# Suggestions for Improvement of the IAEA Radioactive Materials Transport Regulations

*J. Hamard*

CEA - Institut de Protection et de Sûreté Nucléaire, Département de Protection de la santé de l'Homme et de Dosimétrie, France

## INTRODUCTION

The IAEA radioactive material transport regulations (IAEA, 1990) progressively took form between 1960 and 1985 as the result of a series of revisions, the most important of which occurred in 1967, 1972 and 1985. The arrangements were thus modified during the course of time to adapt to changes in the ICRP recommendations, and requirements resulting from the introduction of new types and new transport processes. The current regulations are thus the result of a mixed bag of successive provisions, some of which are relatively old and need to be brought up to date, improved and revised. This study covers three main subjects: the applicability of the regulations, and determination of exclusion or application levels, a better qualification of the risk by means of labelling and marking packages and establishing of a solid basis for the derivation of surface contamination limits.

For reasons of presentation only the first point will be developed in this paper.

## 1. APPLICATION LEVELS FOR THE IMPLEMENTATION OF THE REGULATIONS

At the present time the IAEA regulations for the transport of radioactive materials apply to the materials defined as radioactive by the regulations. In paragraph 139 of the Safety Series n°6 (1) radioactive material is defined as "any material having a specific activity superior to 70 $Bq.g^{-1}$ ($2_n$ Ci $g^1$)".

But if we consider the case of surface contaminated objects (SCO) the non-fixed contamination on accessible surfaces averaged over 300 $cm^{-2}$ must not exceed 4 Bq $cm^{-2}$. Thus for an object of mass = 1000 g and of a surface of 10 000 $cm^2$ contaminated by a single radionuclide, the total activity is 40 000 Bq and the specific activity of the order of 40 $Bq.g^{-1}$. (4 $Bq.g^{-1}$ for the most toxic $\alpha$ emitters).

On the other hand, some packages are "excepted from further prescriptions" (but not exempt from all the requirements of S.S6) on the basis of an insignificant potential hazard, if the activity in a package is not superior to $10^{-3}$ $A_2$ for solids and $10^{-4}$ $A_2$ for liquids. The lowest value of $A_2$ being $2.10^{-5}$ TBq ($2.10^7$ Bq) this limit corresponds to an absolute activity of $2.10^4$ Bq for solids and $2.10^3$ Bq for liquids.

## 2. BASES FOR THE DETERMINATION OF APPLICATION LEVELS

As values of application levels for the regulations one could use a small fraction of the values of $A_2$ selected on more or less empirical criteria. For example:

$$10^{-X} A_2 \ (5 < x < 10)$$

but it seems more cautious to found them on radiological and dosimetric bases [Nevertheless as a basic of comparison the values of $10^{-8}$ $A_2$ (x = 8) have been reported in the first column of Table 1].

If activities of radioactive materials may be considered as being out of the scope of the regulations they shall be at such a low level that they involve a very negligible (trivial) radiological risk. From a radiological point of view, it is generally suggested that a source may be exempted from regulatory control if it involves an individual effective dose of the order of some tens of micro-sievert per year. (A lower value of this dose level is 10 μSv per year) or, in the case of incorporation by inhalation or ingestion an effective committed dose of 10 μSv in 70 years for the public.

Hence a given activity of a radionuclide could be considered as negligible from a radiological point of view for the workers and the public if it does not involve a dose in excess of 10 μSv, whatever the exposure pathway. The most important pathways to consider in case of an accident are currently the following :

- incorporation by inhalation
- incorporation by ingestion
- exposure to the groundshine

So the lowest values of activity corresponding to these modes of exposure could be taken as exempted values for the application of the regulations (they could be completed by values relative to the immersion in a cloud of a rare gas).

## 3. ASSESSMENT OF ABSOLUTE APPLICATION LEVELS

### 3.1 Inhalation and ingestion

The actual available data relative to the dose received by inhalation or ingestion are given by ICRP 30 (ICRP, 1981) which gives the values of effective committed equivalent doses per Bq inhaled or ingested. These data have been corrected if necessary to take into account an integration time of 70 years in place of 50 years. From these values one may derive the levels of inhaled or ingested activities involving a committed effective dose of 10 μSv. This would permit the derivation of absolute activity limits for each radionuclide involving only a trivial risk and below which the regulations could not apply. Results are given in columns 2 and 3 of Table 1.

### 3.2 Exposure due to groundshine

In the case of an accident, for the evaluation of the dose for the workers and the public it would be useful to take into account the dose due to the radionuclides deposited on the ground. Thus, one may calculate the surface activity (Bq $m^{-2}$) resulting from one single deposit, which could deliver an external effective dose of 10 μSv (or an equivalent dose of 75 μSv to the lenses and 250 μSv to the skin following the cases). For this assessment we used the data of the report CEA-R4844 Rev.1 (CEA-1980). The results are given in column 4 of Table 1).

**Table 1. VALUES OF ABSOLUTE ACTIVITY OR SURFACIC ACTIVITY → 10 μSv in 70 YEARS**

| Radionuclides | $10^{-8}$ $A_2$ Bq | Incorporated activity Bq | | Surface activity Bq $m^{-2}$ |
|---|---|---|---|---|
| | | Inhalation | Ingestion | |
| Na 24 | $2.10^3$ | $4.10^4$ | $2.10^4$ | $3.10^5$ |
| Mn 54 | $1.10^4$ | $6.10^3$ | $1.10^4$ | $5.10^2$ |
| Co 60 | $4.10^3$ | $2.10^2$ | $1.10^3$ | 12 |
| Sr 90 | $1.10^3$ | 2.10 | $2.10^2$ | 1 (skin) |
| Zr 95 | $9.10^3$ | $2.10^3$ | $1.10^4$ | $110^3$ |
| Mo 99 | $5.10^3$ | $1.10^4$ | $1.10^4$ | $8.10^4$ |
| Ru 106 | $2.10^3$ | 8.10 ($1.10^2$) | $2.10^3$ | $8.10^2$ |
| I 131 | $5.10^3$ | $1.10^3$ | $8.10^2$ | $2.10^4$ |
| Cs 137 | $5.10^3$ | $1.10^3$ | $8.10^2$ | 10 |
| Ba 140 | $4.10^3$ | $1.10^4$ | $4.10^3$ | $2.10^3$ |
| Ra 226 | $2.10^3$ | 10 | $1.10^2$ | $4.5.10^2$ |
| U 238 | 2.10 | 40 | $2.10^2$ | |
| Pu 239 | 2 | $10^{-1}$ | 8.10 | |

### 3.3 Comments

Let us compare the results in the columns 2, 3 and 4 with the values of $10^{-8}$ $A_2$ given in column 1. Except in some cases, they are of the same order of magnitude. Theoretically, the values of $A_2$ take into account the external exposure ($A_1$) but not the ingestion pathway. We can also verify that the surfacic activity values are sometimes lower than the inhalation and ingestion values and that ingestion values are also in some cases lower than the inhalation or surfacic activity values.

Hence for the assessment of absolute activities of application levels for the regulation, it would be useful to take into account the three main pathways to man, i.e. inhalation, ingestion and exposure to groundshine, calculated on a nominal activity basis.

### 3.4 Choice of an absolute activity application level

Consideration of inhalation and ingestion pathways leads to activity values in Bq and consideration of the groundshine leads to surface activity values in Bq.$m^{-2}$. But, in both cases, we are considering the dose due to 1 Bq whatever the pathway to man. Hence for the choice of an absolute activity levels, it is possible to consider the three sets of values as index quantities, and to choose the lowest numerical value as an absolute activity level for application of the regulation.

## 4. CONSIDERATION OF THE SPECIFIC ACTIVITY

### 4.1 Case of the inhalation

In the transport regulations, for the definition of low specific activity materials (LAS), the following basic hypothesis have been made:

1. "An atmosphere very heavily laden with dust would contain about 10 mg of matter per cubic meter"

2. "It is thought unlikely that more than 10 mg of any radioactive material together with its carrier, would be inhaled during the course of a single accidental exposure" (using the current inhalation constant for the standard man, i.e. 1.2 $m^3.h^{-1}$ and a duration of exposure of 1/2 h to 1 hour).

Hence the radionuclides which have, naturally or in the form they have to be transported, a mass greater than 10 mg associated with their ALI may be transported in quantities greater than $A_2$, unlimited if they are non-combustible, and limited to 100 $A_2$ by conveyance in the other cases (combustible, liquid or gas).

These hypotheses rase the following observation and questions:

1. Only the inhalation risk is considered;
2. Is the hypothesis of 10 mg inhalable confirmed by the experience?
3. How could the specific activity be taken into account in the case of ingestion?

### 4.2 Validity of the 10 mg hypothesis

One has at disposal few data about the concentrations of materials in the atmosphere in accidental transport conditions.

A study (4) relating to the concentrations of solid materials observed in various dusty activities showed that air concentrations superior to some tens of $mg.m^{-3}$ and incorporations by inhalation superior to some tens of mg are rarely observed, although in one reported accidental condition a concentration superior to 100 $mg.m^{-3}$ has been observed, leading to incorporation by inhalation of the order of 100 mg of material. Such high concentrations and incorporations would be more representative of accidents incurring indoor than outdoor. Thus, without questioning a priori the hypothesis relative to the 10 $mg.m^{-3}$ atmospheric concentration and the 10 mg incorporation by inhalation in accidental conditions, it may be useful to estimate what could be the impact of using an higher value like 100 mg as a limit superior of the inhaled material in case of accident to make the calculation of specific activity levels in case of inhalation below which the regulations could not be applied.

The values for inhalation are reported in columns 1 and 2 of Table 2.

### 4.3 Case of ingestion

In the case of workers, the hypothesis relative to the quantity incorporable may be modified taking into account one of the three following schemes:

1. As in the case of inhalation, one supposes that it is unlikely that in accidental conditions a worker could ingest in one time more than 100 mg of material. In this case, the limiting level of specific activity for ingestion ($Bq.g^{-1}$) is ten times the numerical value of ingested activity which delivers 10 µSv in 70 years (as given in column 3 of Table 1);

2. The quantity of ingestable material may not exceed 500 mg. In this case, the limiting level of specific activity for ingestion would be two times the numerical value of ingested activity which delivers 10 µSv in 70 years;

3. The quantity of ingested material may not exceed 1 g. In this case, the limiting level of specific activity for ingestion if numerically identical to the value of ingested activity which delivers 10 µSv in 70 years.

These values are reported in columns 3, 4 and 5 of Table 2. The choice of one of these options is evidently matter of a "value judgement", because there are very few experimental data on this subject.

**Table 2. LIMITING SPECIFIC ACTIVITY LEVELS FOR WORKERS Bq.g[1]**

| Radionuclides | Case of inhalation | | Case of ingestion | | |
|---|---|---|---|---|---|
| | Inhalable Mass | | Ingestable Mass | | |
| | 10 mg | 100 mg | 100 mg | 500 mg | 1 mg |
| Na 24 | $4.10^6$ | $4.10^5$ | $2.10^5$ | $4.10^4$ | $2.10^4$ |
| Mn 54 | $6.10^5$ | $6.10^4$ | $1.10^5$ | $2.10^4$ | $1.10^4$ |
| Co 60 | $2.10^4$ | $2.10^3$ | $1.10^4$ | $2.10^3$ | $1.10^3$ |
| Sr 90 | $2.10^3$ | $2.10^2$ | $2.10^3$ | $4.10^2$ | $2.10^2$ |
| Zr 95 | $2.10^5$ | $2.10^4$ | $1.10^5$ | $2.10^4$ | $1.10^4$ |
| Mo 99 | $1.10^6$ | $1.10^5$ | $1.10^5$ | $2.10^4$ | $1.10^4$ |
| Ru 106 | $8.10^3$ | $8.10^2$ | $2.10^4$ | $4.10^3$ | $2.10^3$ |
| I 131 | $1.10^5$ | $1.10^4$ | $8.10^3$ | $1.6.10^3$ | $8.10^2$ |
| Cs 137 | $1.10^5$ | $1.10^4$ | $8.10^3$ | $1.6.10^3$ | $8.10^2$ |
| Ba 140 | $1.10^6$ | $1.10^5$ | $4.10^4$ | $8.10^3$ | $4.10^3$ |
| Ra 226 | $1.10^3$ | $1.10^2$ | $1.10^3$ | $2.10^2$ | $1.10^2$ |
| U 238 | $4.10^3$ | $4.10^2$ | $2.10^3$ | $4.10^2$ | $2.10^2$ |
| Pu 239 | 10 | 1 | $8.10^2$ | $1.6.10^2$ | 8.10 |

**Comments**

1. The consideration of ingestion for the definition of levels of specific activity for the application of the regulations taking into account an elementary scenario and nominal activities would induce lower values than the inhalation alone. But the results are very dependent on the hypothesis relative to the amounts of ingestable material.

2. For the definition of LSA materials, it would then be possible to take into account the three main exposure pathways to the man. The limiting value for solid LSA could still be based on the 10 mg hypothesis, the value for liquid LSA on the mass ingested hypothesis. It would also be possible to take into account the exposure due to groundshine in place of the direct point source exposure used now.

**Recalculation of limits of surface contamination levels**

A similar approach could be used for the recalculation of limits for surface contamination levels for packages and conveyances. The three basic scenarios used here, i.e. inhalation, ingestion, and exposure to the groundshine, appear sufficient to account for most of the exposure situations. But it would be desirable to reduce the number of the limiting surface contamination values to 2, or at the maximum 3 in view of simplifying the work of the control teams. It is not possible to develop further this topic in this paper.

## CONCLUSION

The assessment of lower levels of absolute activity and of specific activity for the application of the transport regulations would allow some simplifications in the transport of radioactive materials. It could give a more precise definition of the low specific activity materials (LSA) by addressing a lower end limit to the definition of this category. It could be more appropriate to take into account the external exposure risk due to the groundshine in the case of accident involving LSA materials. At least the elementary scenarios used in this study could also provide realistic bases for the calculation of limits for surface contamination of packages and conveyances.

**BIBLIOGRAPHY**


1. IAEA
Regulations for the safe transport of radioactive material, Ed. 1985, Rev. 1990. Safety Series n° 6, IAEA, Vienna.

2. ICRP
Limits for intake of radionuclides by workers. Publication ICRP 30, Pergamon Press, Oxford, New-York, 1981.

3. CEA
Irradiation externe, pendant et après le passage d'un nuage radioactif. Rapport CEA-R-4844, Rev. 1, CEN-Saclay, France, 1980.

4. J. HAMARD CEA - IPSN
The concept of LSA material in the IAEA transport regulations. International Journal of Radioactive Materials, 1990.