A SURVEY OF RADIOACTIVE WASTE TRANSPORT IN ROMANIA

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SUMMARY

The radiological risks of transporting radioactive materials can be determined using probability safety assessment (PSA) techniques and has been evaluated in terms of expected additional latent cancer fatalities, by using generated data on accident severities and frequencies. To generate input data, a large body of information available with national authorities were analyzed. Two risks were estimated: those resulting from normal (accident-free) transport and that resulting from transportation accidents involving radioactive shipments (Smith, 1976). The accident risk calculation incorporated accident probabilities and package release fraction estimates.

INTRODUCTION

Safety in the transport of radioactive material is dependent on packaging appropriate for the contents being shipped, rather than on operational and/or administrative actions required on the package. The IAEA Regulations (IAEA, 1990) ensure safety in the transport of radioactive material by laying down detailed requirement which appropriate to the degree of hazard represented by the material taking into account its form (Institute for Nuclear Research, 1990) and the quantity of it being carried. It is assumed that a package may be damaged in a severe accident and a proportion of the contents may be released. The paper presents, in the first part, the qualification tests performed for the type A packages-industrial package IP-3, used for transport of radioactive materials known as either low specific activity (LSA), up to 0.6068×10^{10} Bq/drum or surface contaminated objects, SCO (IAEA, 1995). In the second part are presented the risk assessment activities aimed at the evaluation of risk categories that may arise either during normal (accident-free) road transportation (Nandakumar, 1995), and those resulting from transportation accidents involving radioactive shipments, also by road. The recent code INTERTRAN II, developed under IAEA CRP, has been used.

QUALIFICATION TESTS FOR TYPE A PACKAGE USED FOR TRANSPORT OF RADIOACTIVE WASTES

The packages (Vieru, 1990) tested are: a standard industrial drum, made of 1 mm thick mild steel (having a volume of about 220 l) and a 220 l INR Pitesti manufactured drum made by 1.5 mm thick of stainless steel. Qualifications tests requirements constitute the compulsory minimum specifications for the manufacturer and were performed by the Reliability and

Testing Laboratory of INR Pitesti in accordance to the Romanian and IAEA Regulations [4, 7, 9, 10]

The mechanical test (free drop test)

The drum was dropped so as to suffer maximum damage, and the drop height was 1.2 m. After the test (IAEA, 1990), the drum was visually inspected and no damages were observed. The simulated content was a real one (waste treated, prepared and encapsulated) in concrete).
Stacking test

The test is intended to ensure that effectiveness of containment, shielding and any spacers is maintained when package is stacked in such a way which is likely to occur normally during loading, unloading, transport and intermediate storage. The requirements for a whistand period of 24 h at 5 times (2.5 t) the package weight were fulfilled (Vieru, 1994). After a visually inspection, no damages were observed.

The penetration test

A 6 kg steel bar with 32 mm diameter having a hemispherical end was dropped from a 1 m height on the surface of the standard package (Vieru, 1995). The damage conditions were : no rupture of the outer shield and no pulling out the sealing lid. The limits of the release fraction of the package contents were in the range of 0.1 % to 1%. The drum shield indented about 0.1 mm so the shield did not rupture. The sealing lid was not affected. No other damage was observed. A penetration test was performed for the manufactured drum but the bar was dropped from a 1.7 m height onto the surface of the drum. The height was measured from its lower end to the point of impact. After a visually inspection, no damage was observed. The simulated content was water.

The 9 m free drop test

The 9m free drop test (Vieru, 1994) was performed in accordance with the IAEA Regulations, Safety Series 6 as additional test for packages designed for transport and storage of liquids waste required. The package have to prevent the loss or dispersal of the radioactive contents (IAEA, 1982) and the loss of shielding integrity will not result in more than a 20% increase in the radiation level at any external surface point. After the tests, the package was subjected to a visual inspection and no severe damage (the package remains intact excepted the lower part whose diameter became little higher), such as to affect the integrity of the content, was observed. The simulated contents was water.

THE EVALUATION OF RISK AND SAFETY IN RADIOACTIVE WASTE TRANSPORTATION IN ROMANIA

Wastes are transported by road and by rail and stored in the disposal site, Baita.
The radioactive wastes are generated by the nuclear research at the Institute for Nuclear Research (INR) Pitesti, NPS Cernavoda and at Institute of Atomic Physics (IAP) Bucharest. The capacity of the disposal (IAEA, 1994) is about 6, 000 cubic meters, (i. e. 25,000 drums of 220 l each) and a quantity of 5, 376 drums were stored on this site up to now. The transportation of wastes is performed under the authority of the National Commission for

Nuclear Activities Control - NCNAC, (NRSTRM, 1975).

Generation of input data

A quantity of 2, 444 waste packages were transported in the last years (by road and rail) to the disposal site.
The frequency distribution i. e. surface dose rate (mSv/h) against package number is shown in Fig. 1:

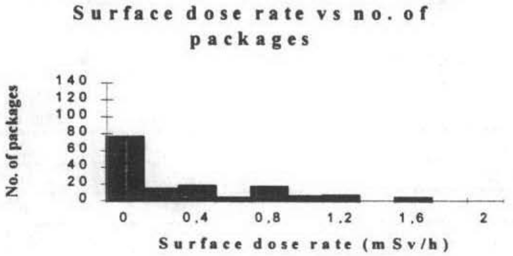

Fig. 1. The distribution of dose rate against number of packages

The frequency distribution of the activity against package (IAEA, 1982) number, is presented in Fig. 2:

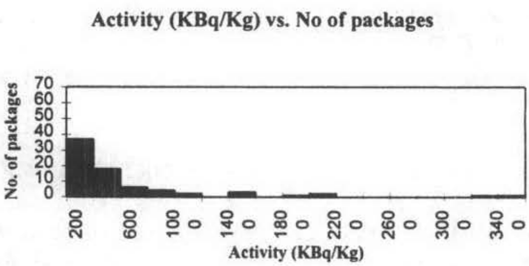

Fig. 2 The activity vs. No. of packages

The isotope distribution contained by each package is useful for the assessment of the expected radiological consequences (Birch, 1992) and accident risk of transporting radioactive material, of a given accidental release. These consequences will depend upon the release location and the atmospheric condition prevailing at the time of the accident. In Fig. 3 the distribution of Co-60 isotope for those 140 packages is presented:

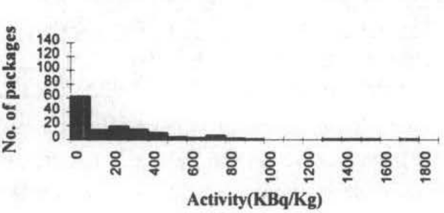

Fig. 3. No. of packages vs. Co-60 isotope activity

The 220 l standard drum (Institute for Nuclear Research, 1990) have been proved to comply with the Romanian Safe Nuclear Transportation Regulation and the IAEA's Regulation impact test requirements. The assessment road route (608 km), from Bucharest to Baita, consist of: 110 km of motorway, 37 km of unclassified road and 461 km of national roads. The population was considered to be distributed among three population density zones (National Commission for Statistics, 1995), as follows: urban (5%), intermediate (45%) and rural (50%). For radiological accident consequence calculations (Birch, 1992), three sites having representative population densities of urban, intermediate and rural areas, were selected along the route. The associated population densities/km^2 are shown in Table. 1

Table 1 Population densities (persons/km^2)

	1km radius	5km radius	10 km radius
urban	1070	470	220
intermediate	115	75	20
rural	15	40	45

The population densities (Ericsson, 1983) around the urban and intermediate sites are concentrated near the route; the rural sites have a higher concentration out at 10 km which is not considered representative. The typical population densities (people/km^2) chosen for each zone are: rural (40), intermediate (45), urban (330). Considering that the route bypasses most population zones a figure of 330 people/Km^2 was considered to be more appropriate for the zone. These data form the input to the normal transport dose calculations (Blythe, 1986). According to the IAEA TEC-DOC - 287/1983, during incident or routine free transport, the package external dose field might result in small radiation doses to workers and general public.

EVALUATION OF RISK IN THE NORMAL TRANSPORTATION OF WASTES

The IAEA Regulation limit of 0. 1 mSv/h at 2 m from the vehicle is applied to all package movements (Vieru, 1996). The use of this limit is considered to be pessimistic (IAEA, 1995). For a package of small dimension (0.9 m), this is equivalent to $0.81X10^{-7}$ Sv s^{-1}. To avoid overestimation of the radiation field around the shipment, the maximum exposure level was calculated at 1 m from any accessible surface of the transport vehicle. The entire shipment was treated as an effective single package and given that the shipment dose rate is properly estimated, a better estimate of incident-free doses is calculated. The collective doses assessed, assuming 10 journeys per year, are shown in Table 2:

Table 2: The collective doses assessed (man-Sv/y)

dose to public alongside route	0.75×10^{-3}man-Sv/y
dose to public during stops	1.12×10^{-6}man-Sv/y
dose to package truck crew	1×10^{-3}man-Sv y
dose to public sharing route	0.3×10^{-4}man -Sv/y

The total annual collective dose (Birch, 1992) to members of the public of 0.58×10^{-3} man-Sv can be compared with what they receive due to naturally occurring sources of radiation. The average Romanian individual dose from such sources cosmic radiation, exposure to terrestrial source is 1.825 mSv/year (ca. 200 mrem/y).The number of people exposed calculated from these areas is about 22.050. The additional collective dose due to package movements is an insignificant percentage over this natural background. Assuming a risk factor of 0.06 Sv^{-1}, the annual collective dose to member of the public corresponds to 0.34 $x10^{-4}$ expected fatalities per year due to routine transport doses. The calculated individual dose is 0,25 μS/y which corresponds to an associated latent cancer fatality risk of 1.2 x 10^{-8}/y. For a person exposed in a traffic jam, the determined individual dose is 10 μS/y corresponding to a latent cancer fatality risk of $1x10^{-7}$/y.

QUANTIFICATION OF ACCIDENT SEVERITIES

The Regulations do not purport to provide " absolute safety" and is possible to postulate accidents which could compromise the containment (package) or shielding performance of the package (proved by mechanical testing). The accident risk analysis for transportation of radioactive wastes was made following the model given in Figure 4:

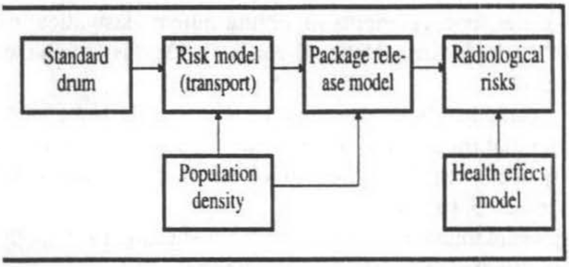

Figure. 4: The accident risk analysis proposed model for radwaste transportation

Transport hazards

A risk assessment of hazards for the route transport Bucharest - Baita was carried-out. Hazards were divided into impact and fire hazards

Fixed impact hazards:

- Underbridges (i. e, bridges that the package vehicle passes across),
- Overbridges (i. e, bridges carrying roads, etc. over which the package vehicle passes),
- Roadside Objects/Overturns /Embankments

Impact of the package vehicle with tunnel abutments and overbridges may threaten the integrity of a package. Drops with the potential to result in impacts of greater severity than IAEA 9m drop test are considered in this assessment. It is judged that at the speeds (max. 40 km/h) associated with road transport, impacts with roadside objects other than those identified above will not threaten the integrity of package (IAEA, 1995).

Mobile impact hazards:

- Collision with second road vehicle (truck or bus, tank carrying flammable),
- Collision with train at level crossing,
- Collision with a train on railway line adjacent to route

The accident scenarios defined for this assessment are :

- Impact with bridge support
- Collision with second road vehicle (head-to-head or head-to-tail):
  a. With other Truck vehicle or bus
  b. With a vehicle carrying flammable material load
- Collision with train at level crossing
- Collision with train on railway line adjacent to route

Accident frequency for road

Since 1985, an important and useful experience has been accumulated and no significant accidents with radiological consequences were recorded. In view of this lack of data it was necessary to develop accident probabilities using general road transport accident information. Based on data for road transport accidents involving human casualties in Romania, such as: motor way (3.5×10^{-6}/(vehicle km), National roads (2.32×10^{-5}/(vehicle km), other roads (4.35×10^{-6}/(vehicle km).
Referring to the fire accidents, from the literature, it was assumed that the probability of ignition to be 0.033, so that the probability per year of a severe fire due to collision is about 0.017. The probability that a truck will be involved in a collision with a tanker carrying petroleum was estimated $2 - 5.4 \times 10^{-11}$/truck km.
The rail level crossing accidents there were 39 in 1995 and the average probability of a level crossing accident was estimated at 1.45×10^{-9}/(vehicle km).

Route Survey Results

A survey of the road route along which packages are transported was carried out by Reliability and Testing Laboratory. The hazards were identified from observations made whilst traveling the route (608 Km) and were classified as follows: Bridges (Overbridges and underbridges); Roadside hazards; Other hazards. There were founded 123 Overbridges having Height < 9 m (98) and < 15 m (35); 16 Underbridges: having Height: < 9m. Other hazards: Level crossings: 13, Railway along side: 127 Km. Brickwall and rocks faces alongside: 0.2 km/2m from road; Factory/Industrial enterprises: 10 m from road.
It was assumed that the package will be breached in any impact with impact velocity exceeding than that experienced in the IAEA drop test, i. e. 13 m/s. The probability calculations to take account of overbridges hazards are shown in Table 3:

Table 3: The probabilities of overbridge hazards

Facing material	Road type	Length (km)	No. of Overbridges to be considered	Hazard size probability	Conditional probability
Concrete	National	498	20	0.0244	2.44×10^{-2}
	M-way	110	5	0.091	9.1×10^{-2}

For a collision with a train alongside route the hazard length is 0.0016 and the conditional probability is 1.6×10^{-3}. The determined road accident probabilities for the identified hazards are:

- impact with bridge support: 3.07×10^{-8} (M-way) and 1.99×10^{-8} (National Roads),
- collision with a truck/bus: 2.222×10^{-9} (M-way) and 2.1×10^{-9} (National Roads),
- collision with a tanker: 1×10^{-1} (M-way) and 1×10^{-1} (National Roads),
- collision with a train at level crossing: 8.1×10^{-1} (National Roads),
- collision with a train alongside route: 3.3×10^{-12} (National Roads)

TOTALS:

- Impacts : 3.292×10^{-8} (M-way) and 2.20144×10^{-8} (National Roads),
- Impacts and Fire: 8×10^{-14} (M-way) and 8×10^{-14} (National Roads)

Summarizing, the accident probabilities are:

- probability of impact only: 0.49×10^{-5}/(package journey)
- probability of impact and fire: 1.36×10^{-11}/(package journey)

Assuming 10 shipments per year, the accident frequencies for each category of accident are:

- probability of impact only: 4.9×10^{-5}/year
- probability of impact and fire: 1.36×10^{-10}/year

IMPACT ACCIDENT RELEASE

It is assumed that, following packaging failure, the content may become available for dispersion in the air. Taking into consideration this scenario (Birch, 1992) two impact release possibility were taken into consideration: a) for low wind speed condition; b) for high wind speed condition. In each case the fraction of solid material released from the package is taken to be 10^{-3}. For impact in low speed conditions, a package release fraction (i. e., the fraction of total package contents released) of 4×10^{-6} is adopted. Also, for impact in high speed conditions, a fraction of 10^{-4} is used (Blythe, 1986).

CONCLUSION

This safety assessment gives the accident probabilities, the frequency of accidents in case of different scenarii assumed. This type of package, will survive most potential road accidents intact but will fail to forces greater than those specified in the IAEA's Regulations. The radiological risk in radioactive materials transportation in Romania results primarily from routine exposure associated with the normal transport process. The routine transport collective dose to member of the public along the route is calculated to be 0.58×10^{-3} man Sv/y, which is equivalent to 0.34×10^{-4} expected fatalities which represents an insignificant increase over the natural background dose. Taken into consideration the best estimation of these accident probabilities, the proposed wastes transport operation would have acceptably low societal, individual and expected risk values.

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