RADIOLOGICAL LIMITS FOR TYPE B PACKAGES WITHIN THE TERMS OF THE IAEA TRANSPORT REGULATIONS

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Abstract

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The paper discusses the radiation levels and activity release limits applicable to Type B packages with particular reference to consignments of irradiated nuclear fuel. Within the IAEA Regulations for the Safe Transport of Radioactive Material, external irradiation and maximum permissible non-fixed surface contamination levels are defined in terms of conventional radiological protection criteria, whereas permitted activity releases are expressed in terms of the non-special form Type A package contents limit A_2 values and are not directly comparable. However, by considering a range of possible exposure scenarios relevant to the transport of Type B packages and noting that an intake of $A_2 \times 10^{-6}$ corresponds to an effective dose equivalent of 50 mSv, it is possible to derive the dosimetric limits implied by the permitted activity releases contained in the Regulations. This facilitates comparisons with external radiation and surface contamination limits under both normal transport and accident conditions. In the latter case, the safety standards for Type B packages implied within the Regulations may be compared with those widely used in the establishment of emergency guidelines at power reactor sites and other fixed nuclear installations.

1. INTRODUCTION

Within the IAEA Transport Regulations [1] external radiation limits and maximum permissible levels of non-fixed surface contamination for Type B packages are defined in terms of conventional radiological protection criteria, viz. $mSv \cdot h^{-1}$ and $Bq \cdot cm^{-2}$ respectively. In contrast, permitted activity releases form Type B packages under conditions of normal transport or following tests to simulate a severe accident are not so directly defined. Instead, they are expressed in terms of the non-special form Type A package contents limit A_2 values, which are not directly comparable with standard dosimetric criteria. However, noting that an intake of $A_2 \times 10^{-6}$ corresponds to an effective dose equivalent of 50 mSv, the permitted activity releases from Type B packages may be expressed as equivalent dose or dose rate limits.

Type A packages are intended for the transport of low activity consignments and the dosimetric criteria appropriate to them are defined in the assumptions of the Q system used in the derivation of their A_1 and A_2 contents limit values [2]. Type B packages are designed for the transport of quantities of radioactivity in excess of the Type A limits and a principle embodied in the Regulations is that intentional leakage should be avoided. However, as absolute containment cannot be guaranteed, and in order to define appropriate and practical test procedures, maximum allowable leakage rates for Type B packages are specified as follows:

(a) $A_2 \times 10^{-6}$ per hour following tests to simulate the conditions of normal transport, and
(b) an accumulated loss of A_2 (or 100 TBq for ^{85}Kr) in a period of up to one week following tests to simulate the conditions of a severe accident.

The dosimetric limits implied by these activity release limits may be evaluated by reference to a range of possible exposure scenarios relevant to the transport of Type B packages [3]. Examples of the derivation of such dosimetric limits are presented in this paper and are compared with external radiation limits specified in the IAEA Transport Regulations, as well as with dosimetric criteria applied elsewhere in the nuclear industry.

2. NORMAL TRANSPORT

The external radiation dose rate limits for Type B packages specified in the IAEA Transport Regulations [1] are 0.1 $mSv \cdot h^{-1}$ at 1 m from the surface of a package or at 2 m from a vehicle under exclusive use. In addition, the radiation level at any point on the exposed surface of the package or transport vehicle should not exceed 2 $mSv \cdot h^{-1}$, while in the special case of road transport that at any normally occupied position in the vehicle is limited to 0.02 $mSv \cdot h^{-1}$. Also, maximum permissible levels of non-fixed surface contamination are specified as 4 $Bq \cdot cm^{-2}$ for β/γ and low toxicity α-emitters, and 0.4 $Bq \cdot cm^{-2}$ for all other α-emitters, both being averaged over an area of 300 cm^2 of any part of the package surface.

The original derivation of the normal transport activity release limit of $A_2 \times 10^{-6}$ per hour considered exposure of a worker in an enclosed vehicle of 50 m^3 volume, with ten air changes per hour [4]. This and other scenarios appropriate to exposure of transport workers and the public during the normal transport of Type B packages are used below to express the above activity release as an equivalent dose rate limit.

2.1. Exposure of transport workers

At equilibrium, and assuming an average adult breathing rate of 1.2 $m^3 \cdot h^{-1}$, the above scenario leads to an intake rate of activity of $A_2 \times 2.4 \times 10^{-9}$ h^{-1}. Based on the dosimetric equivalence of an intake of $A_2 \times 10^{-6}$ noted earlier, this represents an effective dose equivalent rate of 0.12 $mSv \cdot h^{-1}$, which is comparable with the external radiation limit at 1 m from the surface of a Type B package of 0.1 $mSv \cdot h^{-1}$ cited above. For a person working 2000 hours per year and spending 20% of this time in an enclosed vehicle the above intake results in an annual dose of 48 mSv. This is just within the ICRP recommended maximum annual dose for radiation workers of 50 mSv, although the scenario outlined above was judged to represent the most adverse expected condition [4].

An alternative exposure situation relevant to transport workers is exposure in a store room or cargo handling bay of 3000 m^3 volume, with 4 air changes per hour [3]. Assuming the adult breathing rate of 1.2 $m^3 \cdot h^{-1}$ and uniform mixing of the release activity, under steady state conditions the Type B package release limit of $A_2 \times 10^{-6}$ per hour corresponds to an intake rate of $A_2 \times 9.9 \times 10^{-11}$ h^{-1}. This represents an implied dose rate limit of 5 $\mu Sv \cdot h^{-1}$, which compares with an external radiation limit of order 1 $\mu Sv \cdot h^{-1}$ at distances in the range 10–20 m when extrapolated from the 0.1 $mSv \cdot h^{-1}$ level specified at 1 m from the surface of a Type B package.

2.2. Exposure of the public

Members of the public are unlikely to be in close proximity to Type B packages in transit for extended periods of time, hence in this situation it is appropriate to consider exposure out-of-doors to an airborne release of radioactivity. The effective dose equivalent rate corresponding to the IAEA limit of $A_2 \times 10^{-6}$ per hour for a release occurring under average category C/D weather conditions evaluated on this basis is illustrated in Fig. 1. Also shown is the external dose rate as a function of distance corresponding to a level of 0.1 $mSv \cdot h^{-1}$ at 2 m from the centre of the package. Since local entrainment and turbulence effects close to the source are likely to minimise the spatial variations in airborne activity concentrations in this region, the results shown in Fig. 1 indicate that the Type B package activity release and external radiation limits represent a limiting effective dose equivalent rate of $\sim 10^{-2}$ $\mu Sv \cdot h^{-1}$ at downwind distances in the range 50–200 m. This is less than 10% of typical natural background radiation dose rates.

3. ACCIDENT CONDITIONS

Under accident conditions the prime exposure scenario of interest is that of a release occurring out-of-doors. For Type B packages accidents of the severity simulated in the tests specified in the IAEA Regulations are unlikely to occur indoors, or if they did the resulting conditions would be such as to require immediate evacuation of all persons in the vicinity [5]. The IAEA accident activity release limit of A_2 in a period of up to one week may be expressed as an individual dose limit in a

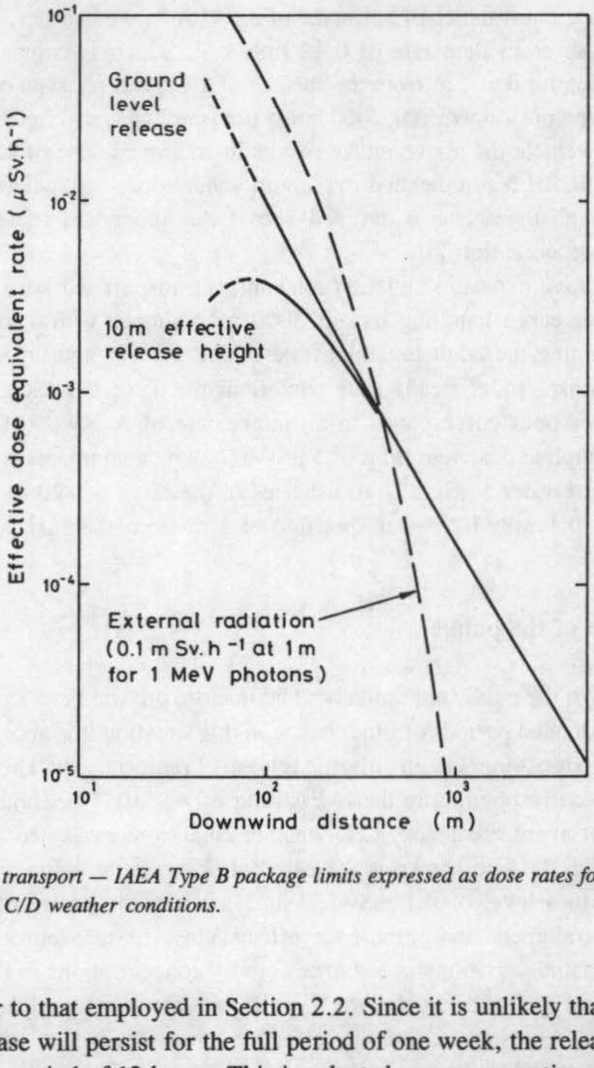

FIG. 1. Normal transport — IAEA Type B package limits expressed as dose rates for a release under average category C/D weather conditions.

manner similar to that employed in Section 2.2. Since it is unlikely that a significant accidental release will persist for the full period of one week, the release is assumed to occur over a period of 12 hours. This is selected as a conservative estimate of the time which might be required for emergency services to reach the scene of an accident and take effective remedial actions to limit the release of activity from the damaged package.

On the above basis the doses as a function of distance from the source for airborne releases occurring at or near ground level under average category C/D and stable category F weather conditions are reproduced in Fig. 2. As noted earlier, possible entrainment and turbulence effects, and also plume rise if a fire were involved, will tend to reduce the spatial variation in doses within the first few tens of metres of the source. Also shown in Fig. 2 is the external radiation dose, integrated over the one week period specified in the Regulations, corresponding to the accident dose rate limit of 10 $mSv \cdot h^{-1}$ at 1 m from the surface of the damaged package for a

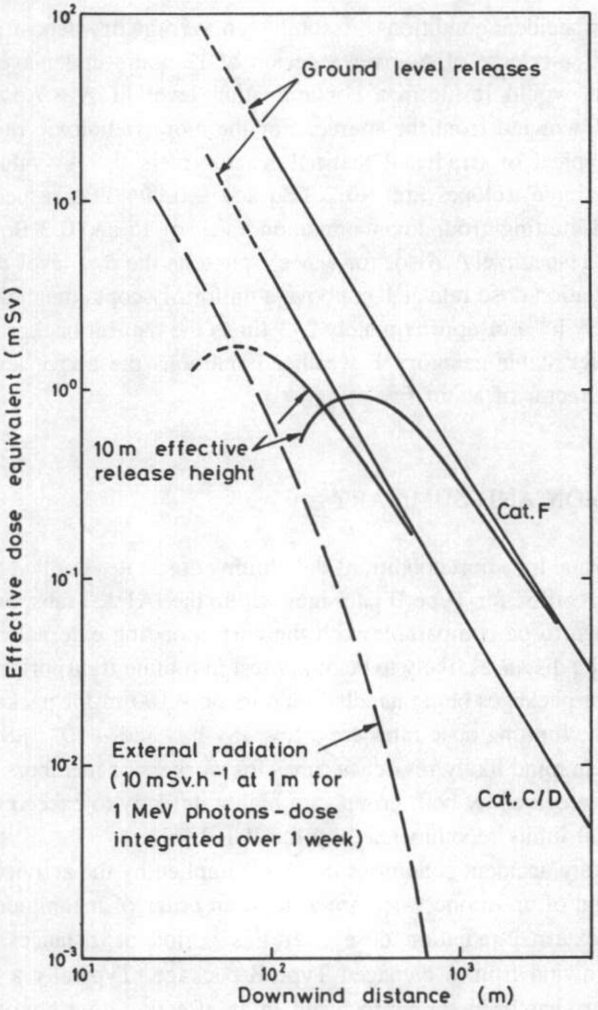

FIG. 2. Accident conditions — IAEA Type B package units expressed as integrated doses under various conditions.

source of 1 MeV photons. This includes the 100 times enhancement of external radiation dose rate permitted under accident conditions compared with that during normal transport [1]. At distances beyond a few tens of metres downwind the external radiation dose over a week is more than an order of magnitude less than the implied limits within the Regulations. In absolute terms these represent an effective dose equivalent limit via inhalation at distances in the range 50–200 m of the order 1–50 mSv, depending upon the prevailing meteorological conditions.

The above approach may also be utilized to evaluate the limiting levels of ground contamination implicit in the IAEA activity release limits for Type B packages under accident conditions. Assuming an average dry deposition velocity of 3×10^{-3} m·s^{-1}, a release of A_2 over a period of 12 hours under average category C/D conditions would result in a contamination level of $A_2\times7.5\times10^{-7}$ m^{-2} at about 100 m downwind from the source. For the more radiotoxic radionuclides or for mixtures typical of irradiated thermal reactor fuels the A_2 values for fission product and actinide isotopes are ~0.2 TBq and ~0.004 TBq respectively. These A_2 values yield limiting ground contamination levels of 15 and 0.3 Bq·cm^{-2} for β/γ and α-emitters respectively. Also, for 1 MeV photons the β/γ level corresponds to an external radiation dose rate at 1 m above a uniformly contaminated plane surface of about 0.3 μSv·h^{-1}, or approximately 2–3 times the natural background radiation dose rate. Under stable category F weather conditions the above levels would be increased by a factor of about five.

4. DISCUSSION AND SUMMARY

Under normal transport conditions the limiting dose rates implied by the activity release limits specified for Type B packages within the IAEA Transport Regulations have been shown to be comparable with the corresponding external radiation dose rate limits. At the distances likely to be of interest in routine transport, namely within a few metres for packages being handled indoors or ~100 m for packages in transit out-of-doors, the limiting dose rates are a few μSv·h^{-1} and ~10^{-2} μSv·h^{-1} respectively. Bearing in mind likely residence times for workers or members of the public, radiation doses received by both groups are highly unlikely to exceed the maximum permitted annual limits recommended by the ICRP [6].

Under severe accident conditions the doses implied by the activity release limit of A_2 in a period of up to one week are at least an order of magnitude greater than the permitted external radiation dose over this period at distances in the range 50–200 m downwind from a damaged Type B package. Typically a release of A_2 over a few hours has been shown to result in an effective dose equivalent limit of ~10 mSv at these distances. The corresponding levels of ground contamination are up to about an order of magnitude higher than the permissible levels of non-fixed surface contamination for Type B packages specified in the Regulations for normal transport and, as noted above, for β/γ emitters would result under average weather conditions in external radiation dose rates about 2–3 times that due to natural background.

Finally, it is of interest to compare the implied accident dose limit of 1–50 mSv effective dose equivalent corresponding to the Type B package activity release limit of A_2 over a period of up to one week derived in Section 3 with emergency dose limits applied at fixed nuclear installations. In the UK emergency action levels at CEGB nuclear power station sites are based upon a whole body dose of 100 mSv, or 300 mSv to the thyroid or other single organs [7], while the whole body dose range for evacuation countermeasures in the event of an accident recently recommended by the ICRP and IAEA is 50–500 mSv [8, 9]. Thus these intervention levels are about an order of magnitude above the implied Type B package accident limit, a situation which may be justified by noting that transport accidents may occur in relatively densely populated urban areas, whereas power stations and other fixed nuclear installations tend to be sited in more remote rural areas. Indeed, the collective doses associated with a given release at typical power station sites and in urban areas within the UK are approximately in the ratio 1:10 (see Fig. 2 of Ref. [10]), thus the collective dose resulting from a reactor accident at the ICRP and IAEA intervention levels would be comparable with that for a severe transport accident occurring in an urban area with an activity release corresponding to the IAEA limit for Type B packages.

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