as LSA II would be transported would be IP-2 under exclusive use or IP-3 under other than exclusive use. As happened to the tanker in the real accident, loss of containment has been assumed.

This would result in the following exposure pathways:

- *Inhalation of tritiated water vapour in the air*
- *Absorption of tritiated water vapour from air by skin*

- *Skin becoming wet with tritiated water due to splashing*
- *Inhalation and Absorption of tritiated water vapour by persons present at downwind distances*

The committed dose resulting from uptake of tritium was taken as [5]

$$D_c = 1.8 \times 10^{-8} \text{ mSv / Bq}$$

Dose due to inhalation

For the purpose of this calculation, it was assumed that relative humidity was 100% and that 50 % of moisture content was from the tritiated water spill.

$$D_I = D_c \; R_B \; C \; \tau \quad \text{mSv}$$

Where R_B: mean breathing rate = 0.02 m^3 /min
C : tritium concentration in air in Bq/m^3
τ : exposure time in min

Dose due to absorption of tritiated water vapour from air by skin (D_{SA})

It was assumed here that there was no absorption of water vapour through wet skin.

$$D_{SA} = D_c \; A_{BS} \; (1 - f) \; I_S \; C \; \tau$$

Where A_{BS}: surface area of the body = 1.9 m^2
f: fraction of the body area wetted
I_S: skin intake rate = 0.005 Bq min^{-1} m^{-2} per Bq m^{-3} of tritium concentration in air

Dose due to skin becoming wet with tritiated water due to splashing, (D_{WS})

Dose from intake of tritium when the skin is splashed with tritiated water is obtained by calculating the intake of tritiated water due to the release. Intake occurs by absorption of tritiated water because of (1) the blotter effect of the skin and (2) the absorption of tritiated water vapour from the contaminated air.

Intake due to skin blotter effect = $A_{BS} \; f \; Q_S \, I_B \; \tau$ Bq

Where I_B: Blotter effect intake rate = 0.001 kg m^{-2}

Q_S: Specific Activity of water in Bq kg^{-1}

Intake due to absorption of tritiated water vapour from the contaminated air = $A_{BS} \; f \; Q_S \; I_S \; H_{S\theta} \; \tau$ Bq where $H_{S\theta}$: Humidity at skin temperature $= 0.04\ kg/m^3$

$$\text{Total Intake} = A_{BS}\ f\ Q_S\ [I_B + I_S\ H_{S\theta}\ \tau]\ Bq$$

$$D_{WS} = D_c * (\text{Total Intake})\ mSv$$

<u>Dose due to Inhalation and Absorption of tritiated water vapour by Persons present at downwind distances receiving exposure, (D_{DW})</u>

Dose to individuals downwind of an accident site would result from inhalation and absorption through the skin of tritiated water vapour.

$$\text{Thus } D_{DW} = D_I + D_{SA}$$
$$= (2.7027 \times 10^{-5})(2\times10^{-2} + 1 - f)\ \tau\ C$$

Here C is the tritium concentration in air in Bq m^{-3} at the distance downwind where the dose is calculated.

$$C = \chi\ Q_R$$

Where χ is the dilution factor at the downwind distance sec m^{-3}

Q_R is the release rate of tritium at the accident site

$$Q_R = E_R\ Q_S\ A_s$$

where E_R is the evaporation rate, kg $sec^{-1}\ m^{-2}$

Q_S is the specific activity of tritiated water Bq kg^{-1} and

A_S is the spill area, m^2 $= V(1 - S_f)\ \Delta h\ m^2$

Where V: Volume of tritiated water released from the package m^3

S_f : Fraction of the released water absorbed by the soil or otherwise rendered unavailable for evaporation

Δh : depth of the pool of tritiated water above the soil.

Assuming that 95 % of the spilled quantity runs off down the fly-over and is unavailable for evaporation and that the remaining 5 % of the tritiated water that is available for evaporation forms a pool of depth 5 mm, the spill of 10 m^3 of tritiated water at the foot of the fly-over on the road would cover a spill area of 100 m^2.

$$\text{i.e. } A_S = V \times 100\ m^2$$

where V is the volume of the released tritiated water that is available for evaporation , m^3

The latent heat of vaporization of D_2O at an ambient temperature of 50 ° C = 5.3×10^5 cal kg^{-1}

The solar heat incident on the spill area ≈ 1 kW m^{-2} ≈ 225 cal sec^{-1} m^{-2}

This will result in an evaporation rate of 1.4×10^{-4} kg sec^{-1} m^{-2}

$$\text{Thus} \quad C = \chi \, V \, Q_S \times 1.4 \times 10^{-2} \quad \text{Bq m}^{-3}$$

The quantity, χ, viz., the dilution factor, for different downwind distances has been calculated and plotted values are available in literature [6] for different weather categories.

The value of the dilution factor was calculated as,

$$\chi = 3.89833 \times 10^{-4} \text{ s m}^{-3}$$

Since the calculated down-wind doses were quite low another method was adopted for computing the dilution factor using the quantity,

$$\chi / Q = (1 / \pi \, u \, \sigma_y \, \sigma_z)$$

where u is the wind velocity, taken as 6 m/s corresponding to C-D weather category [4] and σ_y and σ_z are the horizontal and vertical dispersion factors [7].

The exposure pathway would depend upon whether it was raining or dry when rescue operations are undertaken. In view of the fact that there would be considerable run-off down the fly-over and that a team of response personnel would be engaged in the clean-up operation, it was assumed realistically that an individual is exposed for a maximum period of 15 minutes (which would be less, if it were raining) and that the fraction of the body of an individual that becomes wet is 25%, the calculated values of the dose resulting from an accident involving a consignment of tritiated water are given below:

<u>Dose to response workers:</u>

Inhalation Dose , D_I = 90.81 mSv

Skin absorption Dose, D_{SA} = 32.35 mSv

Wet skin Dose , D_{WS} = 41.10 mSv

<u>Dose to public:</u>

Individual dose at 100 m downwind if exposure period is 1 hour = 5.4 [6] mSv 10.5 [7] mSv

Even if larger periods of exposure and 100 % wetting of the body would not result in significantly higher individual effective dose to response workers. The exposure values at 100 m indicate that even if a larger fraction of the released radioactive material had evaporated and been carried off by the winds, the resulting individual exposure values would be small.

COMPARISON OF COUNTER MEASURES AND CONCLUSION

In the case of the highly inflammable gas the tanker could not be approached though experts and equipment reached the scene shortly after the accident. The situation was brought under control many hours after the accident occurred. Persons living as far away as ten kilometers suffered the odour. Public living within a radius of three kilometers were directed not to light matches nor operate electric switches. Traffic over three major roads leading to the accident spot was closed for over 24 hours.

In the case of the accident involving tritiated water, the external radiation level would not hinder response operations. Ten tons of LSA under rain out conditions may cause increased concentration in the vicinity of the accident site but not affect several kilometers due to run-off and dilution. Closure of the road for general traffic would be necessitated only for the brief duration of clean-up. The response persons during the clean-up operation would receive a low dose, as seen above. Individual dose at 100 m downwind would be low even for a higher period of exposure. At larger distances, the dose values would be negligible.

In terms of the dislocation and inconvenience caused to the public because of the counter measures required to be implemented following an accident, the hazard associated with a radioactive material transported in a tanker is less than that with a hazardous chemical transported in an identical tanker.

Table 1

Calculated dose values (mSv) following an accident involving a shipment of tritiated water of specific activity 0.8 TBq/kg

Period of Exposure (min)	Total Dose (mSv)	
	f= 0.25	f=0.50
10	112.91	136.52
20	215.62	252.84
30	318.22	368.76
60	626.64	716.51

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