



ALARA PRINCIPLE IN TRANSPORT CLASSIFIED “NOT UNDER EXCLUSIVE USE”

Eduardo Gerulis*

Instituto de Pesquisas Energéticas e Nucleares
Av. Professor Lineu Prestes, 2242
05508-000 São Paulo, SP, Brasil
+ 55 11 3133 9522
egerulis@ipen.br

Fábio Fumio Suzuki

Instituto de Pesquisas Energéticas e Nucleares
Av. Professor Lineu Prestes, 2242
05508-000 São Paulo, SP, Brasil
+ 55 11 3133 9663
ffsuzuki@ipen.br

ABSTRACT

Unlike for vessels and aircrafts, for the road and rail transport the international regulations determine formal limits of radiation level outside vehicles because of the potential exposure of persons in the vicinity of the radioactive cargo. In transportations performed in vehicles "under exclusive use", because of the higher radiation levels allowed in each package, it is not possible to guarantee compliance with the limits of radiation levels outside vehicles only by controls on the packages and it is necessary the vehicle monitoring to demonstrate compliance with regulatory requirements. On the other hand, this paper intends to demonstrate that, for transport "not under exclusive use", the compliance with these limits can be obtained indirectly by other controls already required by the regulations, such as the category and number of packages allowed to be part of the radioactive cargo and limiting the maximum sum of transport indexes in each conveyance.

The radiological monitoring can be classified, with respect to their objectives, as special, task-related and routine monitoring. In transport of radioactive materials, the special monitorings are performed when abnormal situations occur during the transport or when new operational procedures are introduced and there is no sufficient information to demonstrate adequate control of the radiation exposure, so measurements of quantities related to radiation are necessary to elucidate these points. The measurements of radiation levels in each package are task-related monitorings that support a decision for its classification. Measurements of radiation levels in cargoes and vehicles are routine monitorings to verify compliance with regulatory requirements of radiation level limits for each situation. The workers who execute the radiological monitoring for shipment of radioactive material, even in normal situations, are exposed to ionizing radiation fields. The routine monitoring of radiation levels outside the vehicle may result in significant doses in relation to the total dose received by the employee during the transport operation.

There are also limits of radiation levels in vehicles in the Brazilian regulation of transport of radioactive material, and routine monitoring is required outside the vehicles regardless the shipment be "under exclusive use" or not. The Brazilian nuclear regulatory authority could change its regulation and no longer require routine monitoring for vehicles "not under exclusive use" and allow the control of external radiation levels only by the category of packages and limiting the transport index. This modification would provide an optimization of radiation dose of the workers who carry out shipments, following the ALARA principle.

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INTRODUCTION

In transport of radioactive material, the packaging is the set of all components required to enclose the radioactive contents completely, including containers and shields, absorbing materials, ventilation, cooling, insulation, handling and fixing or pressure relief devices, among others [1]. Freight containers, tanks and intermediate bulk containers may also be considered packagings. The assembly formed by the packaging and its radioactive content is called package and, despite all the packing components, it presents external radiation levels that increase the dose in persons in its vicinity.

In order to control the doses involved in transport, it must applied an optimized radiation protection program, that is, protection and security measures related to the magnitude and likelihood of radiation exposures. This program should also take into account relations with other transport activities [1].

Recommendations and regulations for the safe transport of radioactive materials already have a structured series of measures which act to control the doses. One such measure is the classification of packages into categories according to the maximum permissible external radiation level on its surface and at 1 meter from it. Table 1 shows the categories in which a package can be classified [1]. Despite this general way to classify the packages, there are situations in the regulations when the package category may not correspond to their radiation levels, as the shipments "under special arrangement", when the package is always classified as III-yellow even though the radiation levels are lower than those related to that category. There are also the excepted packages that are not classified in any of the categories.

Another measure to control the doses issued in the recommendations and transport regulations is to limit the maximum radiation level that a vehicle loaded with radioactive packages can present on its outer surface, 2 mSv/h, and at to 2 meters, 0.1 mSv/h [1]. These values are adopted in order to protect members of the public whose may be exposed to radiation during the transport, so these limits apply to transport by road or rail, but not by vessels or aircrafts.

Other measures in the regulations are addressed to the handling and in-transit storage of the radioactive cargo. An important point in this direction is the definition of shipment "under exclusive use." In this type of transport, a single consignor performs the shipment and, through arrangements made with the carrier, has the sole use of a conveyance or large container, and all loading and unloading of the consignment is carried out in strict accordance with directions from consignor or consignee.

As in an shipment "under exclusive use" the consignor can establish more stringent measures and conduct in the handling and storage of packages, the levels of safety and protection may be kept similar to other types of shipment even though the packages have radiation levels higher than 2 mSv/h on surface, since that there are not intermediate unloading and loading operations and the radiation levels outside the vehicle are not greater than those accepted for other types of shipment. Additionally, as there may still be direct handling of packages, the regulations defines a limit of 10 mSv/h to the radiation level on the package surface, in order to protect those workers [2].

In principle, all shipments where the consignor has the exclusive control of the conveyance, and all loading and unloading operations are performed in accordance with the consignor or consignee

guidelines, are considered "under exclusive use", but this does not necessarily imply that some package of the shipment presents radiation level above 2 mSv/h, because the shipment may be being held under these conditions for other reasons, for example, because the use of industrial packaging of least resistance in the transport of radioactive materials of low specific activity, or in order to allow a larger sum of safety criticality indexes of packages containing fissile material. On the other hand, a proper shipment "not under exclusive use" necessarily cannot provide packages with radiation levels on the surface above 2 mSv/h and transport index greater than 10.

Table 1. Categories of Packages [1]

Maximum radiation level on external surface	Transport index	Category
Not more than 0.005mSv/h	0 ^a	I-White
More than 0.005 mSv/h but not more than 0.5 mSv/h	More than 0 but not more than 1	II-Yellow
More than 0.5 mSv/h but not more than 2 mSv/h	More than 1 but not more than 10	III-Yellow
More than 2 mSv/h but not more than 10 mSv/h	More than 10	III-Yellow ^b

^a If the measured radiation level at 1 m is not greater than 0.0005 mSv/h, the value quoted may be zero.

^b Shall also be transported under "exclusive use".

In shipments "under exclusive use", because of the higher radiation levels allowed in each package, the compliance with the limits of radiation levels outside the vehicles can not be guarantee only with the controls on packages and it is necessary the vehicle monitoring to demonstrate the compliance with the regulatory requirements. On the other hand, in shipments "not under exclusive use", the compliance with these limits can be obtained indirectly by other controls already required by the regulations, such as the category and number of packages allowed to make part of the radioactive cargo and the limitation of the maximum transport index sum in each conveyance.

DISCUSSION

The nuclear and radiological safety in transport of radioactive materials is based primarily on limiting the activity contained in each package, limiting the number of packages considering the transport index and criticality safety index sums in each shipment, and the progressive requirements for package performance.

The protection of workers and members of the public from radiation exposure are based mainly on the control of radiation levels presented by packages and group packages, as well as the stowage and handling requirements. Several dose limits and segregation criteria are established in transport regulations.

Limits for Packages

The regulations require that each package should be prepared for shipment so that the radiation level does not exceed the 2 mSv/h on any external surface and its transport index does not exceed 10. If these values are exceeded, the shipment must be "under exclusive use", the vehicle should be equipped with an enclosure, the packages should remain fixed during transport under normal conditions, loading and unloading operations between the beginning and the end of transport are not allowed and the radiation level limit on the package surface shall be 10 mSv/h [1].

Limits for Vehicles

The radiation levels can not exceed 2 mSv/h at any point on the outer surface of the vehicle, including the upper and lower surfaces or, in the case of a open vehicle, at any point in the vertical



planes projected from the outer edges of the vehicle, on the upper surface of the cargo and the bottom surface of the vehicle. The radiation levels may not exceed 0.1 mSv/h at any point 2 meters from the vertical planes projected from the outer edges of the vehicle [1].

Segregation Criteria

Realistic mathematical models, and conservative parameters should be used to calculate the segregation distance of the radioactive cargo, so that, during transport and storage in-transit, the prescribed dose in the workers do not exceed 5 mSv per year, including drivers and assistants, and the doses to members of the critical group of the public are not higher than 1 mSv in a year. The distance of segregation for undeveloped photographic film must be so that the cumulative dose on each shipment does not exceed 1 mSv [1]. Moreover, there is a restriction that packages category II-Yellow and III-Yellow must not be carried in compartments occupied by passengers, unless those persons are designated to accompany the cargo.

Accumulation Effects

When packages are placed near each other a control must be exercised to limit the amount of packages accumulated in groups, vehicles or containers, in order to prevent the creation of radiation levels higher than acceptable as a result of additive effects of radiation from individual packages. For consignments "not under exclusive use", that is achieved by defining a limit for the transport index sum [2].

The maximum radiation level at 2 m from the surface of a vehicle loaded with packages which the sum of their transport index is 50 is historically calculated as 0.125 mSv/h. This value was considered equivalent to 0.1 mSv/h, since it is unlikely to reach the maximum value. The experience of years of transport of radioactive materials around the world confirms the reliability of these values [2].

Radiological Monitoring

The radiological monitoring is a technique that evaluates normal and potential exposures which is performed through measurements of physical quantities and parameters related to ionizing radiation, and also includes the interpretation of the results obtained in these measurements. Just like any radioprotection activity, it should be achieved efficiently and economically. The radiological monitoring should be organized into monitoring programs and can be divided in respect to their objectives, in special, task-related and routine [3].

Special monitoring is investigative in nature, it is idealized to clarify a situation where the information is not sufficient to demonstrate adequate control of exposures, in order to define future procedures. In transport of radioactive materials, the special monitoring is performed when there are abnormal situations or when new procedures are introduced in the operation and there is no sufficient information to demonstrate adequate control of radiation exposure.

The task-related monitoring provides data to assist in an immediate decision making necessary to continue a running task, and it can also help in the optimization of protection. The measurement of radiation levels in each package are task-related monitoring that support a decision for the package classification.



The routine monitoring is associated with continuous operations, and it is performed to demonstrate that working conditions, including the values of individual doses, remain satisfactory. It is also considered routine monitoring that performed only to meet regulatory requirements, so, it is largely of confirmatory nature only. Measurements of radiation levels in cargoes and vehicles are routine monitoring to verify compliance with regulatory requirements of radiation levels limits for each situation.

Workers who perform the radiological monitoring, even in normal situations, are exposed to ionizing radiation fields, for this reason, the radiological monitoring should be performed just when needed, as unnecessary doses are unjustifiable. The routine monitoring of radiation levels outside the vehicle for shipment of radioactive material result in doses that may be significant in relation to the total dose received by the worker during the transport operation [4].

Brazilian Situation

The current regulation for the safe transport of radioactive materials in Brazil was published in 1988 [5], so, many of the requirements do not include the new guidelines applied internationally. In despite of that, the limits for radiation levels in vehicles are the same required by the international regulations, but the external routine monitoring of vehicles is required irrespective if the shipment is "under exclusive use" or not.

This requirement of the external routine monitoring of vehicles even in shipments "not under exclusive use" forces the workers to be exposed longer to the radiation levels around the vehicle only to fulfill the regulatory requirement. Practices in which the shipment of radioactive materials is rare the dose increment may be low, however, in practices where the shipments are frequent, as in the production and distribution of radiopharmaceuticals for nuclear medicine, this increment can be significant, as 50% of the dose received during the package monitoring for its classification [4]. The time spent in the external monitoring of the vehicle also delays the vehicle departure, slowing down the shipment and, for the radionuclides of short half-life such as fluorine-18, may reduce the activity delivered to the practice.

Some countries like the United States of America, do not require external routine monitoring of vehicles in shipments "not under exclusive use", which is required only in the shipments "under exclusive use" [6, 7]. In practice, this translates into more agile shipments, shorter exposure of transport workers, resulting in lower doses, and larger activities of radioactive material being delivered to the practices.

CONCLUSIONS

In shipments "not under exclusive use", radiation levels higher than acceptable as a result of additive effects of radiation from individual packages can be avoided by limiting the transport index in the vehicle.

Unlike the routine monitoring of vehicles on shipments "under exclusive use", that must be performed to demonstrate that the values meet the regulatory requirements, the routine monitoring of vehicles on shipments "not under exclusive use", with the goal of finding unacceptable radiation levels, are unnecessary.



The Brazilian nuclear regulatory authority could change its regulation and no longer require routine monitoring for vehicles "not under exclusive use" and allow the control of external radiation levels only by the category of packages and limiting the transport index in each conveyance. This modification would provide an optimization of radiation dose of the workers who carry out shipments, following the ALARA principle. This measure would also reduce the time required for shipments "not under exclusive use", important for transport of radioisotopes of short half-life.

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