Investigation of Possible Exemption or Exclusion Levels for Non-aqueous Liquids to Support the RSA93 Exemption Order Review

S F Mobbs

ABSTRACT

As part of the better regulation initiative, the Department of Energy and Climate Change (DECC) and the Devolved Administrations have consulted on a new exemption orders regime under the Radioactive Substances Act 1993 and the Environmental Permitting regulations (EPR) 2010. The overall aim is to have a simpler set of exemption orders, informed by risk, that are more easily linked to the European Basic Safety Standards Directive (BSSD).

As part of the work to support the review of the exemption orders, DECC asked HPA to consider whether it would be appropriate to apply the activity concentration levels recommended by the European Commission for unconditional clearance of solids, to the exclusion or exemption of non-aqueous liquids from the provisions of the revised regime. This report reviews the parameters used in the derivation of the unconditional clearance levels for solids and concludes that the clearance levels would be applicable for the exclusion of non-aqueous liquids, though there may be a need for additional modifying factors for some radionuclides. The unmodified clearance levels for solids would, alternatively, be applicable for the exemption of non-aqueous liquids, with limits specified for the quantity that can be disposed of to a particular route.

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Centre for Radiation, Chemical and Environmental Hazards
Radiation Protection Division
Chilton, Didcot, Oxfordshire OX11 0RQ

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1 INTRODUCTION

The Radioactive Substances Act (RSA 93) (Great Britain, 1993) provides the framework for controlling the accumulation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. In particular, RSA 93 requires prior authorisation for the accumulation, disposal or discharge of radioactive wastes to the environment unless they are outside the scope of the Act (in Schedule 1) or they meet the provisions of one of the Exemption Orders under the Act. The UK Environment Agencies are required to ensure that doses to members of the public do not exceed specified dose constraints, as part of the process of authorising such disposals or discharges.

The Department of Energy and Climate Change (DECC) and the Devolved Administrations (DA) are currently developing a new exemption orders regime under the RSA 93 and the Environmental Permitting regulations (EPR) 2010 (Great Britain, 2010). In England and Wales it is proposed that the revised regime will be incorporated into the EPR in 2011. In Scotland and Northern Ireland RSA 93 will be amended and the new exemption orders will be made at the same time. The overall aim is to have a simpler set of exemption orders, informed by risk, that are more easily linked to the European Basic Safety Standards Directive (BSSD) (European Commission, 1996). A consultation on the proposed new regime was held by DECC and DA in summer 2009 (UK Government et al, 2009). The proposed new regime included a set of exclusion levels defining activity concentration levels that are outside the scope of the regulation (equivalent to the BSSD concept of unconditional clearance) and a single Exemption Order containing a set of exemption levels with associated specified conditions[*].

European guidance on unconditional clearance levels (CLs) for solid wastes containing radionuclides is given in Radiation Protection Report 122 Part 1 (RP122 Part 1) (European Commission, 2001), for practices. The proposed new UK regime used these CLs for solids to define activity concentrations in solids that are excluded from the new regime.

As part of the work to support the review of the exemption orders, DECC asked HPA to consider whether the EC unconditional clearance levels (CLs) for solids could also be used as exclusion or exemption levels for non-aqueous liquids.

[*] UK exemption orders should not be confused with the EC concepts of exemption and clearance. The EC exemption levels apply to exemption from the BSSD reporting requirement and apply to small quantities of materials; use and disposal of exempt material can occur with no prior authorisation under BSSD i.e unconditionally. EC clearance levels define activity concentration levels in solids (from regulated practices) that can be disposed of without requiring prior authorisation under BSSD. Therefore they are also unconditional, but apply to unlimited quantities. The current UK exemption orders generally contain conditions. The exception is the Substances of Low Activity Exemption Order (SoLA), which is unconditional and fulfils the same role as EC clearance levels.

2 DOSE CRITERIA

The CLs were derived on the basis of the criteria used for exemption and clearance in the BSSD, namely:

(a) the effective dose expected to be incurred by any member of the public due to the exempted practice is of the order of 10 μSv or less in a year;

and

(b) either the collective effective dose committed during one year of performance of the practice is no more than about 1 man Sv or an assessment of the optimization of protection shows that exemption is the optimum option.

Two additional dose criteria were applied in the derivation of the CLs in RP122 Part 1: an effective dose criterion of 1mSv in a year to an individual from unforeseen events and an equivalent dose to skin of 50mSv in a year (Harvey et al, 1993, European Commission, 2001).

3 DISPOSAL OF NON-AQUEOUS LIQUIDS

There are many different non-aqueous liquids in use in industry and these include various solvents, oils, organic liquid scintillants and to a lesser extent, mercury. Disposal of non-aqueous liquids in England and Wales is controlled through application of the Environmental Permitting Regulations (EPR) (Great Britain, 2010)*. In summary, some form of treatment is required before disposal. The application of BAT (best available technique) is an important principle applied to the disposal of wastes under EPR and therefore the exact treatment that is used will depend on the nature of the liquid and what treatment is available and appropriate. Possible treatments for non-aqueous liquids can include incineration. Direct disposal of liquids to landfill is generally avoided and is only considered when other options have been ruled out. However, incinerator ash may be disposed of to a landfill site. Disposal to a sewer is an option for some non-aqueous liquids, again depending on the available and appropriate treatment options and the application of BAT. Organic scintillants containing ^{3}H and ^{14}C below 4 Bq ml^{-1} can be disposed of to a sewer under the provisions of the substances of low activity exemption order (see RSA93 for Scotland and Northern Ireland and Schedule 23 of EPR for England and Wales). Direct disposal of non-aqueous liquids to a river is not an option as only clean water should be discharged to rivers.

* In Scotland it is controlled through the Special Waste Amendment (Scotland) Regulations 2004 (Scottish Government, 2004) and in Northern Ireland through the Hazardous Waste Regulations (Northern Ireland) 2005 (Northern Ireland, 2005).

4 APPROACH

Two methods have been considered to identify whether the CLs are suitable for unconditional clearance of non-aqueous liquids:

1) perform simple generic dose assessments for some example non-aqueous liquids. The non-aqueous liquids considered for this work were organic liquid scintillants, oils and mercury;

2) determine whether the parameter values used in RP122 Part 1 to determine the CLs encompass the range of possible scenarios for disposal and recycling of non-aqueous liquids.

The details of these two approaches, the estimated doses and parameter comparisons are given in Appendices A and B, respectively.

The quantity of non-aqueous liquid containing activity concentrations at the CL that could be disposed of to a sewer, an incinerator, a landfill site or accidentally to a river or coastal waters and meet the appropriate individual dose criterion was then investigated. The details and results of the calculations are given in Appendix C.

5 DISCUSSION AND CONCLUSIONS

The scenarios and pathways considered in RP122 Part 1 (European Commission, 2001) encompass the range of scenarios and pathways that apply to contaminated solid wastes. They cover the four exposure pathways: ingestion, inhalation, external exposure and contamination of skin. The RP122 Part 1 scenarios do not include direct ingestion of foodstuffs contaminated at an activity concentration equal to the CL, but they do include ingestion of foods grown on contaminated soils and inadvertent ingestion of dust. The CLs are also more restrictive than the clearance levels for recycling of metals (European Commission, 1998) and building rubble (European Commission, 2000) and hence also encompass these scenarios. Therefore, although the CLs in RP122 Part 1 cannot be applied to drinking water or foodstuffs, they do apply to the recycling, reuse and disposal of solids.

The results given in Appendices A, B and C demonstrate that the CLs for solids, as recommended in RP122 part 1, are suitable for use for unconditional clearance (exclusion in the UK) of non-aqueous liquids for the majority of radionuclides; the exceptions are ^{32}P, ^{33}P, ^{35}S, ^{65}Zn, ^{85}Sr and ^{99}Tc. Hence, for these radionuclides it may be necessary to either reduce the activity concentration that is used for unconditional clearance (by application of a modifying factor) or to restrict the amount that can be disposed of to one particular facility (a small sewage treatment works) by applying disposal constraints. The former approach would correspond to the UK concept of exclusion whereas the latter would correspond to the UK concept of exemption, subject to some conditions.

Disposal of non-aqueous liquids containing activity concentrations equal to the CLs would also be expected to give rise to collective doses well below the 1 man Sv collective dose criterion specified in the Euratom Basic Safety Standards Directive, based on estimates of the amount of contaminated oils, mercury and liquid scintillants disposed of per year in UK. Non-aqueous liquids could give rise to collective doses above 1 man Sv per year of practice if more than 2 10^4 t y^{-1} was discharged or recycled.

Since the proposed revised regulatory regime will contain provisions for either exclusion (equivalent to unconditional exemption in the BSSD) or exemption of materials containing low levels of radioactivity, several options are presented below for consideration:

a) Specify that the CLs for solids derived by RP122 part 1 can be used for the **exclusion** of non-aqueous liquids from the provisions of the regulatory regime, for all radionuclides. This would mean that non-aqueous liquids containing levels of radioactivity below these CLs would not be considered to be radioactive for the purposes of the regulatory regime, and no controls would be placed on the quantities that can be disposed of. Use of the CLs could mean that the individual dose criterion would not be met if a user disposes of more than about 0.5 t y^{-1} of non-aqueous liquids containing ^{32}P, ^{33}P, ^{35}S, ^{65}Zn, ^{85}Sr or ^{99}Tc to a single small sewage treatment works.

b) Specify that **modifying factors** are applied to the CLs for solids derived by RP122 part 1 and that these modified CLs can be used for the **exclusion** of non-aqueous liquids from the provisions of the regulatory regime, for all radionuclides. This would mean that non-aqueous liquids containing levels of radioactivity below these CLs would not be considered to be radioactive for the purposes of the regulatory regime, and no controls would be placed on the quantities that can be disposed of. Use of the modifying factors given in Table 1 would ensure that the individual dose criterion for exemption and clearance was met in the event of disposal of non-aqueous liquids to incinerators, sewers, landfill sites or accidentally to rivers or coastal waters.

TABLE 1 Activity concentrations for exclusion of non-aqueous liquids

Radionuclide	Activity concentration Bq g^{-1}
^{32}P, ^{33}P,	0.05 multiplied by the activity concentration specified in RP122 Part 1 [(a)]
^{35}S, ^{65}Zn, ^{85}Sr, ^{99}Tc	0.1 multiplied by the activity concentration specified in RP122 Part 1 [(a)]
All other radionuclides	1.0 multiplied by the activity concentration specified in RP122 Part 1 [(a)]

Note

(a) The activity concentration specified in RP122 Part 1 as the clearance level in solid for that radionuclide

c) Specify that the CLs for solids derived by RP122 part 1 can be used for the **exemption** of non-aqueous liquids from the authorisation requirement for disposal, for all radionuclides. Also specify that records should be kept of the amounts disposed of but do not specify a limit on the quantity that can be disposed of. This would mean that the non-aqueous liquids would be considered to be radioactive but would not require prior authorisation for disposal. Information would be available to assess the quantities involved and improve

estimates of the resulting individual and collective doses. However, disposal of more than 0.5 t y^{-1} of non-aqueous liquids to a single small sewage treatment works may not meet the individual dose criterion for six of the radionuclides.

d) Specify that the CLs for solids derived by RP122 part 1 can be used for the **exemption** of non-aqueous liquids from the authorisation requirement for disposal, for all radionuclides. The exemption order would also specify **annual disposal limits** of between 0.5 and 10 t y^{-1} per user for disposal to a single sewage treatment works, depending on the radionuclide. Annual disposal limits could also be specified for disposal to an incinerator or to a single landfill site but these may not be necessary if the expected volumes of non-aqueous liquids containing radionuclides are sufficiently small. This would mean that the non-aqueous liquids would be considered to be radioactive but would not require prior authorisation for disposal. The annual disposal limits given in Table 2 would ensure that the individual dose criterion was met.

TABLE 2 Quantity limits for exemption of non-aqueous liquids at the EC clearance level

Radionuclide	Quantity at the activity concentration specified in RP122 Part 1 that can be disposed of to one facility, t y^{-1}		
	Incinerator[(a)]	Sewage treatment works	Landfill site[(a)]
^{32}P, ^{33}P,	100	0.5	10^4
^{35}S, ^{65}Zn, ^{85}Sr, ^{99}Tc	100	1	10^4
All other radionuclides	100	10	10^4

Note (a) These quantity limits may not be required since it is expected that the quantities of non-aqueous liquids for disposal will be smaller than these values.

e) Perform a **detailed dose assessment** specifically for non-aqueous liquids to derive levels that correspond to the exemption criteria and use these derived levels for either **exclusion or exemption** of non-aqueous liquids. This would require a new assessment to be performed but would mean that the exemption or exclusion was risk based.

The choice of the optimum approach will depend on the balance of many considerations, including estimates of the quantities of non-aqueous liquids that would be involved, the associated health impact and the results of a regulatory impact assessment.

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APPENDIX A Generic scoping assessments for the disposal of non-aqueous liquids

A1 INTRODUCTION

Generic scoping assessments were performed for the disposal of contaminated organic liquid scintillants, mercury and oils, based on available data.

A2 ORGANIC LIQUID SCINTILLANTS CONTAINING ^{3}H AND ^{14}C

A2.1 Existing assessment NRPB M1179

An assessment of the doses from the disposal of organic liquids containing ^{3}H and ^{14}C was undertaken by HPA (then National Radiological Protection Board, NRPB) in 2000 and the results were published in NRPB report number M1179 (M1179) (Mobbs et al, 2000). M1179 considered liquid scintillants that could become contaminated with ^{3}H or ^{14}C and radiopharmaceuticals containing ^{14}C. The upper bound of the quantity of organic liquid scintillant disposed of by a single user was assumed in M1179 to be 10 m^3 y^{-1}, with 1 m^3 y^{-1} considered to be a reasonable value for a large user*. The liquid scintillant was assumed to be in 20 ml vials each containing 5 to 10 ml of the scintillant. Following use, up to 100 vials could be present in a bag for disposal, and up to 1000 vials could be present in a waste drum. Liquid scintillant is an irritant, it is highly flammable and sometimes corrosive and therefore its use and disposal is regulated; in England and Wales this is under Environmental Permitting Regulations (EPR), (Great Britain, 2010); in Scotland by the Special Waste Amendment Regulations 2004 (Scottish Government, 2004); and in Northern Ireland by the Hazardous wastes regulations (Northern Ireland) 2005, as amended (Northern Ireland, 2005). Incineration is the usual treatment method. Radiopharmaceuticals introduced into the body for diagnostic purposes are subsequently excreted in urine and hence discharged to sewers.

The M1179 assessment considered the following scenarios: inhalation following a spill or fire, skin dose following a spill, disposal to a landfill site, incineration, disposal to a sewer and accidental disposal to a river. It concluded that the activity concentration levels specified in the Substances of Low Activity Exemption Order (SoLA), 1992 (Great Britain, 1992) for unconditional clearance of organic scintillants met the Basic Safety Standards Directive (BSSD) (European Commission, 1996) dose criteria for exemption. M1179 also estimated that 1500 users each disposing of 1 m^3 y^{-1} of liquid organic scintillant at the exempt activity concentration of 4 Bq ml^{-1} (as specified in SoLA) into the same river (or other disposal route) would still meet the 10 μSv y^{-1} dose criterion.

The M1179 assessment methodology was used in this study to derive activity concentration levels that would meet the exemption criteria specified in the BSSD.

* Based on industrial data.

A2.2 Individual dose

The results in the M1179 assessment were used to estimate the release of activity that would correspond to an individual dose of 10 μSv y^{-1}, by appropriate scaling. The results for the fire and spill scenarios indicate that an individual dose of 10 μSv y^{-1} would correspond to a release of 2 MBq of ^{3}H and 0.2 MBq of ^{14}C. The results for the incineration and disposal scenarios indicate that disposal to a river is estimated to give rise to the highest individual doses for both ^{3}H and ^{14}C: an individual dose of 10 μSv y^{-1} was found to correspond to disposal of about 10 TBq y^{-1} of ^{3}H or 6 GBq y^{-1} of ^{14}C. The discharges corresponding to the individual dose criterion for the other disposal routes were at least an order of magnitude greater.

These results were then used to determine the maximum concentration of ^{3}H or ^{14}C in the scintillant that could be disposed of and still meet the 10 μSv y^{-1} dose criterion. In order to do this it was assumed that one user disposes of 10 m^3 in a year (considered to be a very significant disposal from a user) to a landfill site, incinerator or sewer. The result was 2 10^7 Bq ml^{-1} for ^{3}H and 10^5 Bq ml^{-1} for ^{14}C, for this one user. However, the fire and spillage scenarios restrict the activity concentration for ^{3}H to 8 10^5 Bq ml^{-1} and the activity concentration for ^{14}C to 2 10^4 Bq ml^{-1} when the additional criterion that the effective dose from an unforeseen event is below 1 mSv is applied. If disposal of 10 m^3 y^{-1} to a river is also considered, as an unforeseen event since it would not be allowed due to the hazardous nature of the wastes, then the corresponding derived maximum activity concentration levels are unchanged. (If disposal to a river is considered in the same way as disposal to landfill, incinerator and sewer, then the derived maximum concentrations would be 8 10^5 Bq ml^{-1} and 600 Bq ml^{-1} for ^{3}H and ^{14}C, respectively).

Since more than one user could dispose of waste to the same facility, the same approach was used to derive the maximum activity concentration levels if it was assumed that 100 large users each dispose of 1 m^3 y^{-1} into the same incinerator, landfill site or sewage treatment works. If the fire and spillage scenarios and the accidental disposal of 1 m^3 y^{-1} into a river are also considered then the maximum concentration of ^{3}H or ^{14}C in the liquid scintillant would need to be restricted to about 8 10^5 Bq ml^{-1} and 10^4 Bq ml^{-1}, respectively, in order to meet the relevant individual dose criterion. (Consideration of accidental disposal of 1 m^3 y^{-1} by all 100 users into the same river would only result in a reduction of the maximum activity concentration of ^{14}C to 6000 Bq ml^{-1}).

Hence, a maximum acitivity (unconditional clearance level) of 8 10^5 Bq ml^{-1} for ^{3}H and 10^4 Bq ml^{-1} for ^{14}C would be appropriate for organic scintillants, based on consideration of the dose to an individual.

A2.3 Collective dose

In order to estimate the collective dose, it was assumed that the UK could have up to 500 large users (based on the fact that many would be universities and there are currently fewer than 150 universities in UK). It was also assumed that each large user disposed of 1 m^3 y^{-1} of organic scintillants containing activity concentrations of 8 10^5 Bq ml^{-1} of ^{3}H and 10^4 Bq ml^{-1} of ^{14}C, as derived above.

PC-CREAM08 (HPA, 2009) was used to estimate the collective dose per Bq per year discharged of ^{3}H and ^{14}C, using standard data. This was used to calculate the collective dose per year of practice assuming that 500 users would dispose of 4 10^{14} Bq and 5 10^{12} Bq per year of ^{3}H and ^{14}C, respectively. The estimated collective doses per year of practice were 0.6 man Sv for ^{3}H and 1.5 man Sv for ^{14}C for discharge to atmosphere, and 2 10^{-4} man Sv for ^{3}H and 1.0 man Sv for ^{14}C for discharge to the marine environment. Hence the collective dose criterion of 'no more than about 1 man Sv per year of practice' would be met by disposal of liquids containing activity concentrations at these levels. Obviously, lower concentrations would give rise to lower collective doses.

If each large user experiences one fire or spill in a year then M1179 (Mobbs et al, 2000) estimated that this would result in a collective dose below 1 man Sv.

A2.4 Comparison of derived levels with CLs

The recommended CL for ^{3}H in RP122 part 1 is 100 Bq g^{-1}. Since the density of organic liquids is about 1 t m^{-3}, this CL is assumed to be equivalent to 100 Bq ml^{-1}. This is much smaller than the derived value of 8 10^{5} Bq ml^{-1} that was estimated above using the M1179 methodology.

The recommended CL for ^{14}C in RP122 part 1 is 10 Bq g^{-1}. This CL is actually based on scenarios considered in the EC guidance for clearance of building rubble (RP113) (European Commission, 2000) since the CL based on the scenarios in RP122 was less restrictive, at 100 Bq g^{-1}. Assuming that this is equivalent to 10 Bq ml^{-1}, the CL is much smaller than the derived value of 10^{4} Bq ml^{-1} obtained above, using the M1179 methodology.

Since the CLs are about three orders of magnitude smaller than the derived activity concentrations, the 1 man Sv per year of practice dose criterion will be met unless there are more than 500,000 large users in the UK (each disposing of 1 m^{3} y^{-1} at the CL of 10 Bq g^{-1}). The number of large users in the UK disposing of 1 m^{3} y^{-1} is unlikely to reach this level.

A2.5 Discussion

The M1179 methodology has been used to derive activity concentrations that could be used as exemption or exclusion levels for liquid organic scintillants containing ^{3}H and ^{14}C. The derived levels are about three orders of magnitude greater than the CLs. Therefore the CLs derived for ^{3}H and ^{14}C in solids could be used as exemption or exclusion levels for liquid organic scintillants containing ^{3}H and ^{14}C as the exemption dose criteria will be met. The CLs for ^{3}H and ^{14}C are higher than the exempt activity concentrations that are currently specified in the relevant UK exemption order (SoLA), of 4 Bq ml^{-1}. If there are more than 500,000 large users of liquid scintillants in the UK resulting in disposal of 5 10^{5} m^{3} y^{-1} or more to sewers every year then the unconditional clearance of organic scintillant liquids at the CL would have to be revisited to decide if it was the optimum approach.

A3 SCOPING ASSESSMENT FOR CONTAMINATED MERCURY

A3.1 Individual doses

Exposure to mercury is tightly controlled as a result of its toxicity: it is toxic by inhalation, dermal contact and ingestion (HPA, 2010). Employers have a duty under the Control of Substances Hazardous to Health (COSHH) Regulations (UK Parliament, 2002) to control workplace exposures to hazardous substances, although the regulations do not apply to radioactive substances since they are controlled by RSA93 and EPR. Workplace exposure limits (WELs) are specified by the Health and Safety Executive (HSE) in HSE document EH40 (HSE, 2005); however, the current version does not specify a WEL for mercury. The relevant public health guidelines, quoted by HPA on its website www.hpa.org.uk, are the air quality guidelines for Europe, published by WHO (WHO, 2000). These specify an air quality value of 1 μg m^{-3} for mercury. Assuming an adult is exposed to air at this level for 8760 hours per year with a breathing rate of 0.92 m^3 h^{-1} gives an intake of about 8 mg y^{-1}; the corresponding intake for an infant is 1.9 mg y^{-1}. The tolerable daily intake (TDI) is 0.3 μg per kg body weight per day (www.hpa.org.uk), corresponding to about 8 mg y^{-1} for a 70 kg adult and 1.1 mg y^{-1} for a 10kg infant.

A scoping estimate was made of the dose to an adult or an infant who inhales contaminated mercury at the air quality guideline level, assuming that the mercury is contaminated with radionuclides at the CL.

The lowest CL in RP122 Part 1 is 0.01 Bq g^{-1} and the corresponding annual intake using the assumptions above is 8 10^{-5} Bq (adult) and 2 10^{-5} Bq (infant). The radionuclide with this low CL that also has the highest dose coefficient is ^{231}Pa, with an inhalation dose coefficient of 2.5 10^{-4} Sv Bq^{-1} for an adult and 8.3 10^{-4} Sv Bq^{-1} for an infant. The resulting estimated doses were 0.02 μSv y^{-1}, well below the 10 μSv y^{-1} criterion.

The highest CL in RP122 Part 1 is 10^4 Bq g^{-1} (for ^{103m}Rh and ^{71}Ge). Assuming that the mercury is contaminated to this level and controlled to its air quality guideline value gives an intake of about 80 Bq y^{-1} (of ^{103m}Rh or ^{71}Ge) for an adult and 20 Bq y^{-1} for an infant. Applying the relevant dose coefficients for these two radionuclides gives an estimated annual dose to an adult or an infant below 0.01 μSv. These are also well below the 10 μSv y^{-1} dose criterion.

These generic calculations, based on the highest and lowest clearance levels and the corresponding highest dose coefficients, indicate that other combinations of CL and dose coefficient would also give rise to inhalation doses below the 10 μSv y^{-1} dose criterion. For example, for ^{14}C, with a CL of 100 Bq g^{-1} and an adult dose coefficient of 5.8 10^{-10} Sv Bq^{-1}, the adult intake is 0.8 Bq y^{-1} and the corresponding dose would be 5 10^{-10} Sv y^{-1}.

Considering ingestion pathways, the drinking water guideline value for mercury is 1 μg l^{-1} (DWI, 2003). Assuming an adult intake rate of 600 l y^{-1} gives an intake of 0.6 mg y^{-1}, less than the intake by inhalation considered above and less than the TDI value. The corresponding value for an infant is 0.3 mg y^{-1}, also below the TDI. Using a similar generic approach to the one above by selecting the radionuclides with the smallest and highest CLs (^{231}Pa, ^{106m}Rh and ^{71}Ge) the estimated dose to an adult or an

infant from ingesting contaminated mercury in drinking water would be extremely small, below 0.001 μSv y^{-1}. Advice on cleaning up after breakages or spills involving mercury specifies the use of protective clothing (gloves and masks) (HPA, 2010) and hence inadvertent ingestion of mercury would be expected to be negligible.

Hence it can be concluded that the normal controls that are in place because of the toxicity of mercury imply that it is very unlikely that anyone could receive a dose from ingestion or inhalation of contaminated mercury with activity concentrations at the CLs that was above a small fraction of a μSv y^{-1}.

A different approach was taken in order to estimate the dose from external exposure to contaminated mercury or from contamination of the skin with contaminated mercury. Representative exposure geometries were considered and then these were compared with those assumed in RP122 for the derivation of the CLs, see Appendix B. If the representative exposure geometries were encompassed by those used for the derivation of the CLs then use of the CL for contaminated mercury would result in individual doses below 10 μSv y^{-1}.

A storage tank containing contaminated non-aqueous liquid (mercury) was considered for the external exposure pathway. It is reasonable to assume that an adult spends 10% of their working time near it, ie 200h y^{-1}. The tank is most likely to be finite in size but could be large enough to be equivalent to a semi-infinite source. This scenario was encompassed in the derivation of the CLs, see Appendix B.

A spill of mercury on the skin was considered for the skin contamination pathway. It would be removed quickly, within 10mins and it was assumed that it would be unlikely to involve more than 1 ml of mercury. This scenario was encompassed in the derivation of the CLs, see Appendix B. Even if all of this spilt mercury was absorbed through the skin, the estimated dose to an individual would be less than 0.02 μSv (and this extremely conservative assumption would imply that the TDI would be exceeded).

Hence the scoping calculations of the dose to an individual indicate that the RP122 CLs are suitable for use as exemption or exclusion levels for contaminated mercury.

A3.2 Collective dose

An upper bound of the collective dose was obtained by assuming that 1% of the world production of 200 m^3 y^{-1} of mercury is contaminated with activity concentrations at the CL and disposed of in a year.

PC-CREAM08 (HPA, 2009) was used to estimate the collective dose per Bq per year discharged, for 38 radionuclides (23 single radionuclides and 15 decay chains), using standard data. Assuming that a total of 2 m^3 y^{-1} of mercury contaminated by a radionuclide with an activity concentration at the CL is discharged to the atmosphere, the collective dose was estimated to be well below 1 man Sv, at 10^{-3} man Sv. Discharges to the marine environment would give rise to an even smaller collective dose.

A3.3 Discussion for mercury

The CLs for solids given in RP122 Part 1 are suitable for use for contaminated mercury since the resulting dose to an individual would be well below the 10 μSv y^{-1} dose criterion and the collective dose would be well below 1 man Sv per year of practice.

A4 SCOPING ASSESSMENT FOR OILS

The UK annual consumption of lubricating oil is about 800,000 t (about 800,000 m^3) of which 50% is recycled (http://www.wastebook.org/mineral.htm). If it assumed that a nominal 10 UK nuclear power plants (NPPs) each produce around 10 m^3 y^{-1} of contaminated waste oil which could be recycled, then it is reasonable to assume that less than 0.03% of all recycled oil is contaminated with radionuclides.

Representative exposure scenarios were considered, allowing for the fact that exposure to oils is also limited by other legislation. The resulting intakes and exposure times were estimated and compared with those assumed in RP122 for the derivation of CLs. The results were used to estimate whether the exemption dose criteria would be met if the CLs were adopted for exemption or exclusion of contaminated oils.

A4.1 Individual dose

The occupational exposure limit for inhalation of oil mists is 5 mg m^{-3} (HSE, 1997; HSE, 2005). Hence this would limit the intake by inhalation to approximately 50 g in a year, assuming exposure to this level of oil mists for 2000 h y^{-1} and an inhalation rate of 1.2 m^3 y^{-1}. Assuming that 0.03% of the oil is contaminated, this would correspond to an intake of 0.015 g y^{-1}. This is lower than the value considered for the INH-A pathway in RP122 Part 1 (2 g y^{-1}), see Appendix B, and hence the individual dose would be expected to be below 10 μSv y^{-1}. The individual dose criterion would still be met if up to 4% of the oil mists an individual was exposed to in a year were contaminated at the CL.

The drinking water standard for different solvents or oils ranges from around 0.02 to 1000 μg l^{-1} (Great Britain, 2000; HPA, 2010). Using an intake rate of 600 l y^{-1} of water, this corresponds to an intake of up to 0.6 g of solvents or oils in a year, though it would be reasonable to assume that only a small fraction of this was contaminated. Assuming that inadvertent ingestion of oils is similar to the inadvertent ingestion of dust, this would result in an estimated intake of about 8 g y^{-1} (Smith and Jones, 2003), though not all the oil would be contaminated. Since an intake of 100 g y^{-1} of contaminated material is included in the RP122 Part 1 calculations, see Appendix B, then the individual dose from ingestion of contaminated oil would be expected to be below 10 μSv y^{-1}.

Considering a storage tank containing contaminated oil, it is reasonable to assume that a person spends 10% of their working time near it, i.e. 200 h y^{-1}. The tank is most likely to be finite in size but could be large enough to be equivalent to a semi-infinite source. Even if a person spent all of their working time near a smaller volume of oil (e.g. a 1 m^3 source), their exposure would be equivalent to 200 h y^{-1} near a semi-infinite source since the dose from a 1 m^3 source is about 10% of that from a semi-infinite source (Harvey et al, 1993; Chen et al, 2007). This exposure situation is encompassed by the

CL calculations, see Appendix B, and hence the dose to an individual from external exposure would be expected to be below 10 μSv y^{-1}.

As discussed in the main text, the disposal of waste material such as contaminated oil filters would be regulated (under EPR in England and Wales) and would require prior treatment and the application of BAT. The contaminated oil filters could eventually be incinerated or disposed of in a landfill site, resulting in external exposure of workers. However, it is unlikely that oil filters would comprise a significant fraction of the total waste that a worker at the incinerator or landfill processes. The RP122 Part 1 calculations consider external exposure to a worker at a landfill site where 10% of the material at the site is contaminated at the CL, see Appendix B. Since the CLs are lower than the corresponding clearance levels for recycling of metals (which considers smelting in a furnace) (European Commission, 1998) and this considers similar exposure pathways to an incinerator, it can be concluded that the RP122 Part 1 scenarios also encompass exposure following disposal to an incinerator. Therefore the disposal of oil filters to a landfill site or incinerator is encompassed by the RP122 CL calculations, and the resulting dose to an individual would be expected to be below 10μSv y^{-1}.

Considering contamination of skin, it is reasonable to assume that if a spill resulted in oil covering a person's hands or arms then it would be removed within an hour. The RP122 CL calculations encompass a spill involving 20 ml of oil spread over 2000 cm^2 of skin for an hour, see Appendix B. Since this is a very conservative assumption due to the large contaminated area, it would be expected that the individual dose criterion would be met in the event of a spill of oil.

A4.2 Collective dose

The collective dose was estimated by assuming that a nominal 10 UK NPPs discharge a total of 100,000 l y^{-1} (100 m^3 y^{-1}) of contaminated oils containing radionuclide activity concentrations at the CL.

PC-CREAM08 (HPA, 2009) was used to estimate the collective dose per Bq per year discharged, for 38 radionuclides (23 single radionuclides and 15 decay chains), using standard data. Assuming that a total of 100 m^3 y^{-1} of oil contaminated by a radionuclide with an activity concentration at the CL is discharged to the atmosphere, the collective dose was estimated to be 4 10^{-3} man Sv, well below 1 man Sv. Discharges to the marine environment would give rise to an even smaller collective dose.

A4.3 Discussion for oils

The CLs for solids given in RP122 Part 1 are suitable for use for contaminated oils since the resulting dose to an individual would be well below the 10 μSv y^{-1} dose criterion and the collective dose would be well below 1 man Sv per year of practice.

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APPENDIX B Review of RP122 parameter values

B1 INTRODUCTION

The parameter values considered in RP122 Part 1 for the derivation of the CLs were selected to encompass the range of scenarios and pathways that would apply to the reuse, recycling and disposal of contaminated solid wastes. The pathways considered were ingestion, inhalation, external exposure and contamination of skin. The scenarios did not include direct ingestion of foodstuffs contaminated at the CLs, but they did include inadvertent ingestion of contaminated material and ingestion of foods grown on contaminated soils. The scenarios, pathways and parameter values are described in detail in RP122 Part 1 (European Commission, 2001).

A review of the RP122 part 1 parameter values was undertaken to determine if they covered typical non-aqueous liquid scenarios. This was performed by comparing the amounts of material assumed to be ingested or inhaled, and the exposure times and geometries used for the assessment of external doses.

B2 RP122 SCENARIOS

RP122 Part 1 considered 8 scenarios with the following intakes and exposure geometries:

INH-A: intake by inhalation of dust (adult): intake is 1800 h x 1.2 m^3 h^{-1} x 10^{-3} g m^{-3}

= about 2 g contaminated material per year

INH-B: intake by inhalation of dust (infant): intake is 8760h x 0.1 x 0.24 m^3 h^{-1} x 10^{-4} g m^{-3} = about 0.02 g contaminated material per year

ING-A: intake by ingestion (adult): intake is 20g contaminated material per year

ING-B: intake by ingestion (infant): intake is 100g contaminated material per year

EXT-A: external exposure to large source: 1800 h y^{-1} exposure to a semi-infinite source, of which 0.1 is contaminated (i.e. dilution = 0.1). This is equivalent to exposure of 180 h y^{-1} to a semi-infinite source with no dilution

EXT-B: external exposure to finite source: 200 h y^{-1} exposure to a 5 x 2 x 1 m^3 block, no dilution

EXT-C: external exposure to contaminated walls in a house: 7000 h y^{-1} exposure in a house where 2% walls are contaminated (dilution of 0.02), i.e. equivalent to 140 h y^{-1} in a house made entirely of contaminated material (i.e. no dilution)

SKIN: contamination of skin: exposure to a 0.01 cm thick layer of material, density 1.5 g cm^{-3}, on a 2000 cm^2 area of skin, for 1800 h y^{-1}. This is equivalent to a spill of 20 ml of liquid that stays on 2000 cm^2 of the skin for 1800 h y^{-1}.

Collective dose is not considered explicitly within RP122. However, the two EC reports that consider clearance levels for recycling of metals (RP89) (European Commission, 1998) and building materials (RP113) (European Commission, 2000) do consider collective doses and estimate them to be below 1 man Sv per year of practice. RP122 clearance levels are comparable with or lower than those in RP89 and RP113 and hence RP122 concluded that the collective dose criterion would be met by the derived CLs.

B3 COMPARISON WITH M1179 SCENARIOS FOR LIQUID SCINTILLANTS

For the inhalation pathway, M1179 assumes that 10ml of organic scintillant is spilt and vaporises in a room or that 100 vials are involved in a fire. A person is assumed to be exposed for 1 hour and hence their intake is 0.3 ml (spill) or 30 ml (fire). RP122 part 1 assumes an intake of 2 g, equivalent to 2 ml for liquids with a density of 1 t m^{-3}. Hence RP122 encompasses this spillage scenario for materials with a density that is less than 6 t m^{-3}.

For the skin contamination pathway, M1179 assumes 1 ml is spilt onto 100 cm^2 of skin and remains there for 10 minutes. For an organic liquid with a density of 1 t m^{-3}, this corresponds to 0.01 g cm^{-2} covering 100 cm^2 of skin for 10 mins. RP122 part 1 encompasses this scenario since it considers the same amount of material per cm^2 on the skin, but a much longer exposure time.

It is not possible to compare RP122 directly with the other M1179 scenarios (disposal to a sewer or river, or incineration), since they were not considered explicitly in RP122. However, the generic assessment in Appendix A for ^{3}H and ^{14}C indicates that the RP122 scenarios are more conservative than the M1179 scenarios, since the derived levels in RP122 Part 1 are lower than those derived in Appendix A.

B4 CONTAMINATED MERCURY

For inhalation, the intake of mercury was estimated in Appendix A to be about 8 mg in a year, based on the air quality guideline value. Hence RP122 INH-A encompasses this inhalation scenario.

For ingestion, the intake of mercury was estimated in Appendix A to be very small compared to the RP122 part 1 intake, and hence RP122 part 1 covers the ingestion scenario for contaminated mercury.

For external and skin exposure: the scenarios considered in RP122 part 1 are very conservative for contaminated mercury as it is difficult to imagine how an individual could be exposed to such large quantities and for such long times. Since the density of mercury is greater than water (13 t m^{-3}), then a spill of 20 ml of mercury containing contamination at the CL on the skin would contain proportionally more activity than a spill of 20 ml of water. The clearance level calculations in RP122 part 1 assume a density of 1.5 t m^{-3}, implying that the dose from contaminated mercury on the skin would

be about 9 times greater. However the RP122 CLs assume a spill of 20ml and an exposure time of 1800h y^{-1}: these are both unreasonably large values for mercury on account of its toxicity, and hence it can be concluded that RP122 encompasses this scenario.

Hence the RP122 part 1 scenarios and pathways that were used to calculate the CLs also encompass scenarios that are relevant to contaminated mercury.

B5 OTHER NON-AQUEOUS LIQUIDS

The occupational exposure limit for oil mists limits the intake by inhalation to approximately 50 g in a year, see Appendix A. Since this is 25 times greater than the intake assumed in RP122 (which corresponds to a dose of 10 μSv y^{-1}) then the intrinsic hazard of oil is not sufficient to limit the intake to the level considered in RP122. However, as discussed in Appendix A, not all of the oil will be contaminated with radionuclides and it is reasonable to assume that 0.03% (i.e. less than 0.1%) of the quantity of recycled oil is contaminated. Applying a contaminated fraction of 0.1% to the occupational exposure limit for oil mists, this corresponds to an intake of 0.05 g contaminated oil in a year and RP122 INH-A encompasses this scenario.

Occupational exposure limits for other non-aqueous liquids range from around 1.5 mg m^{-3} to around 500 mg m^{-3} (HSE, 2005) and public health air quality guidelines are generally below 0.5 mg m^{-3} (HPA, 2010). Hence the intake by inhalation could be up to 1 kg y^{-1} for a worker or up to 4 g y^{-1} for an adult member of the public if it is assumed that they are exposed to concentrations in air at these limiting or guideline values for a year. However, the fraction of the intake of non-aqueous liquid that is contaminated at the CL also needs to be considered and this would be expected to be very small. RP122 Part 1 INH-A considers an intake of 2 g y^{-1} and this is 0.2% of the highest worker intake and 50% of the highest member of the public intake derived above. Hence RP122 Part 1 would encompass these intakes if the fraction of the non-aqueous liquid that was contaminated at the CL was below 0.2% (for exposure at the workplace) or below 50% (for exposure of the public).

In Appendix A it was estimated that the intake of contaminated oils in drinking water or by inadvertent ingestion would be less than 8 g y^{-1} and hence this is covered by both RP122 ING-A and ING-B even if it is conservatively assumed that all the material that is ingested is contaminated. Since the inadvertent ingestion rate is assumed to be independent of the material then inadvertent ingestion of any non-aqueous liquids would also be encompassed. Direct ingestion of non-aqueous liquids would not occur, but they could be present in small quantities in drinking water. The intake of 100 g y^{-1} considered in RP122 Part 1 would encompass ingestion of non-aqueous liquids that were present in drinking water at concentrations of up to 170 mg l^{-1}.

The external exposure scenarios discussed in Appendix A for oils are representative of the exposure scenarios for other non-aqueous liquids. They are encompassed by the geometries and exposure times considered in RP122.

The skin exposure scenario for an oil spill with a density of about 1 t m^{-3} represents less activity on the skin than is assumed in RP122 since RP122 used a density of 1.5 t m^{-3}. This means that the resulting dose will be less than the RP122 estimate. Hence it would be expected that the RP122 scenario also encompasses the skin contamination scenario for all other non-aqueous liquids with densities of 1.5 t m^{-3} or lower.

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APPENDIX C Disposal of non-aqueous liquids

C1 INTRODUCTION

The investigation of appropriate scenarios described in Appendices A and B indicates that the unconditional clearance levels for solids given in RP122 Part 1 (EC, 2001) may be suitable for use as exclusion levels for non-aqueous liquids (exclusion in RSA 93 and EPR is equivalent to the EC concept of unconditional clearance). The scenarios in RP122 Part 1 were developed for solids and therefore although they consider disposal to a landfill site, they do not explicitly consider disposal to an incinerator or discharge to sewers or rivers. As described in the main text, disposal of non-aqueous liquids in England and Wales is controlled through the Environmental Permitting Regulations (EPR) (Great Britain, 2010), in Scotland by the Special waste amendment Regulations 2004 (Scottish Government, 2004) and in Northern Ireland by the Hazardous wastes regulations (Northern Ireland) 2005, as amended (Northern Ireland, 2005). Direct disposal of liquids to landfill is generally avoided and is only considered when other options have been ruled out. However, incineration is a treatment option and incinerator ash may be disposed of to a landfill site. Direct disposal of non-aqueous liquids to a river is not an option as only clean water should be discharged to rivers. Disposal to a sewer is an option for some non-aqueous liquids, again depending on the available and appropriate treatment options and the application of BAT. Therefore these disposal routes were investigated to determine the quantity of non-aqueous liquid containing radionuclides at the CL activity concentrations that would meet the individual and collective dose criteria for exemption (European Commission, 1996). This was then compared with the quantity of non-aqueous liquid that would be produced by a very large user of organic scintillants or a single nuclear power plant, estimated to be about 10 t y^{-1} in the main text. The value of 10 t y^{-1} was therefore used as an estimate of the quantity of non-aqueous liquids that could be disposed of by a typical large user.

If the results indicate that the individual dose criterion is met by disposal of a quantity less than 10 t y^{-1} for some radionuclides there may be a need to specify either a) restrictions on the volume of non-aqueous liquids containing radioactivity concentrations at these levels that could be disposed of per year or alternatively b) lower activity concentrations for these particular radionuclides to ensure that the dose criterion is met even without restrictions on the quantity that can be disposed of. A restriction on the quantity that could be disposed of could be specified in the conditions for an exemption order, implying that the CLs could be used for exemption of non-aqueous liquids. The application of modifying factors to the CLs would allow non-aqueous liquids containing activity concentrations below the modified CLs to be excluded from the provisions of the Act.

C2 DISPOSAL TO SEWER

The quantity of non-aqueous liquid containing activity concentrations specified in RP122 Part 1 that could be disposed of per year to a sewer and still give rise to doses below

the 10 μSv y^{-1} individual dose criterion was estimated using four different approaches, as described below.

The first estimate was obtained by scaling the HPA published Generalised Derived Constraints (GDCs) for disposal to sewer for 50 of the radionuclides in RP122 Part 1 (NRPB, 2000; Harvey et al, 2010). The GDC for disposal to sewer is the discharge rate to a sewer, in Bq y^{-1}, that corresponds to a dose criterion of 300 μSv y^{-1}. The GDCs are based on a very small sewage treatment works (STW), serving 500 people and with a throughput of 2.2 10^4 m^3 y^{-1}. The activity disposed of per year that corresponds to the 10 μSv y^{-1} dose criterion was then calculated by scaling the GDC for disposal to sewer (NRPB, 2000; Harvey et al, 2010) and then dividing this by the activity concentration given in RP122 Part 1. This gives the following relationship:

Volume (m^3 y^{-1}) = 10^{-3} (m^3 l^{-1})*GDC (Bq y^{-1})/(30*RP122 Part 1 clearance level (Bq/l)).

The second approach was to perform a separate calculation for 21 radionuclides, including 13 radionuclides not considered in the GDC calculation, using the HPA sewer model (Titley et al, 2000) set up for a small STW with a throughput of 3.7 10^5 m^3 y^{-1}.

Additional estimates of the volume that could be disposed of to a sewer were obtained from IAEA clearance levels for discharge to a river or to a STW serving 20,000 people (IAEA, 1998). The volume at the RP122 clearance level that could be disposed of to a sewer was determined by dividing the IAEA clearance level, in Bq y^{-1}, by the clearance level.

Finally, the EA initial assessment methodology (Lambers and Thorne, 2006; Allot et al, 2006) was used to estimate the volumes that could be disposed of to a STW with a throughput of 3.6 10^4 m^3 y^{-1} and meet the individual dose criterion.

The results are summarised in Table C1.

TABLE C1 Comparison of volumes of non-aqueous liquids containing radionuclide activity concentrations at the clearance levels in RP122 Part 1 that can be disposed of to sewer

Description	GDC[(a)]	HPA[(b)]	IAEA[©]	EA[(d)]
Throughput of STW, $m^3\ y^{-1}$	$2.2\ 10^4$	$3.7\ 10^5$	$9\ 10^5$	$3.6\ 10^4$
Number of radionuclides considered	50	21	33	62
Largest estimated quantity, $t\ y^{-1}$	$7\ 10^3$	$4\ 10^5$	10^4	10^6
Smallest estimated quantity, $t\ y^{-1}$	0.07	7	0.01	1.5
Number of radionuclides with rounded estimated quantity[(e)] below $10\ t\ y^{-1}$	6	0	4	2
Number of radionuclides with rounded estimated quantity[(e)] below $1\ t\ y^{-1}$	3 (^{32}P, ^{33}P, ^{35}S)	0	1 (^{32}P)	0

Notes

a) Derived from GDC for discharges to sewers (NRPB, 2000 and Harvey et al, 2010)

b) Calculated using HPA sewer model (Titley et al, 2000) with parameter values chosen for the National Dose Assessment Working Group (NDAWG) intercomparison case (Watson, 2010)

c) Derived from IAEA clearance levels for discharge to river or sewer (IAEA, 1998)

d) Derived from EA initial assessment methodology (Allot et al, 2006 and Lambers and Thorne, 2006)

e) Rounded to the nearest order of magnitude using the rounding procedure in RP122 Part 1

The estimated quantity for a particular radionuclide varies from approach to approach (by factors of more than 10^3 for some radionuclides) and the radionuclide corresponding to the smallest estimated volume also varied from model to model. It should be noted that the calculations listed in Table C1 are all for small STW and the throughput for a STW serving a city population will be larger, leading to lower doses; Becton STW serves $3\ 10^6$ people in London and has a throughput of nearly $10^9\ m^3\ y^{-1}$ (Titley et al, 2000).

The results in Table C1 indicate that disposal of $10\ t\ y^{-1}$ of non-aqueous liquids containing activity concentrations at the RP122 Part 1 clearance level would meet the individual dose criteria for all except a few radionuclides. Since the discussion in Appendix A indicates that $10\ t\ y^{-1}$ is considered to be an upper estimate of the amount that would be disposed of by a very large user to a particular STW, this implies that either a lower activity concentration or a volume limit could be specified for these radionuclides. Considering the variation in the results from the different models and the fact that they are all for a small STW these restrictions would apply to six radionuclides: ^{32}P, ^{33}P, ^{35}S, ^{65}Zn, ^{85}Sr and ^{99}Tc. The modifying factor that would be applied to the activity concentration given in RP122 Part 1 for solids is specified in Table C2. Hence the unconditional clearance level (exclusion level) for disposal of non-aqueous liquids containing ^{32}P to sewer would be $0.05 \times 100\ Bq\ g^{-1} = 5\ Bq\ g^{-1}$.

TABLE C2 Activity concentrations for disposal of non-aqueous liquids to sewer without a specific restriction on the quantity that can be disposed of

Radionuclide	Activity concentration Bq g^{-1}
^{32}P, ^{33}P,	0.05 x activity concentration specified in RP122 Part 1 [(a)]
^{35}S, ^{65}Zn, ^{85}Sr, ^{99}Tc	0.1 x activity concentration specified in RP122 Part 1 [(a)]
All other radionuclides	1.0 x activity concentration specified in RP122 Part 1 [(a)]

Note

(a) The activity concentration specified in RP122 Part 1 as the clearance level in solids for that radionuclide

Alternatively, the quantity of non-aqueous liquids containing activity concentrations at the CLs that can be disposed of by a single user could be limited to the values in Table C3.

TABLE C3 Quantity of non-aqueous liquids containing activity concentrations at the clearance levels for solids[(a)] that can be disposed of to a sewer

Radionuclide	Quantity, t y^{-1}
^{32}P, ^{33}P,	0.5
^{35}S, ^{65}Zn, ^{85}Sr, ^{99}Tc	1
All other radionuclides	10

Note

(a) The activity concentration specified in RP122 Part 1 as the clearance level in solids for that radionuclide

C3 INCINERATION

The quantity of non-aqueous liquid containing activity concentrations specified in RP122 Part 1 that could be incinerated per year at a specific incinerator and still give rise to a dose to an individual below the 10 μSv y^{-1} individual dose criterion was estimated using three different models, as described below.

The first estimate was obtained by scaling the GDCs for disposal to atmosphere published by HPA for 50 of the radionuclides in RP122 Part 1 (NRPB, 2000; Harvey et al, 2010). The scaling factor is described in section C2 Disposal to sewer.

The second estimate was obtained from the IAEA clearance levels for discharge to atmosphere (IAEA, 1998), by dividing the IAEA clearance level, in Bq y^{-1}, by the RP122 Part 1 clearance level, in Bq g^{-1}.

Finally, the EA initial assessment methodology (Allot et al, 2006; Lambers and Thorne, 2006) was used to estimate the volumes that could be disposed of to atmosphere and meet the individual dose criterion.

The results are summarised in Table C4.

TABLE C4 Comparison of quantities of non-aqueous liquids containing activity concentrations at the clearance level in RP122 Part 1 that can be disposed of to an incinerator

Description	GDC[a]	IAEA[b]	EA[c]
Number of radionuclides considered	50	33	62
Largest estimated quantity, t y^{-1}	2 10^7	10^5	10^7
Smallest estimated quantity, t y^{-1}	3 10^1	1	8 10^1
Number of radionuclides with rounded estimated quantity[(d)] below 100 t y^{-1}	0	7	0
Number of radionuclides with rounded estimated quantity[(d)] below 10 t y^{-1}	0	3 (^{32}P, ^{35}S, ^{45}Ca)	0

Notes

a) Derived from GDC for discharges to atmosphere (NRPB, 2000 and Harvey et al, 2010)

b) Derived from IAEA clearance levels for discharge to atmosphere (IAEA, 1998)

c) Derived from EA initial assessment methodology (Allot et al, 2006 and Lambers and Thorne, 2006)

d) Rounded to the nearest order of magnitude using the rounding procedure in RP122 Part 1

The estimated quantity for a particular radionuclide varies from approach to approach (by factors of more than 10^2 for some radionuclides) and the radionuclide corresponding to the smallest estimated volume also varies from model to model.

Although 10 t y^{-1} is considered to be an upper estimate of the amount that would be disposed of by a very large user, an incinerator could receive waste from more than one user and therefore an upper limit of 100 t y^{-1} was considered to be appropriate. The results from the GDC and EA models given in Table C4 indicate that incineration of 100 t y^{-1} of non-aqueous liquids containing activity concentrations at the RP122 Part 1 clearance level would meet the individual dose criteria for all radionuclides; only the results from the IAEA clearance levels indicate that a lower activity concentration might be specified for a few radionuclides in order to meet the dose criteria. However, the IAEA calculations are very conservative since they assume a low release height and that people live close to the discharge point, and this would not be the case for an incinerator. Hence, considering the degree of conservatism in the models, disposal of 100 t y^{-1} of non-aqueous liquids containing activity concentrations at the CL would be expected to give rise to doses below the 10 μSv y^{-1} individual dose criterion.

C4 DISPOSAL TO A RIVER

As described in section C1, disposal of non-aqueous liquids to a river would not be permitted. However, accidental discharge could possibly occur and hence the quantity of non-aqueous liquid containing activity concentrations specified in RP122 Part 1 that could be disposed of per year to a river and still give rise to doses below the 1 mSv y^{-1} individual dose criterion for unforeseen events (Harvey et al, 1993) was estimated by scaling the HPA published GDCs for disposal to river (NRPB, 2000; Harvey et al, 2010) for 50 of the radionuclides in RP122 Part 1. The results are summarised in Table C5.

TABLE C5 Quantities of non-aqueous liquids containing activity concentrations at the clearance levels in RP122 that would meet the 1 mSv y^{-1} dose criteria if accidentally disposed of to river

Description	GDC[(a)]
River flow rate, m^3 y^{-1}	0.8-1.6 10^8
Number of radionuclides considered	50
Largest estimated quantity, t y^{-1}	1 10^{10}
Smallest estimated quantity, t y^{-1}	10
Number of radionuclides with rounded estimated quantity[(b)] below 100 t y^{-1}	1 (^{32}P)

Notes

a) Derived from GDC for discharges to rivers (NRPB, 2000 and Harvey et al, 2010)

b) Rounded to the nearest order of magnitude using the rounding procedure in RP122 Part 1

The results in Table C5 indicate that disposal of 10 t y^{-1} of non-aqueous liquids containing activity concentrations at the RP122 Part 1 clearance level to a river would meet the 1 mSv y^{-1} individual dose criteria for unforeseen events for all radionuclides.

Discharge to coastal waters would also not be permitted because of the hazardous nature of non-aqueous liquids. However, even if the hazardous nature is not considered, discharge to coastal waters would result in lower doses than discharge to river because of the additional dilution.

C5 DISPOSAL TO LANDFILL

The scenarios in RP122 Part 1 assumed that the waste was disposed of to a landfill site and that 10% of the waste at the landfill site contained activity concentrations at the CL. A typical landfill site could receive around 10^5 t y^{-1} (Chen et al, 2007) and therefore the calculations in RP122 Part 1 correspond to disposal of 10^4 t y^{-1} of waste with activity concentrations at the CL.

C6 COLLECTIVE DOSE

The generic assessments in Appendix A using PC-CREAM08 (HPA, 2009) indicate that disposal of 10^4 t y^{-1} of waste with activity concentrations at the CL to atmosphere or the marine environment would result in a collective dose below 1 man Sv.

C7 DISCUSSION

The results presented in sections C1 to C6 suggest that disposal of 10 t y^{-1} of non-aqueous liquids containing activity concentrations at the CLs to a small sewage treatment works might not meet the appropriate individual dose criterion for six radionuclides. However, disposal of 100t y^{-1} to an incinerator, 10^4 t y^{-1} to a landfill site, or accidentally disposing of 10 t y^{-1} to a river or to coastal water is estimated to meet the

appropriate dose criteria for all radionuclides. Hence, for disposal to a sewer, there may be a need either for restrictions on the volume of non-aqueous liquids containing activity concentrations at the CLs that could be disposed of per year or alternatively for lower activity concentration levels to be specified for the six radionuclides to ensure that the dose criteria are met.

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