Transport of Radioactive Material in Romania-the Assessment of the Radiological Consequences and the Environmental Impacts

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Abstract. The transport of radioactive materials (RAM) is a very important problem considering the potential risks and radiological consequences in carrying-out this activity**.**
Romania as a Member State of the International Atomic Energy Agency has implemented national regulations for a safe transport of RAM in accordance with the Agency's recommendations as well as other international specialized organizations. Based on the IAEA's Safety Standard-TS-R-1 (ST-1), Romanian National Nuclear Regulatory Body – CNCAN adopted and implemented, by Act no. 357/December 21, 2005, the safety regulations for the transport of radioactive materials in Romania under the title: "*Regulations for the Transport of Radioactive Materials"*. The paper will present the main sources of radioactive materials in Romania their transportation routes with a particular interest paid to the radioactive wastes (low level radioactive materials), isotopes and radioactive sources, uranium ore.
Starting from the fact that the safety in the transport of radioactive materials is dependent on appropriate packaging for the contents being shipped, rather than operational and/or administrative actions required for the package, the paper presents, briefly the main packages used for transport and storage of such RAM in Romania.
There are presented hypothetical scenarios for specific problems related to the identification and evaluation of the risks and potential radiological consequences associated with the transport of radioactive materials in Romania, for all these three situations: routine transport (without incidents), normal transport (with minor incidents) and during possible accidents.
As a conclusion, it is ascertained that the evaluated annual collective dose for the population due to RAM transport is less than that received by natural radiation sources. At the same time it is concluded that Romanian made packages are safe and prevent loss of their radioactive contents into the environment.

1. Introduction

The main categories of radioactive materials transported in Romania are: a). radioactive wastes, treated and packaged, to the National Repository, Baita; b). uranium ore to the uranium concentrate plant, Feldioara; c). uranium concentrate from Feldioara plant to the CANDU Nuclear Fuel Plant, Pitesti; d) f fresh nuclear CANDU fuel from Pitesti to the NPP CANDU Cernavoda; e). nuclear fresh/spent from NPP Kozloduy (Bulgaria) to Ukraine (Russian Federation) and vice versa, by Danube; f) radioactive sources to be used for industry purposes; g) others radioactive materials, such as: radioactive sources used in hospitals, research institutes, education, etc. In this paper, the main focus will be on the safe transport of the radioactive wastes. The radwastes resulting from Romanian nuclear facilities are transported to the disposal site both by road and by rail, as shown in Figure 1. In order to approach the risk and the safety of radwaste transport and because accidents were not reported, it was necessary to develop accident scenarios. During these hypothetical events radioactive materials (RAM) might be released from its packaging and could potentially affect the population and the environment.
To assess possible radiological consequences and risks over the environment it was necessary to analyze the characteristics of the transport procedures in terms of packages (geometry, radiological contents, dose rates, etc.), annual traffic (number of conveyances, packages, distance, etc.) and characteristics of exposures (handling and transport process, current individual and collective doses (exposures). Type A packages are used for transport of Low Level Waste (LLW) and have less than 0.1mSv at 2m distance from package surface. The qualification requirements for type A packages

(testing program), environmental impacts and risk assessment activities are presented both for normal (accident-free) transport, and for those resulting from transport accidents involving radioactive shipments, either by road or by rail.

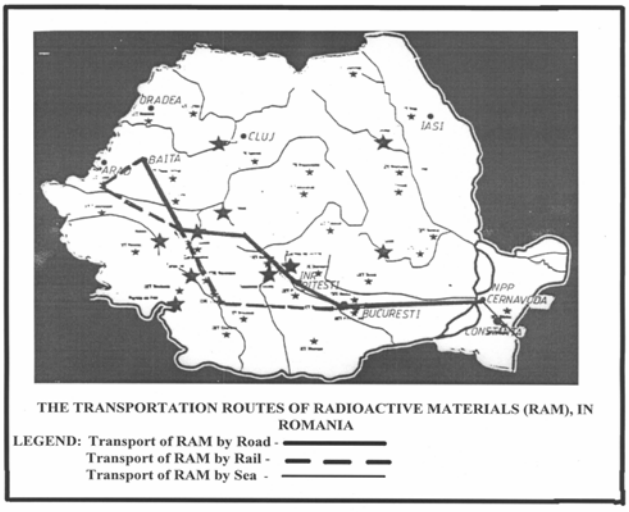

Figure no. 1 The radwaste routes transport in Romania

2. Test requirements for type A packages

The type A package is an industrial drum, made of 1mm thick mild steel having a volume of 220 liters. This package must be able to retain its contents without allowing more than a specified increase in external surface radiation level and shielding integrity if subject to: *free drop test, compression test and penetration test.* These tests constitute the compulsory minimum specifications for the manufacturer.

The free drop test: was performed for 2 hours after the end of the water spray test and the drum was then dropped so as to suffer maximum damage; the drop height was *1.2 m**; Test pass criteria:*** no rupture of the outer shield, no release of the sealing lid and the limits of the release fraction of the package contents, if any, to be within the range of *0.1%* to *1 %; results:* after the test the container was subjected to visual inspection and no damage or defects were observed.

The compression test: is intended to ensure that effectiveness of containment, shielding and any spacers are maintained while package is stacked in such a way normally likely to occur during loading, unloading, transport and intermediate storage. Before testing, the drum was subjected to 1-hour water spray test. *Test pass criteria:* package to withstand for a period of 24 h at 5 times its weight; *result**s:*** no damage was observed at the end of the test.

The penetration test: is intended to demonstrate the capability of the package to withstand the kind of puncture damage that may arise in routine transport, such as: *sharp objects falling on the package, damage from loading hooks, and the like**; Test pass criteria:*** no rupture of the outer shield, and the limits of the release fraction of the package contents, if any, to be within the range of 0.1% to 1%**;** *results:* the drum shield was indented about 0.1 mm and the sealing lid was not affected. No release fraction of the content and no other damages were observed.

The qualification program is conclusive enough to qualify this container as a reliable one, suitable for conditioning, temporary or final storage of LLW wastes.

3. The assessment of the radiological risks due to road wastes transport, in Romania

The transport of radwaste is carried out under the authority of the Romanian National Commission for Nuclear Activities Control (CNCAN). The road route covers 608 Km to the national repository, Baita. To evaluate the probabilities and collective dose for normal transportation and those resulting from accidents involving radioactive shipments, the IAEA computer code INTERTRAN II has been used.

The population along the route was considered to be distributed among three population density zones: *urban 5%, intermediate (45%), and rural (50%).* The collective doses assessed are: *dose to public alongside route: $0.75x10^{-3}$ person Sv/y; dose to public during stops: $1.12x10^{-5}$ person Sv/y; dose to package truck crew: $1x10^{-3}$ person Sv/y; dose to public sharing route: $0.3x10^{-4}$ person Sv/y.* The annual collective dose to members of the public of $2.17x10^{-3}$ *person-Sv* and can be compared with what is received due to naturally occurring cosmic sources: *$1.8x10^{-3}$ Sv/y.* The annual collective dose to a member of the public corresponds to *$0.34x10^{-4}$* expected fatalities/y due to routine transport. The calculated individual dose is *0.25 μS/y* and the associated latent cancer fatality risk is $1.2x10^{-8}$/y. Using the following model given in Figure 2 the accident risk analysis for transportation of radioactive wastes has been done:

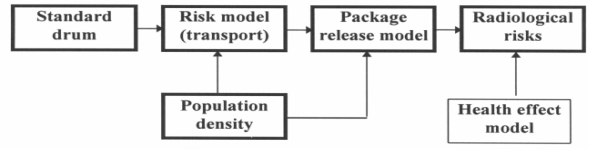

Figure 2 The accident risk analysis model

The defined accident scenarios were: *impact with a bridge; collision with a second road vehicle; collision with a train at level crossing; collision with train on railway adjacent to route.* The accident probabilities are: *probability of impact only: $0.537x10^{-5}$/(package journey); probability of impact and fire: $1.43x10^{-11}$/(package journey).* For 10 shipments per year, the accident frequencies of accident are: *probability of impact only: $5.37x10^{-5}$/year; probability of impact and fire: $1.43x10^{-10}$/year.* It is also assumed that, following packaging failure, the content may become available for dispersion in the air. Therefore, two impact release possibilities were taken into consideration: *low wind speed condition and high wind speed condition.* For an impact in low speed conditions, the package release fraction was taken to be *$4x10^{-6}$* and for impact in high speed conditions, the fraction is *10^{-4}*.

4.The assessment of risks and radiological consequences for wastes transport by rail

The rail route covers 764 Km from Bucharest to Stei*.* There is a single wagon with a capacity of *72* standard packages of *220 liters* each in volume. Between *1995 to 2007*, 7*345* packages were transported to Baita. The average population density along the route is *93 population/Km^2.* Transport and handling accidents may occur posing a risk for human beings and the environment. The magnitude of such a release and the related frequency of occurrence depend on a number of factors such as: type and volume of waste being transported, severity and frequency of accidental events (*collision, rail derailment, striking an object, vehicle derailment, etc).* The risk assessment method adopted includes steps such as: *characterization of the type and quantity of waste shipments; determination, selection and description of the type, severity and probability of occurrence of transport and handling accidents; assessment of transport packaging and waste to specific mechanical impact and release fraction; estimation of radioactive release and frequency of occurrence taking into account the shipping patterns and the accident severities; assessment of potential radiological consequences for the spectrum of wealth condition encountered along the rail transport route.* For this assessment, an accident rate of about $1x10^{-6}$ train. km, was assumed as the most representative. *9 severity categories* were taken into consideration: *3 mechanical* and *6 combined-mechanical and thermal.* The accidents involve: *impact between train and road vehicles, derailment, collision between trains and fire.* Three severity levels were defined: *< 40Km/h, 40 ÷ 80Km/h, > 80Km/h.* The relative frequencies determined were: for mechanical-only accident: 93%; for combined mechanical: 5%; and for fire engulfing: 2%**.** Several kinds of operations contributing to the overall risk: rail transport, road transport, marshaling yard operations and railroad transfer activities. It has been concluded that the transportation by rail represents the most dominant risk contributor. The risk assessment results referred to the total volume of wastes transported in the period of 1985-2007. The container dose rate has conservatively been assumed to be 0.2mSv/h at 1m from the container surface. The computer code INTERTRAN 2 has been used to determine *the collective dose* to population and transport personnel. The results are:

crew: *$1.57x10^{-2}$ person Sv/y****; members of public:*** *$2.39x10^{-2}$ person Sv/y;* ***total:*** *$3.96x10^{-2}$ person Sv/y****.*** It is to be noted that for members of the public, the radiological impacts were calculated along the shipping route (performing the dose calculation over a distance of *800 m* on each side), and during stop time. A total collective dose of *0.01 person Sv/y* for professional exposures concerning crew of train and the loading personnel has been estimated. At each loading terminal radioactivity releases are not expected to occur in close proximity of accident site at a probability level as low as *$10^{-7,}$ i. e,* a chance of *1 in 10 million* for the total volume of bituminous waste. If expressed as probability per year, the corresponding value would be well below *10^{-8} per year.*

5. Conclusions

The type A package will survive most potential road and rail accidents intact but will fail to forces greater than those specified in the IAEA's Regulations. The determined radiological risks from routine and accident exposure associated with the transport process, represent insignificant increase over natural background dose. It is concluded, on the basis of the best estimation of these accident probabilities, that the proposed radioactive materials transport in Romania are safe and would have acceptably low societal, individual and expected risk values.

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