The Approach of the Environmental Consequences and Impacts during Transport of Radioactive Materials (RAM)-A Safety Case # 16420

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ABSTRACT

International Atomic Energy Agency (IAEA) works, together with Member States (MS), to provide a strong, sustainable and visible global nuclear safety and security framework, protecting people and the environment from the harmful effects of ionizing radiation. [1, 2]

In the announcement of this IAEA Conference it is underlined that *„nuclear safety and security are to a great extent scientific in nature, a regulatory body with responsibilities for nuclear facilities and other licensed activities involving radioactive material needs to have permanent access to supporting expertise".* This can be provided internally to the regulatory body or through an external entity such as a ***TSO*** in order to *provide a competent and timely response to regulatory need*s, and *the development and maintenance of an appropriate knowledge base and associated tools and services, including training and tutoring services, are the main areas on which the conference will focus*. [1, 4]

This paper presents certain results obtained during carrying out the IAEA-Romanian Scientific Research Contract entitled: *„Romanian Contribution to the Development of Methodology for Risk Assessment and State Management of Nuclear Security Regime* (**Risk and Radiological Consequences)**" where the author served as CSI (Chief Scientific Investigator) a part of the IAEA CRP-(***Coordinated Research Project) on the: "Development of Methodology for Risk Assessment and State Management of Nuclear Security Regime".***

Also, potential risks and their possible radiological consequences to peoples and environment must not be underestimated. [1]

However, the assessment of risk must be realistic and quantified, and the requirements placed on the appropriate.

The IAEA regulations for the Safe Transport of Radioactive Material, 2012 Edition, Specific Safety Requirements, SSR-6, are applicable to the national and international carriage of radioactive material by all modes of transport- *by road, by rail, by air, by sea or by inland waters.* [1]

The Radioactive Material to be transported must be categorized on the basis of its activity concentration, total activity, fissile characteristics (if any) and other relevant subsidiary characteristics.

Packaging and package requirements are then specified on the basis of the hazard of the contents and range from normal commercial packaging (for low hazard

contents) to strict design and performance requirements (for higher hazard contents). [1, 3]

INTRODUCTION

Romanian national efforts on Nuclear Security and Safety Framework are augmented by Regulatory Authority (National Commission for Nuclear Activities Control-CNCAN) and other institution. The IAEA recommendation on nuclear security and nuclear safety has in common the aim of protecting persons, property, society and the environment. [1, 7]

Security measures and safety measures have to be designed and implemented in an integrated manner to develop synergy between these two areas and also in a way that security measures do not compromise safety and safety measures do not compromise security [5]. The main categories of radioactive materials transported in Romania, as shown in Figure 4, are:

a). ***radioactive wastes***, treated and packaged, to the National Repository, Baita;

b). ***uranium ore,*** to the uranium concentrate plant, Feldioara;

c). ***uranium concentrate*** (powder) from Feldioara plant to the Nuclear Fuel Plant, Pitesti;

d) ***Fresh nuclear fuel*** from Pitesti to the NPP CANDU Cernavoda;

e). ***nuclear fresh/spent fuel*** from NPP Kozloduy (Bulgaria) to Ukraine and the to the 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 safety and security of RAM (Radwastes) transportation. A Safety and Security Transportation Case on RAM (Radwastes) transportation will be also approached. *The Security challenge in transport depends primarily on the probability and consequences of malicious act and only the national government have the ability and information sources to assess the relevant factors within their region and some will be confidential.* Whereas safety is governed [5] by prescriptive IAEA Regulations-**SSR-6,** which are stable and adapted by national government, appropriate provisions for security [6] can vary both in time and place and cannot be prescribed. *It is mainly the responsibility of individual Member States to set up the necessary regulatory framework*. The RAM (radioactive material) resulting from Romanian nuclear facilities, after treating and packaging, are transported to the disposal site Baita, both by road and by rail (see figures no. 3). In order to approach the risk and the safety of RAM transport [7] and because accidents were not reported, it was necessary to develop accident scenarios. During these hypothetical events RAM might be released from its packaging and could potentially affect the population and the environment. To assess potential radiological consequences and risks over to 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 journeys-conveyances, packages, distance, etc.) and characteristics of exposures (handling and transport process, current individual and collective doses (exposures). [7, 8, 9]

The type A packages are used for transport of Low Level Waste (LLW) while Type B packages are used for transport of most radioactive nuclear fuel cycle materials [7, 8, 9]. Test requirements (qualification tests) have to ensure the integrity of the package under possible accident condition such as impacts in crashes, fires or submersion in water. To confirm and certify the safety, through qualification testing of packages, a Testing Facility for type A, B and C packages has been developed and built in Romania, as shown in Figure 2 (Courtesy of IAEA Vienna):

Figure 1-The emblem of testing facility (Courtesy of IAEA Vienna)

The testing facilities have been homologated with the technical support from main Romanian nuclear fuel cycle facilities. At one of the TRANSSC meeting held at IAEA Vienna Headquarters it was accepted and recommended to all IAEA MS the use of the Romanian testing facility, also. 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 (see the Figure 2).

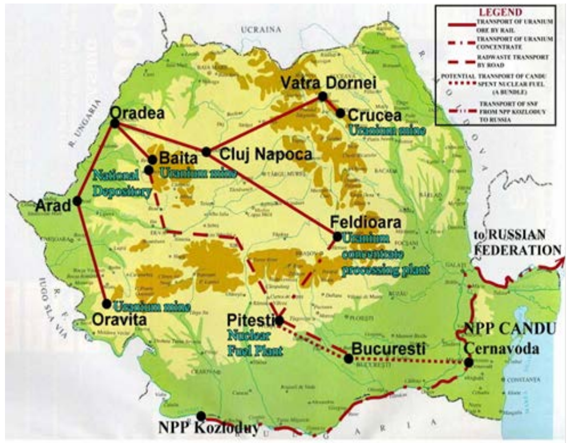

Figure 2–A scheme of the RAM transportation routes in Romania (Courtesy of IAEA Vienna)

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 [7, 13, 14].

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.

THE ASSESSMENT OF THE POTENTIAL RADIOLOGICAL RISKS DUE TO TRANSPORT OF RADIOACTIVE MATERIALS, IN ROMANIA

1. The assessment of the potential radiological risks due to road transportation

The transport of RAM is carried out under the licensing and 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 2 has been used [10]. 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: $0.75x10^{-3}$personSv/y; dose to public during stops: $1.12x10^{-5}$personSv/y; dose to package truck crew:$1x10^{-3}$personSv/y; dose to public sharing route: $0.3x10^{-4}$personSv/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. By using the following model given [10, 14] in Figure 3, the accident risk analysis model for transportation of radioactive wastes has been done:

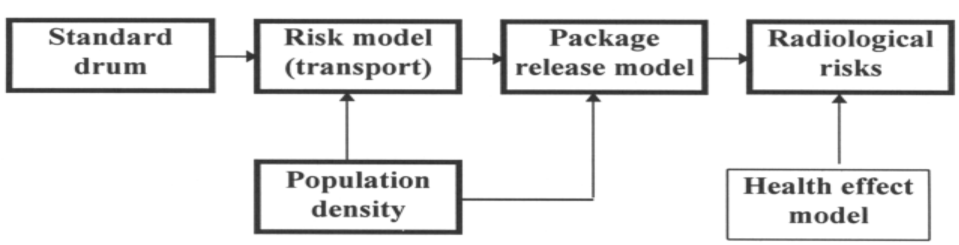

Figure 3. The proposed accident risk analysis model-Courtesy of IAEA Vienna

The defined accident scenarios were [14, 16, 17]: *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 condition; the fraction is *10^{-4}.*

2. The assessment of the risk and radiological consequences for the RAM transportation, by rail.

The rail route covers 764 Km from Bucharest to Stei town*.* There is a single wagon with a capacity of *72* standard packages of *220 liters* each in volume. The average population density along the route is *93population/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 [16, 17, 18] 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 [16, 18]: *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 there 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 [18, 19]: 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÷2008. 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:*2.39 x10^{-2} person Sv/y;* ***total:*** *3.96 x10^{-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.*

SECURITY MEASURES (GENERAL CONSIDERATION**)**

Nuclear Security Recommendation [6, 10] on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev.5) which presents best practices which should be adopted by IAEA MS covers security requirements, including transport, for materials with a potential use in weapons. The UN Model Regulation now contain a basic security level for transport of all dangerous goods, including some radioactive materials classified as Class #7, as well as additional requirements for an enhanced security level for goods defined as–***high consequences dangerous goods***, which have the potential to give rise to serious consequences. The security regime and requirements placed on the transport activities have been fragmented in the past but the transport of RAM has nevertheless been able to operate within this regime.

The IAEA guidelines Security in the transport of Radioactive Material *("Security in the Transport of Radioactive Material*", IAEA Security series No. 9, 2010, Vienna) cover the transport of all radioactive materials, including nuclear fuel cycle materials in addition to those covered by *INFIRC/225/Rev.5*. Although it cannot be prescriptive, the IAEA guidelines are sound and comprehensive and the transport process is able to operate within these.

SAFETY AND SECURITY REGULATION (GENERAL CONSIDERATION)

Safety and Security have many common features but the appropriate requirements are different in some important respects [1, 4, 9, 10]. However, it is important that the requirements for both are closely coordinated, simplified as far as possible and conflicts are avoided. The current policy of the IAEA and MS should achieve the objectives. The IAEA Nuclear Safety Series coupled with the complimentary IAEA Nuclear Security Series are likely to form the basis of National Requirements and this policy framework should be capable of being successfully implemented within RAM transport activities (process).

ANALYSIS OF STATE INFRASTRUCTURE, VULNERABILITY ASSESSMENT OF POSSIBLE ROUTES FOR TRANSPORT OF RAM, DIFFERENT MODES OF RAM TRANSPORTATION, QUANTITY AND TYPES OF RAM AND THE TYPES OF THE TRANSPORT PACKAGES–A SAFETY AND SECURITY TRANSPORTATION CASE

During transport of Nuclear Material, the infrastructure existing within every MS is of maximum importance. A good infrastructure will minimize the possible accident scenarios [10] consequences as an important part of the management of risk assessment for the NM transportation routes. Also, as WINS (World Institute for Nuclear Security) underlined that, an *"effective State infrastructure could be a possible criterion to minimize potential threats related to the damage, sabotage or theft of nuclear materials or equipment".*

An effective risk assessment of the transportation routes should be a part of the Risk Management**.** Risk is a part of Threat, Vulnerability, Consequences, [10, 16, 17, 18] so the assessment must deal with all these components (as provided by ISO 31000).

Taking into account the above stated general features, we analyzed, from the point of view of security, vulnerability, state infrastructure of the Nuclear Material (NM) - Radwastes and out of use radioactive sources, to be transported to the disposal Site Baita, after treatment (see also Fig. no. 4). Approach of the vulnerability for the transport route of Radwastes to the National Repository Baita, as shown in the Figure 4:

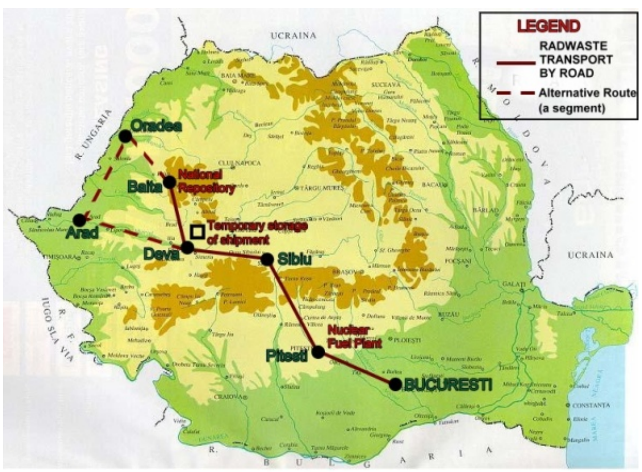

Figure 4 -The route and the possible alternative sub routes for transport of Radwastes (Courtesy of IAEA Vienna)

The contents of NM/package type A is very attractive, the max allowed activity is if of 23.7GBq/package (.64Ci/package). The variety of the radioisotopes contained within the Type A transported packages is also attractive for possible terrorist attacks or other potential threats (sabotage). Only a part of the transportation route–**Deva–Baita** was analyzed. The length is about 60 km. While traveling along this segment of route (mainly a mountain region) there were observed the followings potential roadside hazards: - up to ten potential places where stones possible to be dropped on road, bridges not well maintained, the length of route adjacent to the railway track is immediately next to the level crossing at Brad town. The position of the rock faces identified alongside the route could only lead to glancing impacts from the package vehicle. Such impacts could threat the containment of a type A package. Also, a possible sabotage (using an explosive device) could disperse a significant part of the RAM transported within the environment. There is also a high railway bridge, very old, potential a threat for the shipment. The determined road accident probabilities for the identified hazards (accident risk scenarios) are:

a) Impact *(I) with a bridge support:* 1.87x10-6 (N-roads); (*N-roads-National roads*)

b) Impact *with a truck/bus:* $2.3x10^{-5}$ (N-roads) and $3.77x10^{-6}$ (Others);

c) Impact and fire *(IF) with a tanker carrying flammable*: $8x10^{-10}$ (N-road) and $8x10^{-10}$ (***Others)***; d*)* impact (I) with train at level crossing*:* $8x10^{-9}$ (N-roads); e) Impact (I) with train on railway line adjacent to_route: $3.3x10^{-10}$ (N-road).

Totals are**:** a) $2.84x10^{-5}$ (N-roads) and $3.71x10^{-6}$ (Others); b) Impact and Fire (IF): $8x10^{-10}$ (N-roads) and $8x10^{-10}$ (Others).

Such high accident probabilities could lead to a high expectation value (or average) of risk, measured in terms of expected number of fatalities per year. The expectation value (or average) of risk, measured in terms of *expected number of fatalities for members of the public per year associated with the proposed road transport operation* is based on the expected number of fatalities for each scenario in urban, intermediate and rural population distribution and the probabilities of accidents occurring in each region. The expected number of fatalities/members of the public associated with the road transport operation proposed on this segment is shown below:

- *for radiological effects in accidents*: $5.1x10^{-7}$;
- *for radiological effects in routine transport*: $1.45x10^{-3}$;
- *for non-radiological effects in conventional transport accidents*: $2.5x10^{-3}$.

The risk results for pessimistic worst case releases are the risks associated with the following release of radio nuclides:

a) on impact only events;

b) on impact and fire events.

The risk expectation value is calculated to be **$2x10^{-5}$/y. (very** high!).

To avoid a potential threat, a sabotage-dispersion of radioactive material, it was proposed a temporary storage of the package and an alternative route as shown in the Figure no. 9.

The alternative route is longer (approx. more than 200 km) but assure an optimization of possible nuclear security measures during transportation and an effectiveness state nuclear security regime as a whole for this activity.

PUBLIC PERCEPTION OF RISK

Whereas the potential danger including those with a malicious intent now pose to nuclear fuel cycle transport must not be underestimated, the assessment of the risk must be realistic and quantified. The experience gained in the past need to be taken into account.

It is important to dispel any exaggerated perceptions of the danger in the mind of the public, politicians and regulators.

CONCLUSIONS

The packages used for transport and storage of RAM will survive most potential road and rail accidents intact but will fail to forces greater than those specified in the IAEA's Regulations, and during potential terrorist attacks or other threats (e.g. sabotage by using an RDD-radiological dispersal device).

The determined radiological risks and risk expectation values either from routine and accident exposure associated with the RAM transport process, or during potential threats or malicious acts, should be taken into consideration also.

The result presented within this paper correspond to the *IAEA Action Plan* objectives in order to cover all the relevant aspects relating to nuclear safety and security, emergency preparedness and response, and radiation protection of people and the environment, as well as the relevant international legal framework

It is to be mentioned, on the basis of the best estimation of these accident probabilities, that the proposed radioactive material transport in Romania is safe, secure and would have acceptably low societal, individual and expected risk values. Transportation of RAM, from Security point of view, should be approached in accordance with the *IAEA Security in the Transport of Radioactive Material, IAEA Nuclear Security Series 9***.**

As a general conclusion is that the paper express *the need to further develop the common understanding of the responsibilities, needs, functions and opportunities of TSOs, as well as to strengthen international cooperation and networking among TSOs with a view to maintain and enhancing nuclear safety and security regulation, including through capacity building in countries embarking on nuclear power programme.*

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ACKNOWLEDGEMENTS

The author would like to acknowledge the able assistance of ***IAEA-International Atomic Energy Agency, Vienna****,* both for technical and financial (under contract) assistance.