EVALUATION OF THE RADIATION PROTECTION OPTIONS RELATED TO THE TRANSPORT OF LOW WEIGHT PACKAGES - CATEGORY III YELLOW -

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SUMMARY

According to the IAEA transport regulations, all packages with a transport index exceeding 1 (and less than 10) or with a surface dose rate exceeding 0.5 mSv/h (and below 2 mSv/h) must be classified in the category III Yellow. This classification is independent of the size or weight of the package. As small packages are usually carried by hand, exposures are potentially significant.

Different proposals for reducing the surface dose rate of low weight packages were formulated at the IAEA. One of the options was to eliminate the category III Yellow for packages that are manually handled, inducing a decrease of the surface dose rate from 2 mSv/h to 0.5 mSv/h, although this proposal was not accepted at the last revision panel meetings.

To assess the radiological benefit of such a measure, it is necessary to analyse the characteristics of the transport procedures in terms of packages (geometry, radiological contents, dose rates,...), annual traffic (number of conveyances, packages, distance,...) and characteristics of exposures (handling and transport processes, current individual and collective exposures).

As the radiological benefit is not immediately evident, and taking into account the national context, the feasibility and desirability of adopting different surface dose rate limits have been investigated. Furthermore, based on national experience, alternative or complementary measures dealing with modification of handling processes have been analysed.

INTRODUCTION

The aims of this paper is to present the result of a study assessing the radiological impact associated with a proposed modification of the transport regulation concerning manually handled packages. Different reductions of the surface dose rate from 2 mSv/h to 0.5 mSv/h were envisaged, the final objective being to define the optimal levels of reduction.

According to the transport regulation of the IAEA, all packages with a transport index exceeding 1 (and less than 10) or with a surface dose rate exceeding 0.5 mSv/h (and below 2 mSv/h) must be classified in the category III Yellow. This disposition is independent of the size or weight of the package. As small packages are usually carried by hand, the exposure can be potentially significant. It was thus proposed to reduce the surface dose rate for this category of packages.

A number of factors influence the radiological impact of transporting packaging in this category and a reduction in surface dose rate may not necessarily reduces this impact. Thus, it is important to evaluate the radiological benefits and consequences of the practical implementation according to the present practices. This analysis has been performed in three countries (UK, Germany and France) within the framework of a research project funded by the European Commission DG XVII.

MATERIAL OF CONCERN

In each participating country, information on transport practices and materials associated with low weight packages of category II or III were collected. A selection has been made with respect to the predominance of the activity in the country or/and to the representativness of the practices and exposures. For each selected activity, data were collected in each country on the production (number of packages, physical and radiological characteristics, dose rates,...) and on the exposures (number of people involved, exposure scenarios, current dosimetry,...).

Two main producers were identified: one in France and one in United Kingdom. Their activities concern the production and the transport of radiopharmaceutical sources for medical use and other sources for general industrial use.

Types of material and packaging

More than 10 radionuclides with different activities and physical forms (liquid, gaseous or solid) are produced. The main emitting radionuclides are the Mo-99, I-131, and the Ir-192.

On the basis of a one week survey of the French production of high emitting packages (2900 Type A packages II Yellow and III Yellow), the following distribution was observed: Mo-99: 31%; I-131: 29%; Tl-201: 24% and I-123: 4%.

It is important to point out that in France and Germany, III Yellow packages represents about 1/3 of the medical Type A packages (a lower fraction is observed in UK), category I White totalling only a few percents.

With respect to the number of packages, the following distribution of III Yellow packages is observed (Table 1):

Table 1. Distribution of III Yellow packages per radionuclide

	France	Germany	United Kingdom
Mo-99	44%	95%	41%
I-131	53%	4%	52%
Ir-192	2%	1%	4%
Other	1%	~	3%

Distribution of radionuclides is comparable between France and United Kingdom which are both producers of radiopharmaceuticals. As Germany imports significant quantities of radioactive materials for medical application, the distribution reflects the national supply and distribution pattern.

With regard to radiopharmaceutical packages, two categories of product/package can be distinguished: the radiopharmaceuticals (medical observation, imaging and therapy) and the Tc-99 generators (by decay of Mo-99).

The first type of package is composed of I-123, I-131, Fe-59, Cr-51, Tl-201, Ga-67, P-32 and Y-90 in liquid form, Xe-133 in gaseous form and Ir-192 as wire. These sources are generally packed in a lead pot (2 mm to 35 mm width) inside a steel can. The package activity contents range from some 10^{-3} to 27 GBq and the package weight is from 500 g to 13 kg. Figure 1 shows the distribution of lead thicknesses observed on the French production.

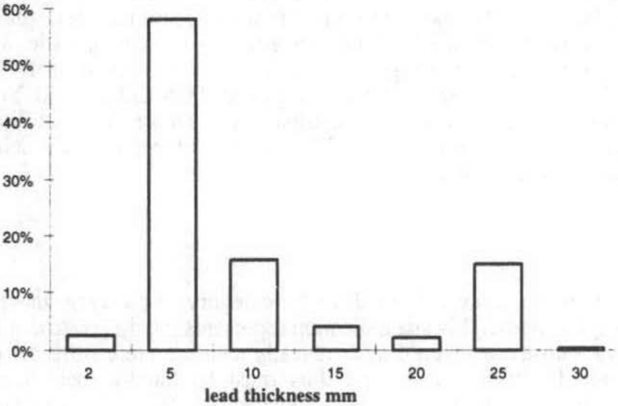

Figure 1. Distribution of lead thickness of radiopharmaceutical packages other than technetium generators (France)

The second category "technetium generator" consists of Mo-99 (which produces Tc-99 by decay) packed in a lead (or depleted uranium) shielded container inside a steel bin. Activity of Mo-99 at the time of transport ranges from 10 GBq to 150 GBq (at calibration time from 2 to 20 GBq). In United Kingdom three generator designs are produced with different shielding materials and thicknesses: two based on lead (38 mm and 50 mm) and one using depleted uranium. Depending on the shielding, the weight can vary from 14.5 kg to 22 kg. In general large shielding corresponds to high activity content. In France, a standard generator is produced, weighing 17 kg with a lead shielding of 52 mm.

In United Kingdom, sample measurements have been made of dose rates from technetium generators and these are given in Table 2 together with other data on these packages.

Table 2. Technetium generator characteristics in UK

Shielding	Weight kg	Activity GBq	Surface dose rate μSv/h	Surface dose rate per GBq
38mm Pb	14.5	43.6	600	14
38mm Pb	14.5	58.1	840	14
50mm Pb	19	67.7	420	6
50mm Pb	19	90.4	530	6
50mm Pb	19	135	660	5
Dep.uran.	22	181	150	0.8
Dep.uran.	22	436	380	0.9

Quantities and Traffic

In France, for the reference year 1991, 2/3 of the radiopharmaceutical packages were sent by road and 1/3 by air (some few % by sea). Moreover, about 64% were shipped to foreign countries. Due to the relatively short half life of some radionuclides, radiopharmaceutical packages are required weekly by the hospitals undertaking such diagnostic work. This gives rise to about 120 000 (United Kingdom and France) to about 150 000 (Germany) radiopharmaceutical packages transported per country (40 000 to 50 000 III Yellow packages). The related road distance covered each year is estimated to be more than 2 million km in France. In United Kingdom and France, some 6000 - 7000 generators per year are delivered nationally to hospitals for nuclear medicine diagnosis.

Dose rate

All packages to be transported are identified by the category of package, the radionuclide, the activity and the transport index. This last indication represents the dose rate at 1 metre expressed in mrem/h. The surface dose rate, even if automatically measured to ensure the compliance with the regulation, is not directly available and thus must be handly measured. Thus, sample measurements have been performed and extrapolated on the basis of the shielding and radionuclide activities.

In France, United Kingdom and Germany, the package transport index is distributed from 0.3 to 3 corresponding to a dose rate at 1 metre of 3 to 30 μSv/h. On average, German radiopharmaceutical packages have a higher TI (2.3) than the French one (1.7) and UK one (1.3), in accordance with the higher percentage of Tc generators which generally have higher dose rates than radiopharmaceutical products.

With respect to surface dose rate, the measurements made in each country reveal good consistency: the surface dose rate varies from 0.1 mSv/h to 1.6 mSv/h for generators and up to 1.3 mSv/h for other small packages. In United Kingdom, the use of different shieldings for generators (especially depleted uranium shielding for high activities) leads to a lower maximum dose rate (about 0.9 mSv/h). According to the selected production in France, about 46% of the number of generators exceed the limit of 0.5 mSv/h for III Yellow packages. In Germany, this percentage reaches 65%. At this point, it is important to note that the dose rates were extrapolated from the initial activity, thus, due to the time of transport, non-producer country appears to have higher dose rates. For other packages (I-131, Ir-192,...) in France, only 24% exceed a surface dose rate of 0.5 mSv/h. To illustrate these results, the distribution of the surface dose rate observed on the whole significant production of high emitting packages (II Yellow and III Yellow) in France is presented in Figure 2.

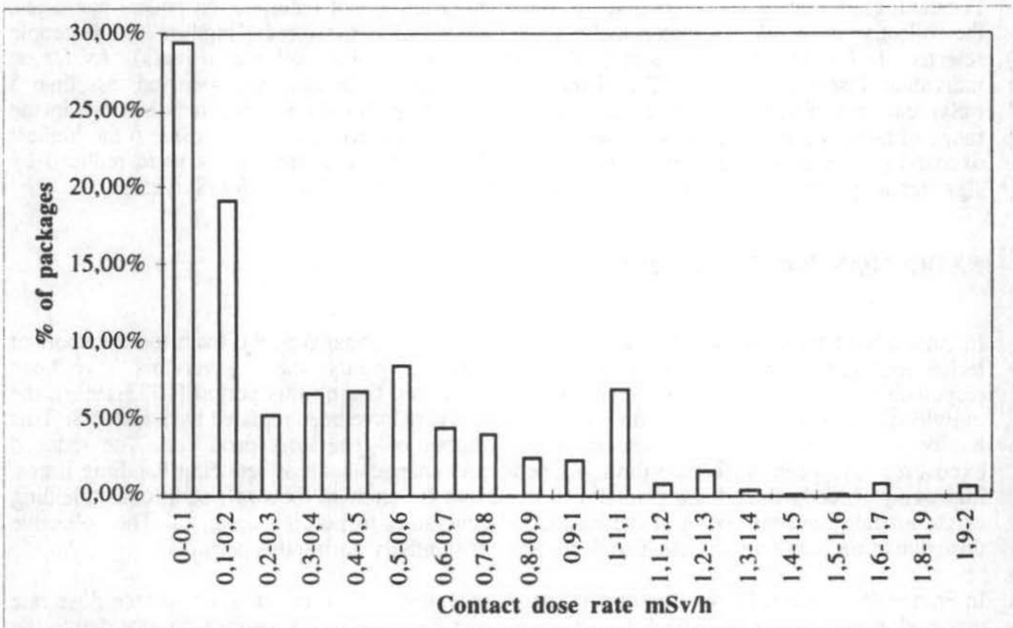

Figure 2. Distribution of the surface dose rate (France)

CONDITIONS OF TRANSPORT AND EXPOSURES

The transport of radiopharmaceutical sources includes successive operations from the preparation of the package to the final delivery to hospitals.

After the production of the radionuclide source and its conditioning, the packages are prepared for the transport in the shipping hall. These practices consist in the packaging in card board boxes, labelling and storing in a departure hall with a sorting as a function of the destination. In France, 11 people are involved in these operations and three separated tasks were identified depending on the packages manipulated (generators and other) and on the practice (e.g. executive staff). The monitoring of transport workers indicates that the individual dose associated with the shipping hall in France ranges from 5 to 10 mSv/year depending of the subgroup. A large fraction of this exposure stems from the ambient dose rate which was estimated to some tens of microsievert per hour in hot areas and up to 0.5 mSv/h at some busy periods in the storage area.

The drivers are in charge of the selection and loading of the packages from the shipping hall to the unloading at destination or at intermediate centre of distribution. Concerning the distribution in France, about 50 drivers are employed. Two worker groups can be distinguished: drivers to Paris, suburbs and airport and drivers to other destinations in France. Transport drivers are generally the most exposed personnel. Average individual doses observed in France are 12 and 18 mSv/year for the two groups of drivers. Cabin ambient dose rates are in the range of 10 μSv/h, but higher values are occasionnally observed when high activities are transported (up to 100 μSv/h).

The receipt of packages in hospitals should not cause significant individual exposure compared to the other transport operations on account of the short duration of transfer and the lower number of packages handled.

For the highest exposed workers associated with the transport of radiopharmaceutical packages, the collective dose was estimated to be about 0.3 man.Sv in United Kingdom (~200 people selected) to 0.8 man.Sv in France (~60 people from shipping hall and drivers). As far as individual dose is concerned, 97% of the transport workers in Germany received less than 5 mSv/year, but maximum recorded annual individual doses for drivers and handlers are in the range of about 12 and 19 mSv/year, respectively. In United Kingdom, the doses to the highest exposed groups of workers are in the range of 2 to 6 mSv/year (the doses were reduced by significant operational changes and were formerly in the range of 10 to 18 mSv/year).

RADIATION PROTECTION OPTIONS

In United Kingdom, the radiation doses to workers and the general public from the transport of technetium generators have been studied for over 15 years: these generators have been responsible for the most significant exposures of workers. During this period (1983-1996), the individual doses to the highest exposed group of workers have been reduced by a factor 3. This has been achieved despite an increase in the number of generators produced. The reduced exposures have been performed through operational changes such as reducing handling times, improving procedures and using additional resources (rotation of the staff, additional shielding of the loading bay, removing of the assembled generators to holding area,...). The collective dose due to these operations has also decreased substantially during this period.

In France, the expected reduction of exposures associated with a reduction of surface dose rate was evaluated. The survey reveals that it was impossible to define exposure scenarios due to the importance of ambient dose rate and due to the diversity of operations performed by the staff. Nevertheless, transport workers were divided in 5 groups of exposure (3 for the shipping hall and two groups of drivers). It can be considered that each group of workers is only subject to exposure from packages they handled. Within a practice, all packages are treated in the same way, and therefore, it is assumed that they contribute to the exposure as a function of their dose rate. As the occupational exposure of each category of workers has been measured, it can be linked to the cumulated dose rate (number of selected packages x dose rate) of the corresponding category of packages. When modifying the distribution of dose rate as a function of number of packages, the exposures to workers can be appraised. The Table 3 presents the exposure benefit associated with a limitation of surface dose rate to 0.5 mSv/h. This calculation has been performed assuming that all packages exceeding 0.5 mSv/h are reduced to this limit (slight under-estimation of the exposure reduction).

Table 3. Exposure reductions and doses for the different groups of workers

	Hall	Drivers	Total
Reduction	30%	28%	28%
Current individual dose (mSv/year)	7.6	16.9	15.2
Modified individual dose (mSv/year)	5.3	12.3	10.9
Number of people	11	47	58
Current collective dose (man.Sv/year)	0.08	0.8	0.88
Modified collective dose (man.Sv/year)	0.06	0.58	0.63

The shipping hall group presents a slightly higher reduction factor than the drivers group. Nevertheless, for the drivers, the individual dose is reduced by 4.6 mSv/year and collective dose by 220 man.mSv/year. On the average, the doses could be reduced by 28 % (close to the reduction for drivers due to the number of people involved) corresponding to a reduction of 250 man.mSv/year on a total of 880 man.mSv/year. To achieve this modification, about 1/3 of the production (some 40 000 packages) would be affected.

An analysis was performed in order to evaluate the sensitivity of the reduction to the limit (Figure 3).

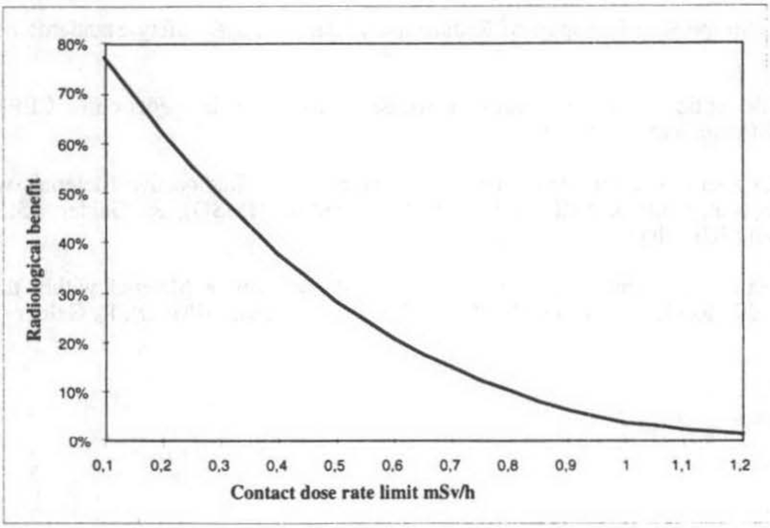

Figure 3. Sensitivity analysis on the surface dose rate limit (France)

The slope of the curve is of exponential shape. It appears that doses could be reduced by 50 % if a maximum admissible surface dose rate of 0.3 mSv/h is retained (about 52% of the packages would be affected). Moreover, the benefit is quite negligible for a 1 mSv/h limit (4% reduction and 14% of the number of packages affected). Thus, on the basis of this calculation, it appears that the surface dose rate limit should be lower than 1 mSv/h, in order to obtain a significant reduction of exposures compared with the present situation.

CONCLUSION

For the purpose of reducing the occupational exposures associated with the transport of low weight packages of category III Yellow, the current practices have been analysed and the effect of a limitation of the surface dose rate to 0.5 mSv/h was estimated. In theory, a significant radiological benefit should be expected. Nevertheless, it is important to point out that, from the one hand, this modification would affect a large fraction of packages and thus should induce significant costs, and from the other hand, the activity or/and design of packages should be modified to satisfy the criteria and could lead to changes of practices and conditions of exposure.

With regard to Tc-99 generators (which contribute significantly to exposure), most of them are manually handled during transport so that heavier packages may have disadvantages. Furthermore, if the Mo-99 activity were reduced then the number of generators transported might have to increase and radiological control may not improve. It has however been shown that under current requirements major improvements in radiological protection of transport workers can be achieved through changes in operational procedures. The benefit gained by implementation of operational control needs to be further explored for the development of an optimised level of protection.

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