TECHNICAL BASIS FOR TRANSPORT OF RADIOACTIVE MATERIALS EMERGENCY PLANNING

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ABSTRACT

The transport of radioactive materials is an activity strictly linked with their use in nuclear installations, industry, medicine, agriculture and research.
Emergency preparedness in case of an accident is one of the main aspects related to the protection of workers, people and of environment from the risks arising from ionizing radiations during transport. The operational organization of emergency response in Italy relies on government's local representative, the Prefect. On the basis of national legislation (Legislative Decree n. 230/1995 and Governmental Decree of the 10th February 2006) the Prefect shall adopt a local plan for emergency response prepared by a local Advisory Committee. This Advisory Committee shall take into account the accident scenarios and the evaluation of the radiological consequences contained in a Technical Report, applicable to the whole national territory, issued by ISPRA (National Institute for Environmental Protection and Research), which in Italy, among other duties in the field of environmental protection, has the role of Regulatory Body for nuclear activities and Competent Authority for transport of radioactive materials.
The paper shows the contents of the Technical Report. The reference accident scenario for emergency planning depends on different factors: mode of transport, nature of accidents, type of materials, shipment and packages, etc. The choice of the reference accident scenarios is based on conservative assumptions and on the statistical analysis of radioactive material transports data available from ISPRA database. The information derived from the data elaboration were used to define the source term associated to the accident scenarios. The results of the evaluations in terms of release of radioactive material and radiological consequences allowed to define the kind of protective measures and actions to be envisaged in the emergency planning. The analysis were performed for all modes of transport and considering both radioactive and fissile materials.

In case of transport of irradiated fuel a specific technical report is prepared by the authorized carrier for each transport campaign and evaluated by ISPRA. The paper presents also the key elements of national experience in the preparation of these reports and associated emergency planning.

INTRODUCTION

The IAEA Regulations TS-R-1 (paras. 304–305) establish that "in the event of accidents or incidents during the transport of radioactive material, emergency provisions, as established by relevant national and /or international organizations, shall be observed to protect persons, property and environment"[1].

The emergency preparedness is one of the elements of the concept of defense in depth used to guarantee the safety of the nuclear activities. The concept of defense in depth is based also on other elements:

- multiple barriers to restrict the release of radioactive material to the environment;
- design and administrative elements having the scope to prevent accidents or incidents that can damage the barriers;
- system and structures to prevent or to limit the damage of the barriers against hypothetical accident or incident scenarios.

The concept of defense in depth adapted to the transport of radioactive material can be summarized as in the following:

Action	Tool
Prevention	• management system • radiation protection program • shipment authorization • itinerary limitation (tunnels, bridges, etc.)
Mitigation	• design of package • physical form of the radioactive material (special form) • package requirements (qualification tests)
Limitation of radio-logical consequences	• emergency preparedness • emergency plan

Therefore to achieve the objective of limitation of radiological consequences due to a transport accident involving radioactive material, irrespective of the magnitude or nature of the accident, emergency plans should be established at national, regional and local level [2].

THE NATIONAL REGULATORY FRAMEWORK

The emergency preparedness linked to accidents having radiological consequences can be classified, according to the general law on Civil Protection (Law 225/1992), on the basis of their impact: local or national. The accidents associated to the transport of radioactive material are classified as "type b" events because they have local consequences. In those cases the emergency preparedness is in charge to the Prefect of the province where the accident takes place with the collaboration of other Prefects of bordering provinces where the radiological consequences can spread. The emergency preparedness regulatory system is structured to manage accidents occurring during two distinct cases of transport of radioactive material.

Transport of radioactive and fissile material
The Governmental Decree of the 10th February 2006 (DPCM 10 February 2006) issued according to the Italian Radiation Protection Law (Legislative Decree 17 of March 1995, No.230) assigns the responsibility to the Prefect of the province to prepare an emergency plan for transport of radioactive material, with the technical support of a local Advisory Committee, on the basis of a Technical Report prepared by ISPRA.

Transport of irradiated fuel
The DPCM 10 February 2006 requests that a specific emergency plan shall be prepared by the Prefect of the province of origin of the shipment, assisted by a local Advisory Committee, on the basis of a technical report prepared by the carrier responsible for the shipment. That technical report, evaluated by ISPRA and approved by a national Technical Commission, represents the basis for the preparation of the emergency plan by the Prefect.

ISPRA TECHNICAL REPORT FOR EMERGENCY PREPAREDNESS

Italy is divided into 107 provinces each of them administered by a Prefect. The DPCM 10 February 2006 assigns the responsibility to the Prefect of the province to prepare an emergency plan on the basis of a Technical Report prepared by ISPRA and approved by a national Technical Commission. This Technical Report gives the technical basis to prepare homogeneously the emergency plans by the Prefects and their local Advisory Committees of each province.
The Technical Report assumes two different accident scenarios to evaluate the consequences and to establish the countermeasures that should be adopted following an accident occurring during the transport of radioactive material. In order to represent the real situation of transport of radioactive material in Italy the choice of the scenarios was made considering the various parameters that can influence the consequences of an accident:

- **mode of transport**
  Many information on transport of radioactive material in Italy are available from the ISPRA database. These data showed that the total number of packages shipped in 2007 (292.000) were transported for 82,5% by road and for 17.45% by air. Only 0,05% of the total packages were transported by sea. Very few shipments were carried out by rail regarding irradiated fuel sent to the reprocessing plant of La Hague in France. Taking into account these data the road transport was the primary mode of transport considered for the accident scenarios. Specific considerations were made to extend the applicability of the evaluations on the radiological consequences of the road accident also for the other modes of transport (rail, air and sea).
- **radioactive material**
  On the basis of data available from the ISPRA database and taking into account the radionuclide, the physical form and the type of packages transported it was decide to define the accident scenario considering that radioactive material involved in the accident is only <u>non special form radioactive material</u>. The physical form of the radioactive material, special form and non special form, is an important element to take into account in relation to the different pathway of exposures that could be derive from the degradation of the shielding and the leak tight of the package. In case of non special form radioactive material the prevalent contribution to the total dose is provided by the inhalation dose and by the dose for

cloud submersion. In case of special form radioactive material the dose is due essentially to direct irradiation.

- **activity involved in the shipments**
  The accident scenarios were associated with two "standard" shipments with the scope to represent a large percentage of the real shipment of radioactive material carried out in Italy. The activity of the radioactive material of the "standard" shipments was set on the basis of the activity threshold values for the notification to the Prefects of the provinces of origin of the shipment established in the DPCM 10 February 2006, as follow:
  *shipment of Type A package*s: activity notification value > $3A_1$ or $3A_2$;
  shipment of Type B packages: activity notification value > $30A_1$ or $30A_2$;
  On the basis of information contained in ISPRA database for the years 2005 – 2007 only few shipments having an activity grater than the above values were notified. Table 1 and Table 2 show the number of shipments notified respectively for Type A and Type B packages in comparison with the total shipments carried out during the three-year period 2005 – 2007.

Table 1. No. of shipments notified for road transport of Type A packages

	2005	**2006**	**2007**
Shipment of SFRM* in Type A packages with total activity grater than 3 A_1	0	0	0
Shipment of non SFRM* in Type A packages with total activity grater than 3 A_2	28	26	25
Total shipments (road transport)	95000	87000	85000

* Special Form Radioactive Material

Table 2. No. of shipments notified for road transport of Type B packages

	2005	**2006**	**2007**
Shipment of SFRM* in Type B packages with total activity grater than 30 A_1	13	14	15
Shipment of non SFRM in Type B packages with total activity grater than 30 A_2	0	0	0
Total shipments (road transport)	95000	87000	85000

* Special Form Radioactive Material

Therefore the values **$3A_2$** and **$30A_2$** were set to represent the activity of non special form radioactive material of the "standard" shipments for the two accident scenarios. According with the data contained in ISPRA database, different radionuclides transported were also considered. The activities $3A_2$ and $30A_2$ of the "standard" shipments were considered as a mixture of radionuclides represented by the radionuclides (20) much more transported in the years 2005 – 2007 as shown in Fig.1. In the Fig. 1 it is also observed, that, among all transported radionuclides in Italy three of these, notably I-131, I-125 and Mo-99, are those much more transported and represent about the 70% of the packages transported.

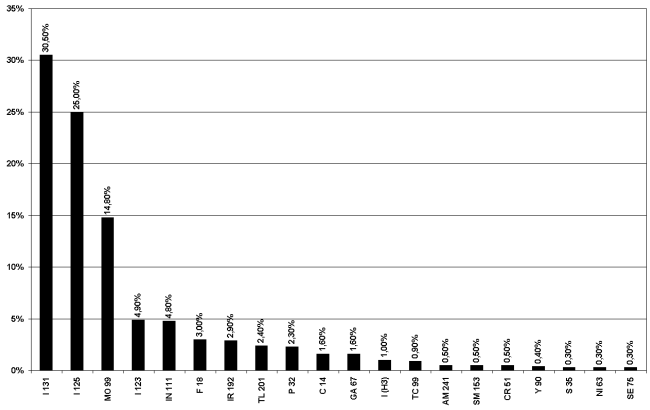

Fig.1. Percentage of Type A and excepted packages containing the 20 much more transported radionuclides for the years 2005 – 2006 – 2007

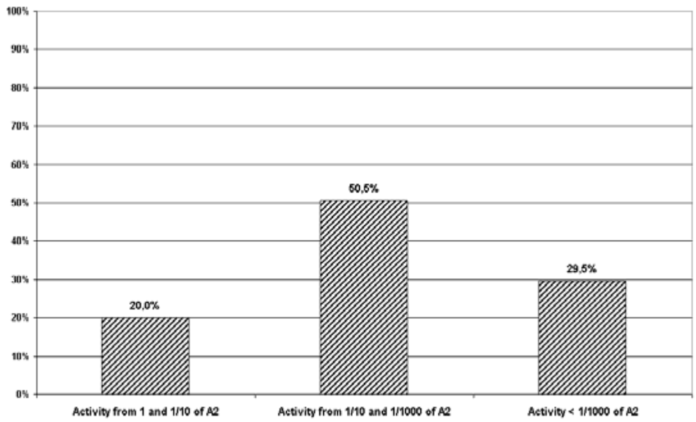

Fig.2. Percentage of Type A packages according with the range of activity A_2 contained (year 2007)

- **accident severity**

Different accident conditions, related to road transport, were defined to estimate the radiological consequences in order to establish the size of the emergency preparedness:

very heavy accident : a crash, with a fire, between the vehicle with the radioactive material on board and another vehicle;

heavy accident: a crash between the vehicle with the radioactive material on board and another vehicle;

light accident: a small crash between the vehicle with the radioactive material on board and another vehicle.

This range of accidents, considered for road transport, has been considered to be representative of accidents occurring in all other modes of transport (rail, air and sea).

Accident scenarios

Two accident scenarios, for road transport of radioactive material, were considered to estimate the radiological consequences associated to a very heavy accident on the basis of the parameters considered above. It has been evaluated that, in relation to the hypothesis and parameters adopted, the two scenarios can envelop the consequences, in terms of dose to the individual of the public, also for other modes of transport:

Scenario No.1: very heavy accident of vehicle with on board Type A packages containing non special form radioactive material with activity of $3A_2$. This scenario has been considered to be representative of accidents involving shipments of Type A and Type B packages with total activity under the notification value of $3A_2$, established in the DPCM 10 February 2006, and it also covers all shipments of radioactive materials in excepted or industrial packages.

Scenario No.2: very heavy accident of vehicle with on board Type A packages containing non special form radioactive material with total activity of $30A_2$. This scenario has been considered to be representative of accidents involving shipments of Type A and Type B packages with activity grater than the notification values respectively $3A_2$ for Type A packages and $30A_2$ for Type B packages.

Radiological consequences related to the accident scenarios

The evaluation of the radiological consequences is linked to the choice of the parameters and they were estimated with a conservative approach. Two “standard” shipments were adopted with the following characteristics:

Scenario No.1

Shipment characteristics: total activity = $3A_2$; packages = Type A; material physical state = non special form; radionuclide = mixture of radionuclides.

In particular, on the basis of information contained in ISPRA database, the mixture is formed by the 20 radionuclides much more transported as indicated in Fig.1. The “percentage” of each radionuclide in the mixture, having the total activity of $3A_2$, is linked only to the number of packages yearly transported of that radionuclide and not to the total activity yearly transported of the same radionuclide. The radionuclides and their percentage considered in the mixture are the following:

^{131}I=31%;	^{125}I=25,4%;	^{111}In=4,9%;	^{99}Mo=14,8%;	^{123}I=5%;	^{18}F=3%;	^{192}Ir=2,9%;
^{201}Tl=2,4%;	^{32}P=2,3%;	^{14}C=1,6%;	^{67}Ga=1,6%;	^{3}H=1%;	^{99m}Tc=0,9%;	^{241}Am=0,5%;
^{153}Sm=0,5%;	^{51}Cr=0,5%;	^{90}Y=0,4%;	^{35}S=0,3%;	^{63}Ni=0,3%;	^{75}Se=0,3%	

On the basis of the A_2 values of each radionuclides and their percentage in the mixture, the total activity of the mixture is 6.95 TBq.

It should be taken in mind that the scenario have the follow margins of conservatism:

- the activity considered $3A_2$, is an overestimated value, taking into account that A_2 is the maximum activity per real shipment according to the statistics;
- the percentage of each radionuclide in the mixture is linked to the number of packages transported, and not on the total activity transported; such assumption could overestimate the contribution of some “worst” radionuclide to the total dose (tritium in particular).

Taking into account of the material physical form and of the scenario’s hypothesis (crash and fire) the most important contribution to the effective dose arising from inhalation pathway (about 95%). The effective dose evaluations was carried out according with the IAEA Q-system dosimetric model, in particular the dose contribution from inhalation (Qc) and from cloud submersion to noble gas (Qe) [3]. For the scope of emergency preparedness in term of actions that could be adopted for the protection of individuals, the effective dose evaluations were performed for different distances, with a radius grater than 50 m, from the point of the accident,. It was estimated that the contribution to the total dose from direct irradiation, prevalent for distances less than 50 m, was important for the rescue team and was negligible for the

population for which the contribution to the total dose due to inhalation and irradiation from the soil and cloud was prevalent. For inhalation dose evaluations, according with the Q-system, it was assumed that the 1% of the total radioactive content of the packages was released to the atmosphere with an aerodynamic equivalent diameter of the aerosol lower than 10 μm. For tritium the release fraction from the package was taken equal to 100%. All the above conditions have been applied considering a Pasquill-Gifford model for the atmospheric dispersion with release at soil level and cloud deposition for all radionuclides, other than tritium. For tritium the same model was adopted without cloud deposition. The parameters adopted were: 2 m/sec for wind speed with Pasquill class F for atmospheric stability with a cloudiness of 40%.
The total effective dose due to inhalation and irradiation was determined for infants, children and adults and for distances from 50 to 4000 meters. The major contribution to the total dose is given from Tritium considering that the release fraction from the package is 100% instead of 1% as for the other radionuclides. Table 3 gives the total dose for different groups of population at various distances from the point of the accident for Scenario No.1.

Table 3. Total effective dose in Sv for different groups of population related to the acute accident phase [distances: 50 – 500 meters]

Groups of population	50	100	150	200	300	400	500
infants	6.32E-03	1.62E-03	7.25E-04	4.09E-04	1.96E-04	1.17E-04	7.77E-05
children	1.15E-02	2.95E-03	1.31E-03	7.36E-04	3.52E-04	2.09E-04	1.39E-04
adults	9.81E-03	2.52E-03	1.13E-03	6.42E-04	3.09E-04	1.84E-04	1.23E-04

Scenario No.2 :
Shipment characteristics: total activity = $30A_2$; packages = Type A; material physical state = non special form; type of radionuclide = mixture of radionuclides.

Both the mixture of radionuclides and their percentage in the mixture are assumed equalto those of Scenario No.1. Only the total activity of the mixture is 69.5 TBq (10 times more than Scenario No.1). As far the atmospheric dispersion model parameters are concerned, the same data of Scenario No.1 are adopted. Table 4 gives the total dose for different groups of population at various distances from the point of the accident for Scenario No.2.

Table 4. Total effective dose in Sv for different groups of population related to the acute accident phase [distances: 50 – 500 meters]

Groups of population	50	100	150	200	300	400	500
infants	6.32E-02	1.62E-02	7.25E-03	4.09E-03	1.96E-03	1.17E-03	7.77E-04
children	1.15E-01	2.95E-02	1.31E-02	7.36E-03	3.52E-03	2.09E-03	1.39E-03
adults	9.81E-02	2.52E-02	1.13E-02	6.42E-03	3.09E-03	1.84E-03	1.23E-03

As far as the evaluation results are concerned, it should be noted that the group of children is the group of individuals more affected by the accident consequences, as highlighted at 100 m in Table 3 for Scenario No.1 and at 300 m in Table 4 for Scenario No.2 [4,5,6].

CONCLUSIONS

The Technical Report integrated by the data on the transport of radioactive material, available for each Italian province by the ISPRA database, will be the basis to develop the emergency plans by the Prefects.

Two reference scenarios were identified in the Technical Report to establish the emergency preparedness for all the modes of transport. Those scenarios were defined for road transport, on the basis of information contained in ISPRA database for the years 2005 – 2007 and taking into account of the activities threshold values of notification established by the national legislation (shipment activity > $3A_2$ for Type A packages and > $30A_2$ for Type B packages). The effective dose evaluations and specific considerations of the total activity per shipment, the number and type of packages transported by other modes of transport have allowed to extrapolate the results, valid for road transport, also to the other modes. As contained in the ISPRA Technical Report, protective actions, that should be taken into account in preparing provincial emergency plans, are summarized in Table 5 .

Table 5. Distances recommended for protective actions for the two scenarios (road transport)

Protective action	Scenario No.1	Scenario No.2
exclusion	50 m	100 m
sheltering	100 m	300 m

It should be noted that such protective actions resulting from an evaluation of the consequences due to a road transport accident can be considered valid also for the other modes. Table 6 reports the relationship between transport mode and reference scenario

Table 6. Reference scenario for all modes of transport

Transport mode	Type of shipment	Reference scenario
road	activity under the notification threshold	1
	activity above the notification threshold	2
air	activity under/above the notification threshold	2
rail	as for road transport	
sea	as for road transport but only for the loading and unloading of the radioactive cargo from the ship	

REFERENCES

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