The Application of Exemption Values to the Transport of Radioactive Materials

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INTRODUCTION

The principles and methods for establishing exemption values have been published by the European Commission DG XI (Radiation Protection 65) and endorsed by the International Atomic Energy Agency (Basic Safety Standards). These documents contain activity and activity concentration values below which reporting is not required. The exemption values are such that the radiological risk or detriment associated with the practice is so small as not to warrant the imposition of the system of reporting or prior authorization. Sources below the exemption values are of no regulatory concern for the IAEA. The main objective of this study is to examine the relevance of the BSS exemption values to the transport regulation.

With regard to the IAEA transport regulation (Safety Series n°6), the Revision Panel of the transport regulation (RP3) and the Standing Advisory Group of the Safe Transport of Radioactive Material (SAGSTRAM -XI) endorsed the basic dose criteria of the International Basic Safety Standards for Protection Against Ionizing Radiation (BSS) and for the Safety of Radiation Sources (Safety Series No. 115-I). The basic dose criteria in all feasible situations for exemption used by the BSS are:

(a) an individual effective dose of 10 μSv/y for normal conditions;
(b) a collective effective dose of 1 man-Sv/y for normal conditions;
(c) an individual effective dose of 1 mSv for accident conditions;
(d) an individual dose to skin of 50 mSv for both conditions.

To derive the exemption values listed in the BSS, various exposure conditions were identified for both normal and accident conditions leading both to activity and activity concentration values for the different radionuclides.

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The BSS approach leads to radionuclide specific exemption values and is not compatible with a single specific activity figure such as the current 70 kBq/kg used in the current transport regulations.

Moreover, no specific transport scenarios have been considered in the methodology used by the BSS, although a specific transport scenario for landfill was considered in the pilot study. Since the transport of radioactive material involves packages, containers, consignments, and conveyances, the specific exposure scenarios associated with transport operations may be different from those of fixed installations. The IAEA Consultant Service Meeting (CS-2) determined the relevant BSS scenarios for transport and added specific transport scenarios for normal conditions as well as an adaptation of the Q-system for accident conditions. This work was endorsed by SAGSTRAM-XI.

This paper presents the calculations of exemption values derived from the relevant transport scenarios for a selection of 20 representative radionuclides. These results are compared to the corresponding BSS exemption values in order to examine if the BSS exemption values are suitable or not to the transport exposure conditions. A comparison is also made with the existing definition of the radioactive material in the IAEA Safety Series (SS6 § 139) (material is considered radioactive only if the specific activity is greater than 70 kBq/kg).

SCENARIOS

Scenarios Extracted From the BSS

Several scenarios used for the BSS exemption values have been considered to be relevant for transport. Those scenarios, listed below, deal with activity concentration and activity and take into account normal and accident conditions of transport:

Activity concentrations:

A1.1 External from handling
A1.2 External from 1 m^3 source
A1.3 External from gas bottle

Activity:

B1.1 External from point source
B1.2 External from handling
B2.1 Spillage: external from hands
B2.2 Spillage: external from face
B2.4 Spillage: ingestion
B2.5 Spillage: inhalation
B2.6 Spillage: external from cloud
B2.7 Fire: skin
B2.8 Fire: inhalation products
B2.9 Fire: external from combustion products

The number of the scenarios refers to the notation adopted in the report 'Radiation Protection 65' (RP 65)

Specific Transport Scenarios

Four basic scenarios were considered to be relevant for normal conditions of transport by the IAEA Technical Committee 946. Those scenarios provide exemption levels in terms of activity concentration and activity.

Scenario 1: A postman or courier delivers a package containing radioactive material to a laboratory or a hospital after having carried it during their delivery round.

Scenario 2: A driver, either an employee or member of the public, transports bulk material or packages in a truck or van.

Scenario 3: An employee or member of the public loads bulk material or packages into a truck or van.

Scenario 4: Members of the public traveling in an aircraft are exposed to radioactive materials being transported in the hold of the aircraft.

For accident conditions of transport, an additional scenario based on the Q system (IAEA Safety Series n°7, Appendix I) has been retained since this scenario considered the main exposure pathways associated with accident situations of transport. This scenario, initially defined for the derivation of a limit for the activity of a Type A package, has been revised with the dose criterion of 10 μSv for the purpose of exemption and provides exemption levels in terms of activity.

Within the four basic scenarios, there are several subscenarios. All those specific transport scenarios together with the Q-system are listed in Table 1.

METHODS

The main methodology used to calculate exemption values was consistent with that used in the determination of the BSS values. These calculations were supported in part by results obtained from the standard computer code Microshield. This methodology is detailed in the report « The Application of Exemption Values to the Transport of Radioactive Materials ».

Specific transport accident situations were taken into account by application of the results of the latest Q-system analysis. The most limiting Q value was divided by 50 mSv/10 μSv = $5\ 10^3$ (except for skin dose which was divided by 500 mSv/50 mSv = 10) to take account of the different dose criteria used in this system.

RESULTS

The results for the transport specific scenarios were listed together and compared with the relevant ones used for the BSS exemption values to provide limiting values. From Table 2, it can be seen that the transport scenarios generally provide the slightly more restrictive values for activity concentrations. It should be noted that one of the restrictive scenarios concerns the external exposure of a truck driver transporting 20 m^3 of bulk material for a duration of 400 hours per year (TC2.1). The restrictive activity values come from several scenarios but many of the results are similar. The values obtained from application of the Q-system are not limiting.

DISCUSSION

The main purpose of this analysis was to check the adequacy, with regard to the dose criteria, of the BSS exemption values in the case of exposure situations associated with transport. Furthermore, since the current exemption level for transport practices is 70 kBq/kg for all radionuclides, the comparative analysis aims also at comparing the consequences of having a single exemption value or a set of exemption values.

SAGSTRAM accepted that, with reference to the BSS exemption values, if the figures provided by the analysis of transport scenarios differ from those provided by the BSS by one to two orders of magnitude, then it is preferable to directly apply the BSS figures instead of defining a specific set of exemption values for transport operations. This provides consistency with other practices. However, if differences of more than two orders of magnitude are observed, it could be relevant, for radionuclides that are transported, to use figures other than those of the BSS and obtain conditional exemption values for transport.

Comparisons of BSS exemption values with those calculated for the agreed transport scenarios show that most are within one order of magnitude. Only Kr-85 is two orders of magnitude different. It can be argued that krypton is not transported in such large containers. For activity values the greatest difference is for Tc-99m, where a factor of 47 lower is observed.

For the transport scenarios, activity concentrations range from 0.3 kBq/kg to 36 000 kBq/kg. A comparison of the basic dose criteria of 10 μSv to the doses associated with the 70 kBq/kg is illustrated in Figure 1. Figure 2 presents the radiological impact of the BSS exemption levels.

The Figure 1 reveals that a dose of up to 2.2 mSv could be expected with 70 kBq/kg of Co-60 and doses greater than 1 mSv could be expected with 70 kBq/kg of Ra-226, Th-232, and U-238. On the other hand, the 70 kBq/kg is too stringent for radionuclides such as C-14 or S-35. A single value of 70 kBq/kg for all radionuclides is not compatible with the results from the agreed transport scenarios. For the radionuclides listed in the BSS, more than two thirds of them have an exemption value less than 70kBq/kg or result in a dose greater than 10 μSv for an activity concentration of 70 kBq/kg.

CONCLUSION

The activity concentrations and activities for the agreed 20 radionuclides in the transport scenarios are within two orders of magnitude of the BSS values. Such a range is insufficient to establish transport values different from those of the BSS. The generic BSS figures are therefore representative for transport.

Concerning the activity concentration, as far as the main justification for the adoption of the exemption principle is based on dose criteria considerations and refers to the level of negligible risk, a single exemption value is not consistent with the adopted dose criteria. Furthermore, because of the general agreement between the transport specific exemption values and those of the BSS, it seems reasonable to adopt, in the 1996 Edition of the Transport Regulations, the BSS exemption values below which the transport regulation would not apply.

The activity concentration values can be applied to a package or to a conveyance. As far as the activities are concerned, although there is a need to delineate the scope of their application, the use of such a set of values should avoid the adoption of stringent requirements for the transport of 'small sources' for which the concentration may be higher than the exempted value, but without any significant radiological exposure provided these small sources are not transported in very large numbers. In practice, it seems more appropriate to restrict the activity per consignment because it is more operationally convenient.

This work was performed under contract to the EC and has been discussed by the international transport community at the IAEA. On the basis of this study, further developments could be envisaged to examine the impact of the implementation of the BSS exemption values to the transport practices. This could be done in the scope of the Radiation Protection Program.

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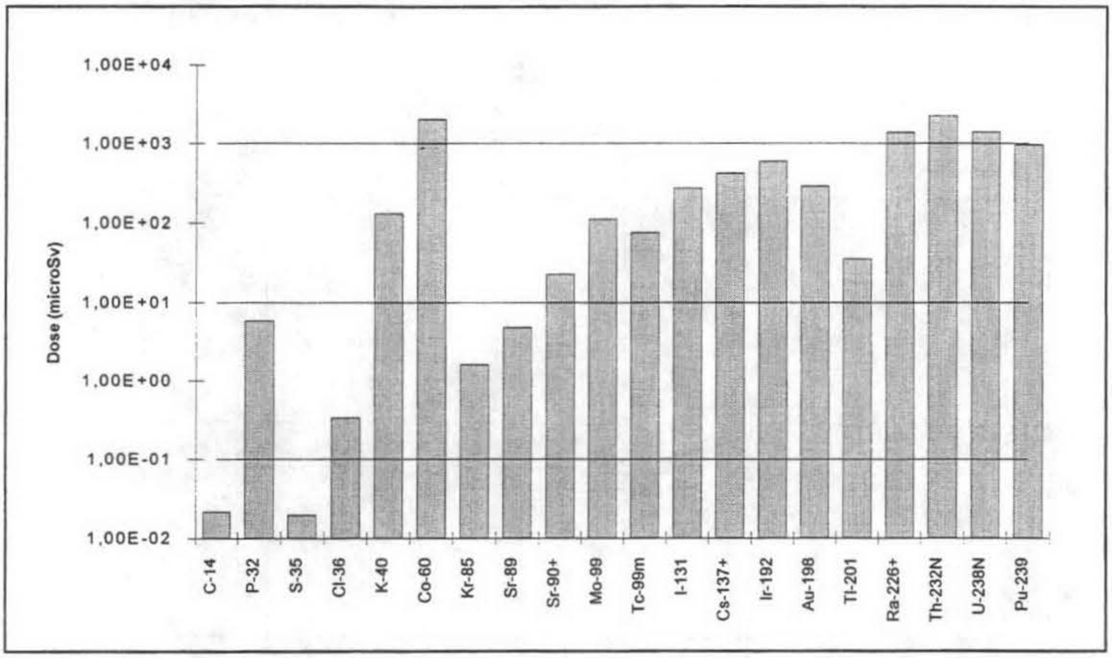
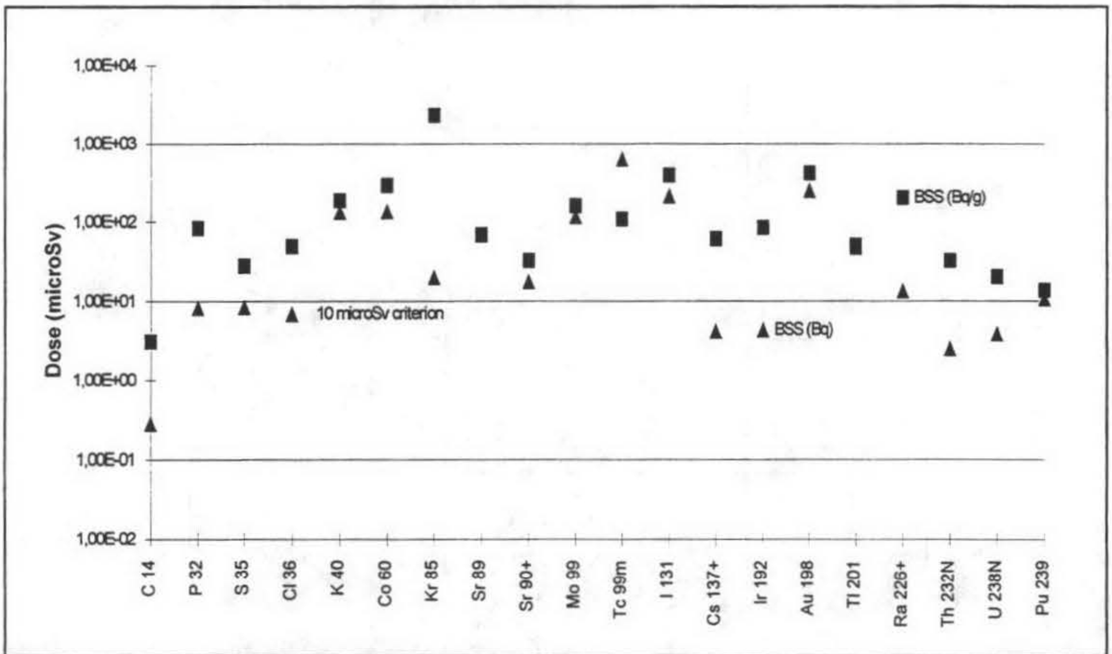


Figure 1 : Radiological impact of the 70 kBq/kg exemption level.



(for Kr85 the restrictive scenario TC2.1 (Bq/g) is not representative)

Figure 2 : Radiological impact of the BSS exemption levels.

The transport specific exemption values are generally rather more restrictive than the BSS exemption values. However, these two sets of values are much closer to each other than the transport values are to the single value of 70 kBq/kg.

Table 1: Representative Scenarios for Transport

Scenario	Exemption type	Mode of transport	Physical form of materials	Exposure time (h/y)	Distance to source (m)	Source dimension (w x h x l)	Shielding	Exposure Pathways
T.A.1	total activity	bicycle	small package	200	0.5	point	paper	External and skin dose
T.C.2.1	activity concentration	truck	bulk (about 20 m^3)	400	1.5	2 x 1.5 x 7 m	2 x 0.25 cm of steel	External
T.A.2.2	total activity	van	packages for a total of 1 m^3	200	1.0	1 x 1 x 1 m	1 x 0.25 cm of steel	External
T.C.2.2	activity concentration							
T.C.2.3	activity concentration	van	bulk (about 1 m^3)	50	1.0	1 x 1x 1 m	paper	External
T.A.2.4	total activity	truck	bulk	200	1.5	2 x 1.5 x 7 m	1 x 0.25 cm of steel	External and skin dose
T.A.3.1	total activity	by hand	packages	200	0.2	0.2 x 0.2 x 0.25 m (10 liters)	paper	External and skin dose
T.C.3.1	activity concentration							
T.C.3.2	activity concentration	using shovel	bulk (about 1 m^3)	50	1.0	1 x 1x 1 m	none	External, inhalation and ingestion
T.A.3.3	total activity	by hand	solid (stones, bricks)	50	0.2	point	none	External and skin dose
T.A.3.4	total activity	by hand	dust contamination as planar	200	1.0	Infinite plane source	none	External, inhalation, and ingestion
T.C.3.4	activity concentration							
T.A.4	total activity	air	packages for a total of 1 m^3	200	1.0	1 x 1 x 1 m	1 x 0.25 cm of Al	External
T.A.Q	total activity	Accident	from the Q system	0.5	1.0	from the Q system	from the Q system	from the Q system

T. A. : Transport scenario leading to exemption values in terms of total activity.

T. C. : Transport scenario leading to exemption values in terms of activity concentration.

Table 2. Comparison of BSS Exemption Values with Values From Transport Scenarios.

ACTIVITY CONCENTRATION (Bq/g)					TOTAL ACTIVITY (Bq)				
Nuclide	**RP-65 Value (1)**	**Transport value (2)**	**Transport Scenario**	**BSS**	**RP-65 value(3)**	**Transport value (4)**	**Transport scenario**	**Value for Q system**	**BSS**
C-14	1.79 e+04	3.26E+04	TC3.4	**1,00E+04**	1.77e+07	3.58e+08	B2.8	1.72e+10	**1,00e+07**
P-32	9.29 e+02	1.20E+02	TC3.1	**1,00E+03**	2.51e+05	1.20e+05	TA3.1	9.00e+07	**1,00e+05**
S-35	3.33 e+04	3.59E+04	TC3.4	**1,00E+05**	3.29e+07	1.18e+08	TA3.3	7.60e+09	**1,00e+08**
Cl-36	8.26 e+03	2.04E+03	TC3.1	**1,00E+04**	1.68e+06	1.44e+06	TA3.3	1.44e+09	**1,00e+06**
K-40	1.01 e+02	5.35E+00	TC2.1	**1,00E+02**	7.54e+05	7.55e+04	TA3.1	1.88e+08	**1,00e+06**
Co-60	6.64 e+00	3.42E-01	TC2.1	**1,00E+01**	6.31e+04	7.38e+03	TA3.1	9.00e+07	**1,00e+05**
Kr-85	5.24 e+04	4.34E+02	TC2.1	**1,00E+05**	5.00e+03	5.00e+03	B1.2	2.80e+09	**1,00e+04**
Sr-89	1.34 e+03	1.46E+02	TC3.1	**1,00E+03**	3.44e+05	1.46e+05	TA3.1	1.24e+08	**1,00e+06**
Sr-90+	1.58 e+02	3.10E+01	TC3.1	**1,00E+02**	5.68e+03	5.68e+03	B1.2	6.40e+07	**1,00e+04**
Mo-99	1.07 e+02	6.25E+00	TC2.1	**1,00E+02**	8.88e+05	8.49e+04	TA3.1	2.40e+08	**1,00e+06**
Tc-99m	1.32 e+02	9.30E+00	TC2.1	**1,00E+02**	7.37e+06	1.56e+05	TA3.1	1.96e+09	**1,00e+07**
I-131	5.38 e+01	2.53E+00	TC2.1	**1,00E+02**	4.92e+05	4.71e+04	TA3.1	4.60e+08	**1,00e+06**
Cs-137+	2.95 e+01	1.65E+00	TC2.1	**1,00E+01**	2.36e+04	2.36e+04	B1.2	3.60e+08	**1,00e+04**
Ir-192	2.03 e+01	1.18E+00	TC2.1	**1,00E+01**	2.29e+04	2.29e+04	B1.2	2.60e+08	**1,00e+01**
Au-198	4.10 e+01	2.39E+00	TC2.1	**1,00E+02**	7.74e+05	3.99e+04	TA3.1	2.20e+08	**1,00e+06**
Tl-201	1.88 e+02	1.99E+01	TC2.1	**1,00E+02**	5.00e+05	2.11e+05	TA3.1	2.40e+09	**1,00e+06**
Ra-226+	4.67 e+00	4.96E-01	TC2.1	**1,00E+01**	4.54e+03	7.43e+03	TA3.1	5.40e+05	**1,00e+04**
Th-232N	8.49 e-01	3.13E-01	TC3.4	**1,00E+00**	1.55e+03	3.98E+03	TA3.4	5.40e+07	**1,00e+03**
U-238N	1.83 e+00	4.93E-01	TC2.1	**1,00E+00**	2.57e+03	2.57e+03	B1.2	2.60e+07	**1,00e+03**
Pu-239	2.21 e+00	7.30E-01	TC3.4	**1.00 E+00**	8.06e+03	9.25E+03	TA3.4	2.20e+05	**1,00e+04**

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