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Impact of changes to exemption and clearance values for specific radionuclides: review and industry survey

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Public Health England (PHE) exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. It does this through world-leading science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. PHE is an operationally autonomous executive agency of the Department of Health.

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Executive Summary

Public Health England (PHE) was commissioned by the Department of Energy & Climate Change (DECC) to undertake a review of the potential impact to the UK from the implementation of new criteria for the exemption and clearance of radioactive substances, as specified in the European Basic Safety Standards Directive (BSSD) (2013/59/Euratom)[1]. This review was limited to a specified set of radionuclides (both artificial radionuclides and naturally occurring radioactive material (NORM)) and industry sectors. This review considered the implementation of the new BSSD criteria within the framework of the Environmental Permitting (England and Wales) (Amendment) Regulations 2011, and the equivalent legislation in the devolved administrations (referred to collectively as EPR).

The potential changes were presented to a list of industry contacts in the specified sectors, who were invited to assess the practical impacts (positive and negative) of these changes. This report presents the responses received and provides a summary of the overall industry views.

For two of the artificial radionuclides considered (carbon-14 and caesium-137) the listed BSSD exemption and clearance values are lower, by a factor of 10, than the equivalent values currently applied under EPR. For the nuclear sector, the introduction of these values is regarded as having a significant negative impact, especially with regard to the decommissioning of nuclear sites. This is due to increased quantities of waste being subject to regulation, significant technical and operational challenges in terms of radiological monitoring, and extended decommissioning schedules. In rounded terms, the total additional decommissioning costs associated with such changes, are reported as being of the order of two billion pounds. Additional operating costs are also envisaged.

The primary waste disposal facility for low level radioactive waste in the UK raised concerns that an increase in the amount of in scope waste would put a strain on current UK capacity for managing radioactive wastes. However, further work would be required to better establish this risk.

Due to concerns about the more restrictive exemption and clearance values for carbon-14 and caesium-137, the method by which the values listed in the BSSD were derived was also reviewed. From this, the derivation of UK-specific exemption and clearance values for these radionuclides, as is allowed by the provisions of the BSSD, was also considered. For carbon-14, the exemption and clearance values in the BSSD are based on a very cautious drinking water scenario: applying the more realistic scenario results in a value which is an order of magnitude higher ie 10 Bq g^{-1}. This approach is recommended in a European Commission study and should be considered for the UK. For caesium-137, the exposure calculations used in the EPR and BSSD actually produce similar results: however, due to the rounding procedure, the published values are different by an order of magnitude. Given the

[1] On 23 June 2016, the EU referendum took place and the people of the United Kingdom voted to leave the European Union. Until exit negotiations are concluded, the UK remains a full member of the European Union and all the rights and obligations of EU membership remain in force. During this period the Government will continue to negotiate, implement and apply EU legislation. The outcome of these negotiations will determine what arrangements apply in relation to EU legislation in future once the UK has left the EU.

small differences in the unrounded values and the potential difficulties associated with the lower rounded result, consideration should be given to adopting 1 Bq g^{-1} in the UK.

The nuclear sector also raised concerns about the exemption and clearance of radium-226. In the BSSD, there are provisions for the exemption of naturally occurring radium-226+, but no value is given where it has been processed for its radioactive property, suggesting a default value of 0.01 Bq g^{-1}, which is significantly lower than the natural concentration in UK soils. This poses significant technical and practical problems when remediating contaminated land. As a way of avoiding these problems it is suggested that a value of 0.1 Bq g^{-1} could be adopted.

The research sector also expressed concerns about carbon-14, in terms of the increased time and costs associated with site decommissioning. Although the overall costs are likely to be very much lower than those reported by the nuclear industry, they could well be significant for small and medium sized enterprises. Furthermore, the future liability associated with such costs may have a negative effect on future business investment. In comparison, in the medical and education sectors, little impact was expected from the proposed changes.

The only consistently positive responses were from the radioactive waste management industry, which could expect an increase in business. Overall, however, the reported positive impacts were small compared to the negative impacts.

In the case of NORM industries, the implementation of the BSSD implies a small increase in exemption and clearance values, which is widely regarded as producing a positive benefit in terms of reduced waste disposal costs and encouraging greater reuse and recycling of materials. The largest reported benefits are for the titanium dioxide industry, in terms of reduced waste disposal and site remediation costs.

The BSSD allows for the option of increased EPR conditional exemption values for certain types of NORM waste containing lead-210+ or polonium-210. This could potentially produce significant savings in waste disposal costs for the gas exploration and production sector and the steel industry. In the case of the steel industry, these costs are reported to be millions of pounds per year, which are considered large enough to affect the industry competitiveness overall.

This review also considered the use of the naturally occurring radionuclide potassium-40 by the fertiliser industry. This radionuclide is currently not subject to EPR requirements, but is included in the BSSD provisions for exemption and clearance. The possible impact on the fertiliser industry from including potassium-40 in the EPR framework is hard to gauge. However, there is evidence to suggest that this would produce little or no radiological benefit, and that the current EPR approach is consistent with the general BSSD principles of exemption and clearance for naturally occurring radionuclides.

Contents

1 Introduction and scope

The Department of Energy & Climate Change (DECC) commissioned Public Health England, Centre for Radiation, Chemical and Environmental Hazards (PHE) to undertake a review of the impact to the UK from the introduction of revised criteria for the exemption and clearance of radioactive substances from regulatory control. As instructed by DECC, the scope of this review was limited to a specific list of radionuclides and sectors of use, as shown in Table 1.

This review involved contacting specific industrial and other sectors in which radioactive materials are used, and from which radioactive wastes are produced, in order to gather views on the potential practical impact of these changes.

Table 1 List of radionuclides and industry sectors specified by DECC

Industry	Radionuclide
Nuclear	Carbon-14, Calcium-45, Caesium-137+, Radium-226+, Radium-228+
Medical/Research facilities	Tritium (H-3), Carbon-14, Fluorine-18, Phosphorus-32, Chromium-51, Germanium-68, Selenium-75, Molybdenum-99+, Technetium-99m, Indium-111, Iodine-123, Iodine-125, Iodine-131+, Lutentium-177, Radium-223+, Radium-226+, Radium-228+
Education and research	Chlorine-36, Cobalt-60, Strontium-90+, Americium-241, Plutonium-239
Specified NORM industries • Oil and Gas • Steel • Titanium Dioxide • Fertiliser	Uranium-238(sec), Thorium-232(sec), Radium-226+, Radium-228+, Lead-210+, Polonium-210+ Potassium-40 (fertiliser industry only)
Waste management facilities: landfill and incinerators	Carbon-14, Caesium-137+, Radium-226+, Radium-228+

In the UK, the concepts of exemption and clearance are implemented through the environmental permitting regime, in particular the Environmental Permitting (England and Wales) (Amendment) Regulations 2011, and the equivalent legislation in the devolved administrations[*] (hereafter referred to collectively as 'EPR'). This review focuses on the impact in terms of potential changes to EPR; however the interface with other regulations, such as those governing the transport of radioactive materials and transfrontier shipment of radioactive wastes, is also considered.

[*] Radioactive Substances Act 1993, The Radioactive Substances Act 1993 Amendment (Northern Ireland) Regulations 2011, The Radioactive Substances Exemption (Northern Ireland) Order 2011, The Radioactive Substances Act 1993 Amendment (Scotland) Regulations 2011 , The Radioactive Substances Exemption (Scotland) Order 2011

The EPR approach to exemption and clearance is based on the previous European Basic Safety Standards Directive (BSSD) (96/29/Euratom) (European Commission, 1996) and corresponding Community guidance RP 89, RP 113 and RP 122 (European Commission, 1998), (European Commission, 1999), (European Commission, 2000; European Commission, 2002). The new European Basic Safety Standards Directive (2013/59/Euratom) (referred hereafter as the 'new BSSD') (European Commission, 2013) has to be implemented in UK legislation by 6 February 2018. The new BSSD contains a revised approach to exemption and clearance that may, in turn, require revisions to EPR. A description of the different approaches to exemption and clearance, together with a summary of the potential changes to EPR, is given in Section 2 of this report.

PHE assembled a list of contacts from the sectors shown in Table 1: these are described in Section 3. The potential revisions to the EPR provisions for exemption and clearance were presented to these contacts, who were invited to assess the practical impacts (positive and negative) of these changes. The questionnaires used are described in Section 4, and the responses received are presented in Section 5. These responses identified carbon-14, caesium-137 and radium-226+ as key radionuclides, and a review of the methodology for deriving exemption and clearance values for these radionuclides is given in Section 6. The overall conclusions are given in Section 7.

2 Revisions to the approach to exemption and clearance

2.1 General approach

The basic concepts of exemption and clearance are unchanged; they are based on a level of radiation risk that is considered too low to warrant the introduction of regulatory controls (exemption) or else allow for release from regulatory control (clearance). As indicated in Section 1, however, the implementation of these concepts in the new BSSD differs from that in the previous BSSD (96/29/Euratom) and also in EPR. The origins of the exemption and clearance values in both BSSDs, and how these relate to EPR, are described in Appendix A.

In terms of this review, the following approach was agreed with DECC:

- The BSSD approach to exemption and clearance is laid out in Annex VII: this includes exemption values given in Table B, in terms of total activity (Bq) and activity concentration (kBq kg^{-1}), for moderate amounts of any type of material. The same values already appear in EPR (Table 3.1 of the supporting guidance[*]) (Defra et al., 2011); consequently there is no expected change[†], and these values will not be considered further in this review.
- BSSD Annex VII, Table A, (Part 1 and Part 2) specifies exemption and clearance values (in kBq kg^{-1}) which can be applied by default to any amount of solid material. The equivalent values currently used in the UK are the 'out of scope' values specified in EPR.

[*] In this report, references to EPR tables relate to those in the Government Guidance Document, which applies to all the versions of EPR used in the devolved administrations.

[†] BSSD, Annex VII 3(d) states that the activity concentration values may be used for exemption from authorisation, which is a change from the previous BSSD. It is also different from the UK approach, where they are used for exemption from notification. Consequently, DECC have confirmed that there will be an impact on regulation and Government will lead on this separately.

For some radionuclides, there are differences between the BSSD and EPR values: the potential impact arising from these differences is the main focus of this review.

- Where the EPR and BBSD values are the same, there is no impact and these radionuclides will not be considered further in this review.
- There are some radionuclides specified by DECC (Table 1) for which no new value is specified in BSSD, Annex VII Table A, Part 1. For such radionuclides, it is assumed that the existing EPR values will be retained.
- Annex VII allows competent authorities in Members States to set higher exemption and clearance values than those given in the BSSD, provided these satisfy general exemption and clearance criteria. Evidence to support the retention of higher EPR values is considered as part of this review.
- EPR specifies out of scope and exemption values for solids (and relevant liquids), other liquids, and (in the case of NORM) gases. In comparison, the exemption and clearance values specified in BSSD, Annex VII Table A, are for solid materials only. Consequently, any comparison is limited to solid materials (and relevant liquids): it is assumed that any values for other liquids and gases specified in EPR will be retained.

EPR also includes a series of conditional exemptions, for example for: keeping and disposing of low activity sealed sources and luminised articles; disposal of very low level waste (VLLW); and accumulation and disposal of solid NORM waste. There is no direct equivalent to these in the BSSD (although they are allowed provided that the general exemption and clearance criteria are satisfied), and it is assumed that these will be retained in EPR. As such, they may serve to mitigate any potential impacts in practice from changes to the out of scope values, and this is considered as part of this review.

2.2 Artificial radionuclides

As indicated above, this review is limited to a comparison of the exemption and clearance activity concentration values in BSSD Annex VII Table A Part 1, and the out of scope values specified in EPR (Table 2.3 of the supporting guidance). A comparison of these two sets of values for the radionuclides listed in Table 1 is given in Table 2, which indicates:

- For 13 radionuclides (in yellow), the values are unchanged; therefore, there is no potential impact from implementing the BSSD.
- For nine radionuclides (in green) the new BSSD value is higher, by either a factor of 10 or 100. This represents a relaxation in regulatory control for these radionuclides, by increasing the amount of radioactive materials and radioactive waste that would be considered out of scope of EPR.
- For two radionuclides (in red) is the BSSD value is lower by a factor of 10 than the current EPR out of scope value. These are carbon-14 and caesium-137, for which an increase in the scope of regulatory control is indicated. The potential impacts of these changes (to the nuclear, medical and research, and waste management sectors) have been a primary focus in this review.

Table 2 Comparison of EPR out of scope values and BSSD exemption and clearance values for artificial radionuclides

Radionuclide	Existing EPR out of scope value (Bq g^{-1})	BSSD exemption and clearance value (Bq g^{-1})	Factor difference
Tritium (H-3)	100	100	Same
Carbon-14	10	1	0.1
Fluorine-18	1	10	10
Phosphor-32	100	1,000	10
Chlorine-36	1	1	Same
Calcium-45	100	100	Same
Cromium-51	10	100	10
Cobalt-60	0.1	0.1	Same
Germanium-68	0.01	0.01*	Same by default
Selenium-75	1	1	Same
Strontium-90+	1	1	Same
Molybdenum-99+	1	10	10
Technetium-99m	100	100	Same
Indium-111	1	10	10
Iodine-123	10	100	10
Iodine-125	1	100	100
Iodine-131+	1	10	10
Caesium-137+	1	0.1	0.1
Lutentium-177	10	100	10
Radium-223+	1	1*	Same by default
Radium-226+	0.01	0.01*	Same by default
Radium-228+	0.01	0.01*	Same by default
Plutonium-239	0.1	0.1	Same
Americium-241	0.1	0.1	Same

* Radionuclide not listed in BSSD (2013/59/Euratom) Annex VII Table A Part 1. As indicated in Section 2.1, it is assumed that these radionuclides will retain the existing EPR out of scope values for artificial radionuclides.

2.3 Naturally occurring radioactive material (NORM)

For NORM, BSSD Annex VII, Table A, Part 2 specifies the following exemption and clearance values that can be applied by default to any amount and any type of solid material:

- Natural radionuclides from the uranium-238 series: 1 Bq g^{-1}
- Natural radionuclides from the thorium-232 series: 1 Bq g^{-1}

The above values relate to the uranium and thorium decay chains in secular equilibrium. For segments of the decay chain, which are not in equilibrium with the parent radionuclide, the BSSD states that higher values may be applied. Annex VII also allows Competent Authorities to set higher values for specific applications, provided that the general criteria for exemption and clearance are met. For NORM, the requirement is that radiation doses likely to be received by an individual should be 'of the order of 1 mSv or less in a year'. Member States may specify lower dose criteria for specific types of practices or specific pathways of exposure.

The equivalent to the BSSD NORM exemption and clearance values are the out of scope values specified in EPR (Table 2.2 of the supporting guidance). These values include the decay chains in equilibrium (ie an out of scope value of 0.5 Bq g^{-1}), as well as decay chain segments (out of scope values between 0.5 and 5 Bq g^{-1}). The current EPR use of higher values for decay chain segments is considered consistent with the provisions of BSSD Annex VII.

EPR also includes provisions for the conditional exemption of NORM waste containing up to 5 Bq g^{-1} ('type 1 NORM waste')[*]. Although the BSSD makes no explicit provisions for <u>conditional</u> exemption values, Annex VII, does allows Member States to set higher values for specific applications, provided that the general criteria for exemption and clearance are met. The EPR criterion for determination of out of scope and exemption of NORM is a radiation dose of 300 µSv y^{-1} to a member of the public. For conditional exemption of NORM waste, an additional limit of 1 mSv y^{-1} to landfill workers is applied. It is considered that these are already consistent with the general criteria for exemption and clearance specified in BSSD Annex VII for NORM.

Based on the above comparison between the BSDD and EPR, the possible changes relevant to NORM are given below.

Change 1: EPR out of scope

Replace the current 0.5 Bq g^{-1} values (ie for uranium-238(sec), radium-226+, thorium-232(sec) and thorium-228+) with 1 Bq g^{-1} to match the values specified in BSSD Annex VII (and leave all the other values, ie for decay chain segments, unchanged).

Change 2: EPR exempt NORM waste

A further change could also be made to the existing EPR provisions for exempt NORM waste. As noted above, the BSSD allows higher exemption and clearance values to be set for NORM decay chain segments. The work done to support the EPR values (Anderson and Mobbs, 2010) calculated the activity concentration values for different chain segments, ie that would meet the basic exemption criteria. It was decided to use a single value in EPR, which was at

[*] Unlike out of scope, the EPR exemption for NORM waste makes no special provisions for decay chain segments.

the lower end of this range (ie close to the values produced for the decay chains in equilibrium). For lead-210+ and polonium-210, the calculations indicate that the dose criteria are met at activity concentrations up to 600 Bq g^{-1}. These chain segments are commonly encountered in certain NORM waste streams, and it is considered that there is an argument for setting specific exemption levels. For these radionuclides, the regulations governing the transport of radioactive materials would apply at activity concentrations above 100 Bq g^{-1}. Consequently, to ensure comparable provisions for both transport and waste disposal, the proposed change is to expand the definition of type 1 NORM waste to include up to 100 Bq g^{-1} of lead-210+ or polonium-210 (and retain a value of 5 Bq g^{-1} for other NORM radionuclides).

Table 3 summarises the two possible changes described above.

Table 3 Possible changes to EPR out of scope and exemption values for NORM radionuclides*

Radionuclide	Existing EPR out of scope value (Bq g^{-1})	Proposed out of scope value from BSSD (Bq g^{-1})	Existing exemption value for type 1 NORM waste (Bq g^{-1})	Proposed exemption value for type 1 NORM waste (Bq g^{-1})
Uranium-238(sec)	0.5	1	5	5
Radium-226+	0.5	1	5	5
Lead-210+	5	5	5	100
Polonium-210	5	5	5	100
Thorium-232(sec)	0.5	1	5	5
Thorium-228+	0.5	1	5	5

* Only those radionuclides (or chain segments) for which a change in value is proposed are shown.

3 Industry contacts

PHE has a substantial client base across the industries listed in Table 1, and a number of these clients were invited to take part in this project. Collaboration with professional societies, industry bodies and other relevant contacts has also been undertaken in order to obtain a representative response. The contacts who participated in this review are described in the remainder of this section.

3.1 Medical and research

In the medical sector, the Institute of Physics and Engineering in Medicine (IPEM) was used as the primary means of disseminating the questionnaire. Contacts were also drawn from the PHE client base and from existing professional relationships with persons working in this sector. In total, 20 direct contacts were made with persons working in the medical and research sector; further distribution of the questionnaire also occurred from invited contacts forwarding to other interested colleagues or associates.

In the research sector, contact was made with a number of radiation protection specialists within universities using the radionuclides identified in Table 1, and with the Association of University Radiation Protection Officers (AURPO).

In addition to this response, the corporate knowledge and experience of PHE acting in the capacity of Radiation Protection Adviser (RPA) and Radioactive Waste Adviser (RWA) to various organisations was taken into consideration.

3.2 Waste management

The main contacts in the waste management sector were drawn from the PHE client base. Responses were received from Veolia and Augean who operate permitted landfill and incinerator sites in the UK. The views of the Low Level Waste Repository (LLWR), as the primary disposal repository for UK low level wastes (LLW), were also sought.

It is recognised that there are several companies who currently dispose of out of scope and exempt waste (at 'normal' landfill and incinerator sites). There could potentially be an impact on these companies if the out of scope values were to change. However, because such companies do not accept waste that is currently defined as radioactive it was concluded that there would be no existing evidence base on which to gauge any impacts.

3.3 Nuclear sector

As part of this project PHE attended a meeting of the nuclear industry Clearance and Exemption Working Group (CEWG), where the scope of this project and the impact on the nuclear industry was specifically discussed. All attendees of the meeting were invited to complete the questionnaire and responses were obtained from:

- Atomic Weapons Establishment (AWE)
- Dounreay Site Restoration Ltd (DSRL)
- EDF Energy
- Horizon Nuclear Power
- Magnox Ltd
- Ministry of Defence (MoD)
- Nuclear Decommissioning Authority (NDA) (incorporating Dounreay and Sellafield responses)
- Sellafield Ltd
- Rolls-Royce
- URENCO Group

3.4 Education and research

None of the radionuclides specified in Table 1 for the education and research sector are indicated as requiring a change to the current EPR out of scope values (see Table 3). Consequently, it was concluded that no contact needed to be made with general education establishments such as schools and colleges.

3.5 NORM industries

A list of NORM industries was specified by DECC as part of the original project scope, as shown in Table 1. The zircon manufacturing industry also expressed an interest in the project, and was consulted as part of this review. Where possible, contact was made with industry associations, with the aim of obtaining a response representative of each of the industries as a whole.

The representatives of the NORM industries that provided a response are shown below:

- Oil and Gas UK, Radiological Issues Technical Group
- Tata Steel
- UK Heavy Mineral Sands Association (Titanium Dioxide)
- Zircon Industry Association
- Agricultural Industries Confederation, Fertilisers Section.

In addition to the above, responses were also received from:

- PHE CRCE, acting in the capacity of RPA and RWA to a variety of NORM industrial users and NORM waste disposal facilities
- Studsvik, in terms of the management of NORM waste.

4 Questionnaire

A separate questionnaire was developed for each of the sectors described in Section 3. Each questionnaire included a brief description of the potential changes to the existing EPR values, as well as a short series of questions designed to enable the practical impact of the changes to be assessed. The importance of providing quantitative information wherever possible was highlighted. An example of one of the questionnaires (for the medical and research sector) can be found in Appendix B.

The questionnaire was emailed directly to the contacts within the organisations identified as relevant for each sector and also to the industry bodies as outlined in Section 3.

It should be noted that potassium-40 was not included on the general NORM questionnaire as direct contact was made with the fertiliser industry instead.

5 Responses from industry and other sectors

5.1 Medical and research

5.1.1 Medical establishments

The majority of the completed questionnaires came from within the National Health Service (from hospitals and University Health Boards). Five of the respondents are currently permitted to use and dispose of carbon-14, which is the only radionuclide in this sector for which a decrease in the out of scope value is indicated. However, most of these users reported that they dispose of waste in accordance with a permit (normally as VLLW or LLW), and do not routinely dispose of out of scope waste. Consequently, the impact of any changes would be negligible.

One research establishment reported that it disposes of animal carcasses containing low levels of carbon-14, below the current out of scope threshold. These are currently disposed of using the normal bio-hazard waste route as the radioactive content is not of concern. There would be an increased cost associated with the disposal of carcasses as radioactive waste, which could have a negative impact on this research work in future (eg the work may cease to be undertaken due to excessive disposal costs).

The other responses from this sector were in relation to radionuclides which would have a potential increase in the out of scope value. Some positive impacts were suggested (but not quantified), including reduced future decommissioning costs, reduced quantities of VLLW, and a decrease in decay storage time periods for waste material to become out of scope.

5.1.2 Private research companies

A low response rate was achieved amongst private research organisations, however, one bio-research company reported a significant negative impact with respect to on-site decommissioning. It noted that the financial provision in place to cover the potential costs of site decommissioning would need to be increased; the estimate is >£400,000 which the company considered to be a significant financial burden. The current decommissioning plan includes the use of the current EPR values for carbon-14 in order to dispose of much of the site material as out of scope waste. Reducing the out of scope value for carbon-14 to 1 Bq g^{-1} would require the company to reassess the decommissioning plan.

It was also noted by the same company that use of best available techniques require it to carry out manufacturing trials prior to the use of carbon-14, the resultant ‘cold’ products are used by customers to validate and test their procedures prior to work with the carbon-14 labelled product. Currently this is possible, although the cold product can contain carbon-14 at 3 to 10 Bq g^{-1}. If the out of scope value for carbon-14 were reduced to 1 Bq g^{-1} it would not be possible for this beneficial use of test product to take place and there would be adverse impacts upon the business and its customers in the pharmaceutical, veterinary medicine and agrochemical industries. It was also noted that a lower out of scope value for carbon-14 would present technical challenges in terms of monitoring and assay.

From PHE corporate RPA and RWA experience, similar issues could affect other research laboratories, which handle solid materials and waste containing carbon-14. Decommissioning issues could potentially affect, to some extent, all research sites that have previously used carbon-14. A recent example has involved the decommissioning of a pharmaceutical research laboratory contaminated with tritium and carbon-14. Analysis of the waste records from the decommissioning was carried out to assess the possible impact of changing the carbon-14 out of scope value from 10 to 1 Bq g^{-1}. The following conclusions were reached:

- A total of 1,700 kg of waste containing 80 MBq (80% carbon-14) was produced as part of the decommissioning. The total waste activity would not have increased significantly (ie because the vast majority of the activity was accounted for by LLW, which remains unaltered by changing the clearance value).
- The amount of VLLW produced would have increased because less waste would be out of scope of EPR. This would be mostly significant in terms of VLLW mass, which would have increased four-fold from 250 kg to 1000 kg. As VLLW is disposed of with ordinary waste, there would be little impact in terms of cost.
- With a lower clearance value for carbon-14, more extensive decommissioning would have been required and therefore more out of scope waste (and possibly VLLW) would have been accumulated. It is estimated that an additional two to three weeks decommissioning effort would have been required, increasing the costs by approximately 50%. Secondly, an additional 1 to 2 tonnes of waste would have required characterising and streaming (approximately a 100% increase).

GE Healthcare provided a report on the impact to its facilities in Cardiff and Amersham. It anticipates a negative impact as a result of any reduction in the carbon-14 and caesium-137 out of scope values. At both sites there would be an increase in the volume of LLW waste generated, with this being reported as ‘significant’ for caesium-137 wastes at Amersham. The company reported three main concerns: increased costs to dispose of waste; greater assay time for wastes (with an associated increase to the practical and financial burden); the increased quantity of waste that will need to be sent to UK waste facilities with a finite capacity (eg LLWR). When asked to quantify the likely financial impact to the business the company quoted a ‘factor of around 30 increase in the affected wastes from the sites’.

5.2 Waste management

Three major radioactive waste management operators responded to the questionnaire. Taken collectively, these operators deal with the permitted disposal of solid radioactive waste and NORM waste (incineration and landfill), receipt of LLW for treatment and disposal, and disposal of VLLW (incineration and landfill).

5.2.1 Augean Plc

Augean Plc carries out waste treatment and disposal operations at three facilities in the UK.[*] All three facilities treat and dispose of radioactive wastes including the artificial and NORM radionuclides identified in Table 11. For the facilities that mainly encounter carbon-14 and

[*] Augean Plc’s business has moved on significantly between the time that this report was prepared in 2016 and when it was made publically available online in 2018. At the time of online publication, Augean Plc have seven permitted facilities for the treatment and/or disposal of radioactive waste. These include the high temperature incinerator, two landfill, a descaling facility and treatment/transfer centres.

caesium-137, the financial impact of the proposed changes is expected to be positive as there will be an increase in waste arising, which would previously have fallen out of scope.

The site that is permitted to treat and dispose of NORM waste primarily deals with radium-containing wastes. Currently, further investment in additional treatment facilities for such wastes is being investigated by the company. However, the proposed changes to the NORM out of scope values could make this too high risk an investment as the long term impact on the amount of wastes arising is not known. The company acknowledged that a quantitative response is difficult to provide as it does not have adequate information from the waste producers on the impact the changes would have on the total volumes of waste produced.

5.2.2 Veolia Environmental Services (UK) Ltd

The Veolia facility at Ellesmere Port is permitted to receive and dispose of radioactive wastes including all the relevant radionuclides (artificial and NORM) listed in Table 1. It reported that a decrease in the out of scope values for carbon-14 and caesium-137 may have a small positive impact on its business as there may be an increase in the volumes of waste received. However, they reported that the overall effect is expected to be negligible as there are numerous competitors who are able to deal with low-activity wastes and these account for only a small proportion of its business.

5.2.3 Low Level Waste Repository Ltd

LLWR accepts of all the radionuclides listed in Table 1, although from a disposal point of view none of the radionuclides are dominant in the radiological fingerprint.

LLWR is the primary LLW disposal facility for the UK. It is not anticipated that the proposed changes would have a significant impact on the company's activities; however, on a UK-wide basis it anticipates significant impact on waste management. The majority of the waste streams from the largest waste producers (Sellafield, Magnox Ltd and MoD) do contain radionuclides considered in this report and in many cases are dominated by caesium-137. For such waste streams, the potential changes would significantly reduce the volume of solid radioactive waste that can be classified as out of scope and would therefore increase the volume that would require managing as VLLW. The issue surrounding the minimum detectable activity by both direct measurements and wipe tests would also need to be investigated to ensure that it still remains suitable at the reduced caesium-137 threshold.

A significant increase in the volume of VLLW was reported as having a number of adverse effects including:

- Increased costs of waste management for the waste producers.
- Increase in volume of VLLW may threaten the capacity in the supply chain (at licensed and permitted landfill sites). This could lead to an increase in the volume of waste requiring disposal at LLWR and further development of the VLLW disposal sites.
- Project and programme delivery may be deferred by waste producers owing to waste management capacity and affordability implications.
- Some materials (hand tools etc) contaminated by carbon-14 or caesium-137 would no longer be managed as out of scope and would essentially become VLLW.

Although not directly affected by the changes, LLWR have attempted to quantify the financial implications for affected waste producers (ie its customers). It reported that for out of scope wastes currently managed by landfill disposal, the cost of disposing of this as VLLW would be four to five times higher. For a large disposer of such wastes, it estimated that the cost of managing the rubble and demolition wastes currently treated as out of scope would increase from £90,000 per annum to £450,000 per annum. This is a significant impact for waste producers, and could have adverse effects on project and programme scheduling (ie projects may be deferred or cancelled due to concerns regarding affordability).

5.3 Nuclear industry

An overview of the impact of the possible changes to the nuclear industry was provided by the Nuclear Decommissioning Authority (NDA). The NDA manages a number of sites across the UK through Site Licence Companies and Parent Body Organisations. The NDA noted that radioactive wastes rarely comprise of a single radionuclide, and to expedite clearance and exemption practices radionuclide fingerprints are used in conjunction with a sum-of-fractions calculation. As caesium-137 is typically used as the primary, measurable, radionuclide in a fingerprint any reduction in the out of scope values will result in a reduction in the overall volumes of wastes suitable for clearance.

The NDA also noted that a reduction of the caesium-137 activity concentration to 0.1 Bq g^{-1} would mean in many cases trying to measure levels at 0.05 Bq g^{-1} or less. This may prove challenging for a number of measurement techniques and would certainly result in longer monitoring times and an increase in levels of uncertainty and hence greater pessimism in the results. The industry is generally very conservative when it comes to characterising wastes as out of scope as the penalties for mis-sentencing, both financial and reputational are severe. Ultimately this will reduce the volumes of wastes that can be classified as out of scope and increase the volumes that will need to be managed as VLLW or LLW.

The NDA noted that it is difficult to quantify the potential impact from a financial perspective, as it is only in the final stages of the process that the waste can be declared as out of scope with the necessary level of confidence. However it points to the LLWR analysis of Magnox out of scope consignments during the last financial year as providing a useful example of costs (see Section 5.2.3). Based on these cost estimates, for every 1,000 m^3 of out of scope waste, applying the revised values would increase disposal costs by approximately £300,000. Given that the overall inventory of VLLW and out of scope wastes is estimated to be 3,000,000 m^3, the NDA concluded that any significant reduction in the volumes of wastes that can be demonstrated to meet the out of scope criteria will have a massive impact on the overall decommissioning costs either through increased disposal costs as VLLW and LLW or through an increase in on-site disposal.

5.3.1 Sellafield Ltd

Sellafield reported that the potential decrease in the caesium-137 out of scope value would have the biggest impact. The company has made estimates of the increased costs from waste disposal and monitoring which are given below.

- The 2013 UK Radioactive Inventory (NDA, 2014) refers to the waste stream 2D148 which is high volume very low level waste (HV-VLLW) from final decommissioning at Sellafield. These volumes are currently estimated at 2.8 million m^3. Sellafield stated that the current assumptions are that 80% of these materials will either be clean, or classified as out of scope, based on operational experience (Sellafield Ltd, 2014).
- Analysis of the likely amount of waste which would no longer be classified as out of scope ranges from 15% to 45%, with 30% being the most realistic estimate. The financial impact of the potential changes in the BSSD values were estimated to be in the range £1,300 million ± £700 million.
- Sellafield also estimates that monitoring costs would be increased due to increased length of time to perform additional monitoring (£150,000 ongoing cost) and the need to purchase improved instrumentation and provide additional training (set-up costs of £600,000 and £30,000, respectively).

More detail on the derivation of the above values is given in Appendix C.

5.3.2 Dounreay Site Restoration Ltd

Dounreay Site Restoration Ltd (DSRL) reported that caesium-137 is one of the predominant isotopes in the site's waste fingerprint with carbon-14, radium-226 and radium-228 being of minor significance. DRSL uses the out of scope route particularly for recycling of metals and has used this route rather than exemption since it became available. DRSL state that the reduction in the caesium-137 out of scope value to 0.1 Bq g^{-1} would require changes to the operational processes at Dounreay to ensure that the waste complies with the new values. It noted that the counting times will have to be greatly increased to ensure the measurement uncertainty allows a reasonable safety margin below the 0.1 Bq g^{-1} value. Therefore, DRSL reported that the throughput of material would be significantly reduced impacting on project duration and costs. It stated that upgrading equipment is unlikely to help, and that the reputational risk of breaching this lower value (which is more likely given the lower limit of detection) would mean that it would have to give serious consideration to removing the out of scope route from its waste strategy with a resultant increase in VLLW or LLW disposal.

It stated that the current use of the out of scope route is cost neutral as the value of the material recycled pays for the transportation costs. If there is no out of scope waste route, DRSL indicated that the metal waste plus other material, which is currently re-used or recycled on-site (eg such as demolition waste from decommissioned buildings) would have to be consigned to the LLW vaults. It estimates that this would greatly increase the overall LLW volume for the site by some 40,500 m^3, at a total contractual cost to the NDA of some £303 million, excluding the cost of constructing the additional two LLW vaults at the Dounreay LLWR.

5.3.3 EDF Energy

The proposed changes were reported as being unlikely to have significant impact on current operations at EDF Energy sites as the key radionuclides (carbon-14 and caesium-137) are not dominant in the majority of waste streams, and in any case, the majority of wastes generated are already sentenced as radioactive. It estimated that the potential impact across the UK organisation would be limited to a few 10's of m^3 of solid waste and oil per annum, which would no longer be out of scope. The additional cost of treatment and disposal of this waste would be approximately £100,000 per annum. This, however, does not include the allocation of extra resources (people, plant, measurements, transport, processing etc) that would be required to expedite this additional work.

The estimated impact on decommissioning costs is anticipated to be substantially higher, particularly as EDF Energy predicts that out of scope waste volumes at AGRs (reactor steels and concrete) are expected to have relatively high carbon-14 concentration. As a result of the changes, EDF Energy estimates that the increase in decommissioning costs could be in the range of £95 million to £160 million at current prices.

5.3.4 Magnox Ltd

Magnox Ltd holds 12 nuclear site licences and is responsible for the decommissioning of 10 Magnox nuclear power stations and two other sites, Winfrith and Harwell. Magnox Ltd currently disposes of, or recycles, approximately 1,000 tonnes of out of scope waste per financial year. This is waste that arises in areas where radioactive contamination is possible, but the waste can be shown by measurement to contain radionuclides below the current EPR out of scope values. About half of this is metallic waste that is sent for recycling on the open market, allowing application of the waste hierarchy.

Approximately 70% of this waste contains between 1 and 10 Bq g^{-1} of carbon-14, or between 0.1 and 1 Bq g^{-1} of caesium-137, so a direct effect of the proposed change would be that such wastes would have to be managed as LLW (including LLW metals recycling, controlled burial or HV-VLLW disposal routes), with associated increased costs.

Caesium-137 is a key radionuclide for sentencing much of the radioactive waste arising on the Magnox Ltd sites. The envisaged new caesium-137 out of scope value would be below minimum detectable limits for monitoring instrumentation currently used for sentencing of waste (typically about 0.8 Bq g^{-1}). As an example, it has been estimated that the counting times of typical fingerprints of contamination found at the Harwell site which are currently relatively easy to measure would increase by a factor of 10 or 20. In the absence of more sensitive instrumentation, it is likely that conservative decisions will be made, in which waste that is, in fact, below the new out of scope criteria will be sentenced as radioactive waste. This effect cannot readily be quantified, but could be of similar order to the direct effect of the change detailed above. In order to bring in sentencing processes reflecting the new out of scope values, more sensitive, higher resolution instrumentation for monitoring and analysis would need to be purchased for all 12 sites and sentencing procedures adapted to ensure that the risk of mis-consignment of radioactive waste to non-radiological facilities is managed. Overall, the envisaged changes would result in a substantial capital cost and potentially ongoing increased burden of operating the new procedures, which may be more time-consuming than current arrangements. This is a negative effect in terms of cost, which could not be quantified in the time available. However an estimate of 12 high resolution gamma ray systems including commissioning costs could be more than £10 million, before considering other assay equipment that would be needed for waste sentencing.

Carbon-14 is a minor radionuclide in some reactor waste streams in which cobalt-60 is typically the key radionuclide used for waste categorisation and sentencing. The potential change in the out of scope value for carbon-14 is not expected to have a major effect on present-day management of such wastes. However, over the life-cycle of the Magnox-type reactor sites, cobalt-60 will decay, while long-lived carbon-14 may remain; in which case carbon-14 may be a more significant radionuclide in determining what will be deemed to be radioactive waste when the sites are finally cleared in the latter part this century. The potential change in the out of scope value for carbon-14 could have a bearing on the ultimate fate of many thousands of tonnes of concrete from the reactor biological shields.

Of the routes available for off-site disposal or recycling of solid LLW, metals recycling is the most expensive (up to about £8,000 per tonne). Diversion of metals currently recycled on the open market, which would no longer be out of scope, would result in an additional cost of the order of £2 million per year over a period of roughly 10 years; therefore of the order of £20 million in total.

The Harwell site provided information on potential costs from the changes in the caesium-137 value. Using the example of two recent remediation projects, 10% of samples fell into the 0.1 to 1 Bq g^{-1} range for caesium-137 for a fairly ‘clean’ remediation project whereas approximately 60% of samples were in this range for waste from the excavation from one of the active drains. The range of estimated costs for the Harwell site is given below (these costs do not include landfill tax):

- Assuming 10% increase in low activity low level waste (LA-LLW) would result in an extra £2 million disposal costs
- Assuming 10% increase in inert wastes such as steel concrete, soil and building rubble being defined as LA-LLW would result in an extra £13 million disposal costs
- Assuming 60% increase in LA-LLW would result in an extra £13 million disposal costs

On nuclear sites, ground contaminated with radioactive material is regulated by the Office for Nuclear Regulation under relevant licence conditions, including Licence Condition 1, which refers to the EPR out of scope values. The potential new out of scope values (especially for caesium-137) will increase the volume of ground on Magnox Ltd sites that falls within this regulatory regime. There may be a requirement for additional characterisation and surveys to delineate the extent of such contamination. Allowing for the presence of other radionuclides, the levels of caesium-137 to be delineated may in some cases not be much above regional background levels arising from atmospheric fall-out and permitted discharges.

On some sites, the highest concentrations of radionuclides in the ground may be at levels that are below the current out of scope values, but above the potential new values (especially for caesium-137) triggering a requirement for arrangements for control of such contamination that previously did not apply. This would be a small negative effect in terms of cost.

The final end states of decommissioned Magnox Ltd sites may involve leaving residual radioactive material on the site, including that within contaminated structures and in lightly contaminated rubble used as infill to below-ground voids. Where concentrations are above out of scope values, permission for disposal of radioactive waste will be required. The potential new out of scope values for caesium-137 and carbon-14 may increase the volume classed as disposed radioactive waste on a given site. For some sites the new values might trigger the requirement for a radioactive waste disposal permit where one would not previously have been required. The permitting process for on-site disposals on nuclear sites undergoing decommissioning is under development, but is expected to place additional requirements on-site operators and regulators. In most cases this is likely to involve some form of public consultation, including via the planning (development control) regime. This is a small negative effect in terms of cost, except perhaps at any site where the change would introduce a permitting requirement that would not otherwise arise.

5.3.5 Ministry of Defence

The MoD provided a response with respect to the effect of the proposed changes at a number of its operational sites across the UK. Of these, Her Majesty's Naval Base (HMNB) Portsmouth and Vulcan Naval Research Test Establishment reported no impact as a result of the changes. For the other sites the main impact is expected to be an increase in LLW generated and an associated increase in costs and operational effort to monitor wastes at the new out of scope values.

Carbon-14 is present in solid, liquid and gaseous wastes generated from work on nuclear powered submarines at Devonport Royal Dockyard. Caesium-137 is also present in some wastes but only in trace quantities. The changes will impact on the ability to clear certain solid wastes as out of scope (eg solid wastes from dismantling of redundant facilities, disposal of redundant equipment, etc) due to the need to measure carbon-14 at the new out of scope value along with the associated requirement to measure other key radionuclides (specifically cobalt-60) at lower levels in order to comply with out of scope 'summation' criteria in EPR. This would result in a potential increase in operational costs due to a reduction in the operational exclusion limit (ie clearance of carbon-14 in solid wastes is based on the ratio of gamma-emitting radionuclides, specifically cobalt-60, to meet the out of scope summation criteria in EPR). Solid waste material containing carbon-14 and caesium-137 is also generated from submarines alongside at HMNB Devonport; this waste is transferred to the Devonport Royal Dockyard Licensed Site for further processing. The changes will make it more difficult to sentence certain materials as out of scope by using current operational equipment (eg gamma dose rate measurement using hand-held instrumentation). Instead, additional radiochemical laboratory analysis may be required to determine the carbon-14 activity concentration to confirm the waste is out of scope. This would inevitably lead to delays in processing materials from operational submarines and potentially when disposing of redundant equipment or facilities in the future. HMNB Clyde stated that the possible reduction in the carbon-14 value will increase the amount of LLW by 30% with the costs increasing as these will be tied to the LLWR price schedule rather than local domestic disposal. It noted that at the clearance value of 1 Bq g^{-1} the decision making process becomes more challenging and there will be a tendency to err on the side of caution and therefore less waste will be cleared as out of scope.

Both Devonport Royal Dockyard and HMNB Devonport reported that it was not possible to quantify the additional costs that would be incurred if these proposed changes were implemented. However, both stated that they are likely to be significant when the additional monitoring requirements and laboratory analysis is taken into account. This will impact on current operations for materials generated by the operational submarine programme but could be even more significant when decommissioning redundant equipment or facilities including out of service vessels as part of the submarine dismantling programme (SDP). Following these comments, the SDP team were contacted to see if an estimate of costs could be provided. The response was that more restrictive parameters have been factored into the SDP's costings and therefore there should not be any additional costs arising from the potential changes in clearance values. However this does not rule out extra costs emerging at some point during further site decommissioning work. The team said that it was not possible to quantify the costs associated with SDP as the scale and time of the final decommissioning is some way off.

5.3.6 Other companies

For other companies that hold or plan to hold Nuclear Site Licences (AWE, Horizon Nuclear Power, Roll- Royce and URENCO Group) no significant impacts were foreseen, although a number of more limited negative impacts and one positive impact were identified. A summary of the responses is given below.

- AWE reported that the change in the plutonium-241 value (from 1 to 10 Bq g^{-1}) would have a positive effect for them.
- Horizon Nuclear Power reported that it does not expect these changes to affect its waste management plans.
- Rolls-Royce reported that carbon-14 and caesium-137 are present in small quantities and are currently being disposed of as LLW waste. Therefore any changes in the values would broadly mean no impact under current waste practices.
- URENCO Group noted that although it would not be directly affected, the increased amount of waste defined by other sites as LLW rather than out of scope might make it more expensive to dispose of waste.

5.4 NORM industries

5.4.1 Oil and gas

The proposed change to the out of scope values (from 0.5 to 1 Bq g^{-1}) for NORM radionuclides was generally regarded as positive, even though it is expected that this would only have a limited impact on UK oil and gas operations.

The proposed change to the exempt NORM waste values (from 5 to 100 Bq g^{-1} for lead-210+ and polonium-210), was viewed as being potentially very beneficial, especially for gas exploration and production facilities. For such facilities, much of the NORM waste currently produced would be considered exempt under the new values. The potential savings were not quantified; however, the unit costs of disposal of non-exempt lead-210 and polonium-210 waste are likely to be similar to those quoted for the steel industry (see Section 5.4.2).

Although the exemption and clearance of NORM in other liquids and gases is outside the scope of this project (see Section 2.1), there was strong support for these to also be reviewed, especially in respect of liquid wastes for which the existing out of scope values are very low, and for which there are limited disposal routes for NORM contaminated water produced in the UK from offshore operations. It was also noted that the very low values for liquids are difficult to confidently detect by laboratory analysis.

5.4.2 Steel industry

It was noted that the proposed changes to the out of scope values (from 0.5 to 1 Bq g^{-1}) would be beneficial from a recycling perspective. In terms of input materials (ie scrap steel for recycling) the change would help reduce the amount of NORM contaminated scrap that is rejected, and in turn reduce waste disposal volumes and costs. A much bigger benefit, however, would be from increasing the amount of intermediate waste materials that could be accepted for reuse or recycling in other processes. This benefit was not directly quantified, but could equate to major cost savings for the industry, and a significant reduction in the amount of waste that has to be directly disposed of.

The proposed changes to the exempt NORM waste values (from 5 to 100 Bq g^{-1} for lead-210+ and polonium-210), were viewed as being especially welcome. The industry is continually exploring ways of recycling and reusing more intermediate materials and residues from the steel making process. A number of these materials contain lead-210 and polonium-210 at activity concentrations that can slightly exceed either 5 Bq g^{-1} (type 1 exempt NORM waste) or 10 Bq g^{-1} (type 2 exempt NORM) waste. Currently, such materials have to be disposed of as radioactive waste under the EPR permitting arrangements (the reuse or recycling of non-exempt materials is not regarded as a practical option). Disposal costs for such waste exceed £4,000 a tonne, resulting in reported annual disposal costs of millions of pounds. Due to these cost implications, a process improvement scheme was reported as being stalled due to the potential creation of a non-exempt NORM waste. This was deemed to outweigh any benefit to the overall process.

It was also noted that the current exemption values affect industry competitiveness compared to other non-UK steel manufacturers, with the Netherlands being quoted as applying a 100 Bq g^{-1} value for lead-210 and polonium-210[*].

5.4.3 Titanium dioxide

The proposed changes to the out of scope values (from 0.5 to 1 Bq g^{-1}) for NORM radionuclides are regarded as positive by the industry. The impact in terms of routine operations depends on the manufacturing process employed. In some cases, NORM residues and waste already exceed 1 Bq g^{-1}, and consequently there would be no practical impact. In other cases, there are high volume waste materials produced that fall within the 0.5 to 1 Bq g^{-1} range. It was reported that these wastes exceed 100,000 tonnes a year. These would be regarded as out of scope under the proposed new values, producing significant savings in terms of disposal costs, and potentially encouraging reuse and recycling options.

Another significant impact would be in relation to site remediation, when manufacturing sites are decommissioned. Most of the plant residues are generally well above 1 Bq g^{-1} and would not be affected by the change. However, historical ground contamination from feedstock residues (ie which become a waste material at the time of decommissioning) can fall within the 0.5 to 1 Bq g^{-1} range. It was reported that the proposed increase in the out of scope values could significantly reduce the amount of low activity concentration material (principally in the form of ground excavations) that would need to be removed from site. This is consistent with

[*] It is understood by the authors that, since 2000, this would be interpreted as 33 Bq g^{-1} of lead-210+ (ie due to three radionuclides being present).

PHE experience from titanium dioxide site remediation. The savings in terms of cost and time will vary according to the site being remediated, but could be substantial.

The titanium dioxide industry does not produce lead-210 and polonium-210 wastes, and the proposed changes to the exempt NORM waste values for these radionuclides is not expected to have an impact.

5.4.4 Zircon industry

In terms of the proposed changes to the out of scope values (from 0.5 to 1 Bq g^{-1}) most respondents saw no impacts, while one respondent saw a positive benefit when considering land remediation. A higher clearance value would entail less remediation time and costs, although the potential savings were not quantified.

In terms of NORM wastes routinely arising from the industry, it is considered that there would be no significant impact from the proposed changes to either the out of scope or the exemption values.

Respondents also noted that there is currently an inconsistency between the exemption values in EPR and those applied to the transport of NORM. For example, waste containing 5 to 10 Bq $g^{-1}$of uranium-238(sec) and thorium-232(sec) is exempt from the transport regulations but not from EPR. They also noted that the proposed changes do not, however, address this inconsistency.

5.4.5 Fertiliser industry (potassium-40)

Potassium-40 is completely out of scope of EPR, thus, materials and wastes containing potassium-40 (at any activity concentration) are not regarded as radioactive. As a result, the fertiliser industry has little prior experience on which to gauge the impact of the introduction of an out of scope value of 10 Bq g^{-1}. The industry representatives did confirm that potassium fertilisers can commonly contain 30 to 40% potassium by weight, and some widely used fertilisers contain up to 50% potassium-40 by weight: these are equivalent to 10 to 15 Bq g^{-1} of potassium-40.

The current EPR approach to materials in which the presence of NORM is incidental, is that raw materials, intermediates and final products are not deemed to be radioactive; only waste materials (ie in this case above 10 Bq g^{-1} potassium-40) need be regarded as being in scope. Assuming the same system would apply to fertilisers, the impact on the industry (ie in which potassium is intended for the final product), could potentially be low. By the same token, however, it can be argued that any possible benefits of introducing regulatory provisions for potassium-40 (ie which cannot possibly exceed 31 Bq g^{-1}), are equally low.

There was no information available from the UK fertiliser industry on radiation exposures from potassium-40, however, there have been studies in other countries. Internal exposures from potassium-40 are excluded from international standards as potassium is an essential minor element under homeostatic control and such exposures are not amenable to further control. Therefore, only external radiation exposures need be considered. In an international study (Wymer, 2007), the estimated radiation doses to workers from three main types of potassium fertiliser were in the range 0.15 to 0.18 mSv per year*, and it was concluded that this was most unlikely to warrant regulatory control.

5.4.6 Waste management industry

Comments were received from the waste management industry, essentially confirming that increasing the out of scope values could potentially decrease industry disposal costs and encourage reuse and recycling. It was also noted that many NORM wastes have other hazardous properties, and these would take precedence if the waste was no longer regarded as radioactive.

PHE itself is aware of the practical issues that some waste disposers currently have when accounting for NORM wastes, especially where they handle a mixture of out of scope, exempt and permitted wastes. The proposed increase for lead-210+ in exempt NORM waste to 100 Bq g^{-1} could present a challenge in terms of the waste screening measurements currently undertaken, but this is one that is likely to be manageable.

5.5 Other issues identified by respondents

5.5.1 Nuclear industry

NDA raised the issue that the existing and proposed out of scope values for radium-226 depend on whether the source is of artificial or natural origin. The current value of 0.01 Bq g^{-1} for artificial radionuclides is not practical to measure for large samples, and is less than the background level for many natural materials. Adequate detection levels can be achieved, but for smaller (gram level) quantities. It has been noted that the clearance value is based on a dose assessment where the majority of the dose is received from ingestion of the material, which for most disposal scenarios is not credible. NDA made the point that the impact of disposal is the same, regardless of the source of the material, and a consistent approach to clearance for radium-226 from artificial and NORM sources would be welcomed.

Sellafield noted that it also makes use of the EC RP89 values (European Commission, 1998) with respect to the clearance of metallic items or wastes. Sellafield has assumed that EC RP89 will still be a valid clearance methodology post any change to the BSSD. If this is not the case, then there is an additional impact of the order of £5 million per year (£500 million lifetime cost).

Magnox Ltd suggested that further consultation should be made with the nuclear industry to identify any radionuclides where the absence of a value specified in EPR could be problematic. The production of authoritative values for such radionuclides that could be incorporated into UK legislation (or into updated guidance to the legislation) would be beneficial, so that different operators within the industry do not end up deriving different values themselves. An example is calcium-41, a long-lived electron capture radionuclide that is present in the concrete biological shields of many UK nuclear reactors including the Magnox type. Use of 0.01 Bq g^{-1} as a default out of scope value for calcium-41 gives it a distorting

* These estimated doses also include exposures from the natural uranium and thorium present in the fertilisers, as well as potassium-40.

effect when defining which parts of biological shields will be out of scope, especially when considering long timescales.

Additionally Magnox Ltd (Harwell) noted that the BSSD (in Articles 26, 27 and Annex VII (2c and 3)) allows for more flexibility than EPR10, in that assessments can be used to demonstrate that the radiological risks are sufficiently low. Magnox Ltd reported that this is an important issue as currently, using the HSE delicensing guidance (Health and Safety Executive), it can delicense an area based on a robust site specific risk assessment. However, technically there may be some material (often of quite a small volume, well below ground level) that is slightly in scope of EPR according to Bq g^{-1} values. Therefore it argues that in order to get closer to the spirit of the BSSD, EPR10 should be changed to allow for the assessments to demonstrate that the radiological risks are sufficiently low.

AWE noted that in some of its facilities, depleted uranium (DU) is used for its physical properties, which is therefore a NORM activity, and AWE should be able to dispose of wastes using the NORM exemption criteria. However, it is prevented from doing so because the transport limit for DU is 1 Bq g^{-1}; the transport limit for natural uranium is 10 Bq g^{-1} despite DU being less radioactive. A review of the transport limits, to correct this inconsistency would be welcomed.

AWE reported that it has legacy radium-226 contamination at one of its sites. It has the option to dispose of any soil contaminated with radium-226 using the EPR exemption because the soil was contaminated prior to the issue of the nuclear license. If this exemption were removed from legislation (at any point) then significant quantities of soil could fall into the radioactive waste category.

5.5.2 NORM Industries

More than one industry commented on the differences between EPR and the regulations for transporting radioactive materials, in terms of their application to NORM. While the proposed changes to exemption and clearance of NORM described in this report do not necessarily change the situation, some further clarification on the interface between these two sets of regulations, including the application of summation rules for NORM radionuclide mixtures, was requested by the industries.

It was stated that the new BSSD contains a revised definition of ‘practice’, which no longer only includes natural radionuclides where they are processed for their radioactive, fissile or fertile properties. This is not an issue with the BSSD itself (ie which clearly does apply to NORM industries), but has raised questions in terms of the interface with other legislation. Specifically, the previous BSSD definition of a ‘practice’ is also used in the Transfrontier Shipment of Radioactive Waste and Spent Fuel Regulations 2008 (TFSW). As a consequence, these regulations do not apply to NORM wastes, for example from the oil and gas industry (although the general TFSW regime may apply instead). Although the new BSSD does not repeal the original Directive (2006/117/Euratom) on which these regulations are based, there are still concerns that the new BSSD definition will affect (perhaps unintentionally) the application of the regulations governing transfrontier shipment of waste. Clarification of these issues has been requested from DECC.

6 Changes in carbon-14, caesium-137 and radium-226 out of scope values

Given the particular significance of these radionuclides to the nuclear industry and to a lesser extent the research sector, the rationale behind the derivation of the values for cabon-14, caesium-137 and radium-226 (as an artificial radionuclide) is considered in this section. In addition, alternative approaches to a direct transposition of the BSSD values listed in Annex VII into EPR are suggested.

Details on the derivation of the carbon-14, caesium-137 and radium-226 values in EC RP122 and IAEA RS-G-1.7 are provided in Appendix D. For carbon-14 the proposed value in the BSSD is an order of magnitude lower than that in the existing EPR. The value of 1 Bq g^{-1} in the BSSD is taken from IAEA RS-G-1.7 which is based on a water exposure pathway, assuming that activity leaches from landfilled solid waste into an aquifer used for drinking water. European Commission Report EC RP157 concludes that the pathway is based on restrictive model assumptions and generally leads to very low clearance values in international comparisons. In addition it states that 1 Bq g^{-1} for carbon-14 is not manageable for routine clearance measurements. If this pathway is excluded, as recommended by EC RP157, the other pathways result in a value of 10 Bq g^{-1} which is consistent with the existing out of scope value within EPR.

For caesium-137 the proposed value in the BSSD is an order of magnitude lower than that in the existing EPR. The scenarios governing the values in both documents (EC RP122 Part 1 and IAEA RS-G-1.7) describe the same exposure situation, but the assumptions in EC RP122 are slightly less restrictive than those in IAEA RS-G-1.7. Although the calculated values are 0.38 Bq g^{-1} and 0.12 Bq g^{-1} for EC RP122 and IAEA RS-G-1.7, respectively, the rounding procedure means that the published values are 1 Bq g^{-1} and 0.1 Bq g^{-1}. Given that the calculated values are very similar, the potential costs and the difficulty of measuring caesium-137 at 0.1 Bq g^{-1}, it is suggested that consideration should be given to adopting a value of 1 Bq g^{-1}, ie to ensure consistency with the current EPR approach.

For radium-226+ no value is given in the BSSD for artificial radionuclides. IAEA RS-G-1.7 quotes a value of 1 Bq g^{-1} based on the assumption that any radiological levels being derived for radionuclides that occur naturally need only be based on considerations pertaining to their natural occurrence. However, this value cannot be used: Article 30 of the BSSD states *'Member states shall ensure that for the clearance of materials containing naturally-occurring radionuclides, where these result from authorised practices in which natural radionuclides are processed for their radioactive, fissile or fertile properties, the clearance values comply with the dose criteria for clearance of materials containing artificial radionuclides'*.

One possibility is that the existing EPR value (taken from EC RP122 Part 1) of 0.01 Bq g^{-1} could be used. This value is based on the scenario of a small child playing on soil or ground which consists of undiluted material having been cleared from a nuclear site and eating 100 g y^{-1} of the undiluted contaminated material. This is an extremely cautious scenario, although it is also intended to include other ingestion scenarios such as ingestion of food and water.

The average concentration of radium-226 in soils in the UK is 0.037 Bq g^{-1} (International Atomic Energy Agency, 2005) which is higher than the out of scope value. Given that there is also significant variation in the natural background level, the use of 0.01 Bq g^{-1} for remediation of radium-226 contaminated sites is extremely challenging from a technical viewpoint, and almost impossible to demonstrate with any certainty. As a way of resolving these issues, a value of 0.1 Bq g^{-1}, as given in EC RP113, could be adopted. This value is based on the same scenario as EC RP122 Part 1 but assumes that the waste has been diluted by a factor of 10 before consumption by a child.

7 Conclusions

7.1 Artificial radionuclides

7.1.1 Nuclear sector

The implementation of the BSSD could result in changes to the EPR out of scope values for some of the radionuclides within the scope of this review. A potential reduction in the out of scope value is only indicated for two radionuclides (carbon-14 and caesium-137); however, the potential negative impact of these changes has been reported as being very significant for the nuclear industry and (to a lesser extent) for some research establishments.

In the nuclear sector the proposed changes to the out of scope value from 10 to 1 Bq g^{-1} for carbon-14, and from 1 to 0.1 Bq g^{-1} for caesium-137 are both regarded as having a significant negative impact, especially with regard to the decommissioning of nuclear sites. This is a result of increased quantities of waste being in scope of the legislation, significantly increased radiological monitoring requirements and, in turn, extended decommissioning schedules. Companies actively involved in decommissioning have estimated additional costs of £1,300 million (Sellafield), £300 million (DSRL), £30 million (Magnox) . In rounded terms, the total reported additional costs for nuclear decommissioning from changing the out of scope values is of the order of 2 billion pounds. EDF Energy also reported a likely increase in operating costs, from managing routine waste arisings, of the order of £100,000 per year.

A reduction in the out of scope values also presents technical challenges. The NDA reported that a reduction to 0.1 Bq g^{-1} in the case of caesium-137 would prove challenging to a number of measurement techniques currently used, some of which would no longer be regarded as acceptable. Even where existing monitoring techniques are potentially adequate, there would likely be a need for substantial upgrades to equipment, significantly longer monitoring and analysis times and an increase in levels of uncertainty. Similar concerns were expressed in terms of reducing the carbon-14 out of scope value.

It was also noted that the nuclear industry is generally very conservative when sentencing wastes as out of scope, as the penalties for mis-sentencing, both financial and reputational, are severe. Thus, a reduction in the out of scope values would almost certainly reduce the volumes of wastes that would even be considered suitable for classification as out of scope, and increase the volumes that will need to be managed as VLLW or LLW.

LLWR Ltd raised concerns that a reduction in out of scope values would put a strain on current UK capacity for managing radioactive wastes: however, further work would be required to quantify this risk.

7.1.2 Other sectors

The research sector also raised concerns about the increased time and costs associated with site decommissioning, especially in relation to carbon-14. These costs are directly associated with the increased volume of waste that would be defined as radioactive. It is estimated that disposal of waste as VLLW compared with landfill disposal of out of scope waste is around four to five times more costly. Although the overall costs are likely to be very much lower than those reported by the nuclear industry, they could well be significant for small and medium sized enterprises. Furthermore, the future liability associated with such costs may have a negative effect on future business investment.

In terms of the medical and education sectors, only one example was given of a negative impact, from reducing the EPR out of scope value for carbon-14. In these sectors, there is typically little or no use of the EPR out of scope provisions, and so no significant impact would be expected. The increase in the out of scope values for some of the radionuclides used in these sectors is welcomed as this will result in a reduction in both the decay storage periods for wastes and the final disposal costs.

Across all the sectors, there are nine radionuclides for which a potential increase in the out of scope values is indicated. Despite this, only one specific example of a positive impact (for plutonium-241) was received as part of this review. In fact, the only consistently positive responses were from the radioactive waste management industry, and these were in relation to reduced out of scope values for caesium-137 and carbon-14, which would be expected to provide an increase in business. Overall, however, it is fair to conclude that the reported positive impacts were very small compared to the negative impacts.

7.1.3 PHE review of carbon-14, caesium-137 and radium-226 out of scope values

Given the stated importance to the nuclear industry and to a lesser extent the research sector, this review specifically considered the derivation of the values for cabon-14, caesium-137 and radium-226+ (ie as an artificial radionuclide). The BSSD allows Member States the flexibility of specific clearance values for the management of large volumes of materials arising from the dismantling of authorised facilities and references Community guidance documents EC RP 89, EC RP113 and EC RP122.

As described in Section 6, for carbon-14 and caesium-137, it is possible to argue for exemption and clearance values of 10 Bq g^{-1} and 1 Bq g^{-1}, respectively, which would be consistent with the current EPR approach. For radium-226+ defined as an artificial radionuclide, due to practical considerations associated with its occurrence in the natural background, a value of 0.1 Bq g^{-1} is suggested as an alternative to the existing EPR value of 0.01 Bq g^{-1}.

7.2 NORM

As explained in Section 2.3, the implementation of the BSSD allows for possible changes to the EPR out of scope values and the EPR exempt NORM waste values, for some NORM radionuclides. In addition, it suggests that potassium-40 should be included within the EPR framework. Each of these changes, and the reported impact on NORM industries, is summarised below.

7.2.1 EPR out of scope (uranium-238 and thorium-232 decay series)

This option would replace the current 0.5 Bq g^{-1} values in EPR* with 1 Bq g^{-1} and match those specified in BSSD Annex VII.

For most NORM industries this is a small change, which is expected to have a small positive benefit in terms of routine operations and NORM wastes arising. The main exception is the titanium dioxide industry: some manufacturing plants produce bulk waste materials (exceeding 100,000 tonnes a year) which would be regarded as out of scope (rather than exempt NORM waste) under the proposed values, producing significant savings in terms of disposal costs, and potentially encouraging recycling options.

The titanium dioxide industry also identified a significant benefit in terms of site remediation. Even this small increase in the values could significantly reduce the amount of material (principally in the form of ground excavations) that would need to be removed from site. The savings in terms of cost and time will vary according to the site being remediated, but would be expected to be substantial. In fact, facilitating site remediation is likely to be a benefit for all other NORM industries, albeit to a lesser extent.

7.2.2 EPR exempt NORM waste (lead-210 and daughter products)

The BSSD allows higher exemption and clearance values to be set for NORM decay chain segments, although no specific values are quoted. Annex VII also allows Competent Authorities to set higher values for specific applications, provided that the general criteria for exemption and clearance are met. From a review of the original calculations made for EPR, there is scope for increasing the exempt type 1 NORM waste values for lead-210+ and polonium-210 from 5 to 100 Bq g^{-1}, while still meeting these dose criteria.

This option was particularly welcomed by the gas exploration/production sector and the steel industry. Both of these produce NORM wastes containing lead/polonium-210, which currently require disposal under EPR permitting requirements at a significant cost. In the case of the steel industry, these costs are reported as being of the order of millions of pounds per year, which are considered sufficient to inhibit process improvements, and affect the industry competitiveness overall.

7.2.3 EPR out of scope (Potassium-40 in the fertiliser industry)

Annex VII of the BSSD suggests an exemption and clearance value of 10 Bq g^{-1} for potassium-40: in comparison, some commonly used phosphate fertilisers may contain 10 to 15 Bq g^{-1}.

At present, potassium-40 is completely out of scope of EPR, and the fertiliser industry has little prior experience on which to gauge the impact of its introduction into the EPR framework. Depending on how EPR is applied, it is possible that the practical impact could be very low. By the same token, any benefits from introducing regulatory provisions for potassium-40 would be equally low.

* For uranium-238(sec), radium-226+, thorium-232(sec) and thorium-228+

International studies of the fertiliser industry suggest that radiation exposures of workers are well below the dose criteria which underpin the BSSD system of exemption and clearance. This provides an argument for continuing to exclude potassium-40 from EPR, while still meeting the requirements of the BSSD.

7.3 Interface with other regulations

The review also examined the interface between the exemption values in the proposed regulations and those in other regulations. The responses focussed mostly on the regulations governing the transport of radioactive material. Several respondents, across a number of sectors, commented on differences between the EPR exemption values and those in the transport regulations and suggested that these inconsistences should be addressed.

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Appendix A Background information on the origin of exemption and clearance values

A brief description of the common terms used is given below. The definitions of the terms ‘exclusion’, ‘clearance’ and ‘exemption’ are taken from International Atomic Energy Agency Safety Glossary (International Atomic Energy Agency, 2007).

Exclusion is defined as: ‘The deliberate exclusion of a particular category of exposure from the scope of an instrument of regulatory control on the grounds that it is not considered amenable to control through the regulatory instrument in question’. Examples would be cosmic radiation at the Earth’s surface, potassium-40 in the human body, and naturally occurring radioactive material in which the activity concentrations of natural radionuclides are below the relevant values given in IAEA safety standards.

Exemption is defined as: ‘The determination by a regulatory body that a source or practice need not be subject to some or all aspects of regulatory control on the basis that the exposure due to the source or practice is too small to warrant the application of those aspects’.

Clearance is defined as: ‘The removal of radioactive materials or radioactive objects within the authorised practices from further regulatory control’.

For the purpose of UK legislation exclusion, exemption and clearance are addressed through a consideration of whether a material (and in the case of NORM, an industrial activity) is considered within the scope of the environmental permitting regulatory regime. Thus substances which meet exemption and clearance criteria are referred to as **out of scope** in the guidance which accompanies the legislation (Defra et al., 2011). The guidance states that ‘effectively *out of scope* equates to *not radioactive* for the purposes of the legislation.’

The European Union (EU) specifies the basic standards for the protection of the health of workers and the general public from the dangers from exposure to ionising radiation. It does this through European Council Directives. These EU Basic Safety Standards Directives (BSSD) have to be adopted by Member States, including the United Kingdom.

The current BSSD (96/29/Euratom) (European Commission, 1996) specifies exemption values for moderate amounts of individual radionuclides in substances based on the values given in European Commission Radiation Protection Series RP65 (European Commission, 1993). The BSSD does not contain specific clearance values but does give the criteria to be considered in deriving them. Subsequently the European Commission (EC) published guidance on clearance for recycling, reuse and disposal of general materials RP122 Parts 1 and 2 (RP122) (European Commission, 2000; European Commission, 2002); recycling and reuse of metals RP89 (European Commission, 1998); and recycling and reuse of buildings and building rubble RP113 (European Commission, 1999). These are levels below which any amount of any type of solid material can be completely released from regulatory control as there is considered to be negligible risk to the public or the environment from a radiation protection perspective.

The current legislation (based on BSSD (96/29/Euratom)) in England and Wales is the Environmental Permitting (England and Wales) (Amendment) Regulations 2011 (DECC, 2011) and in Northern Ireland and Scotland is the Radioactive Substances Act 1993 (HMSO, 1993) and associated Exemption Orders (collectively referred to as EPR in this report). This legislation is accompanied a guidance document on the scope of and exemptions from the radioactive substances legislation in the UK (Defra et al., 2011).

EPR contains criteria for artificial radionuclides and naturally occurring radioactive materials (NORM) to determine whether a substance is out of scope. Substances that are out of scope are not defined as a radioactive material or radioactive waste, and are not subject to the provisions of EPR.

EPR also allows for conditional exemption of certain materials and sources from the permitting requirements. Such materials and sources are in scope of EPR, and subject to regulatory conditions such as record keeping, storage and labelling, along with requirements to make notifications to the regulators in certain circumstances.

Following new recommendations from the International Commission on Radiological Protection (ICRP, 2007), the EU issued a new Basic Safety Standards Directive (2013/59/Euratom) (European Commission, 2013) on 5 December 2013. This Directive amalgamates five existing Directives and must be implemented into UK legislation by February 2018. The Directive specifies revised basic safety standards for protection against the dangers arising from exposure to ionising radiation. The new BSSD states that the activity concentration values in IAEA Safety Guide RS-G1.7 (International Atomic Energy Agency, 2004) should be used for both exemption and clearance values. However, Article 26 notes that Member States may exempt specific types of practices subject to demonstrating compliance with the general exemption criteria (given in point 3 of Annex VII). In addition it notes that specific clearance values, as well as corresponding community guidance (RP89, RP113 and RP122), remain important tools for the management of large volumes of materials arising from the dismantling of authorised facilities.

Table A1 summarises the source of the exemption and clearance values given in recent EC and UK legislation.

Table A1 Summary of the origin of exemption and clearance values given in recent EC and UK legislation

Legislation	Value	Source of value
EC BSSD 96	Clearance	No values specified but criteria for deriving given. Subsequent guidance published RP122 Part 1 (Artificial) and Part 2 (NORM), RP89 and RP113
	Exemption – Table A	RP65
EPR 2011	Out of scope	
	NORM - Table 1 of Schedule 1	RP122 Part 2 NORM
	Artificial - Table 2 of Schedule 1	RP122 Part 1 Artificial
	Exemption - Table 5	RP65
EC BSSD 2013	Exemption or clearance Table A Part 1 (Artificial) Table A Part 2 (NORM)	IAEA RSG1.7
	Exemption for moderate quantities[10] Table B	RP65

[10] EC RP65 defines moderate quantities of material as amounts 'at most of the order of a tonne'.

Appendix B Example of questionnaire issued

REVIEW OF IMPACT OF POSSIBLE CHANGES TO EXEMPTION AND CLEARANCE VALUES FOR RADIOACTIVE MATERIALS

FEEDBACK FROM EDUCATION AND RESEARCH ESTABLISHMENTS AND USERS IN THE MEDICAL SECTOR

INTRODUCTION AND SCOPE

DECC has commissioned Public Health England, Centre for Radiation, Chemical and Environmental Hazards (PHE) to undertake a review of the potential impact to the UK from the implementation of the exemption and clearance criteria specified in the European Basic Safety Standards Directive (BSSD)[11].

This review focuses on the impact of potential changes to the Environmental Permitting (England and Wales) (Amendment) Regulations 2011, and the equivalent legislation in the devolved administrations (collectively referred to as ‘EPR’).

The BSSD includes exemption and clearance criteria for artificial radionuclides and for naturally occurring radioactive materials (NORM). This document focuses on the use of low activity radioactive materials in education and research establishments and in the medical sector.

BSSD

The BSSD approach to exemption and clearance is laid out in Annex VII: this includes exemption values in terms of total activity (Bq) and activity concentration (kBq kg^{-1}) for moderate amounts of any type of material in Table B. Table A, (Part 1 and Part 2) specifies exemption and clearance values (in kBq kg^{-1}) which can be applied by default to any amount and any type of solid material.

EPR

EPR incorporate the concepts of exemption and clearance through a framework of out of scope values and a series of (conditional) exemptions. In terms of a comparison with the BSSD Annex VII requirements described above:

- The Table B values already appear in EPR (Table 3.1 of the supporting guidance); consequently there is no potential impact, and the values in Table B will not be considered further in this review.
- The equivalent Table A values currently used in the UK are the out of scope values specified in EPR (Table 2.3 of the supporting guidance).

[11] Council Directive 2013/59/Euratom of 5 December 2013; laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom.

POTENTIAL CHANGES TO EPR

For some radionuclides there are differences between the BSSD and EPR values: the potential impact arising from these differences will be the main focus of our review.

- There are some radionuclides listed in BSSD, Annex VII for which there is no value specified in EPR – it is assumed that these currently are assigned a default 'any other radionuclide' out of scope value of 0.01 Bq g^{-1}.
- Where the EPR and BBSD values are the same, there is no impact and these radionuclides will not be considered further in this review.
- There are some radionuclides listed in EPR for which no new value is specified in BSSD, Annex VII. It is, therefore, assumed that the existing values will be retained, and these radionuclides will not be considered further in this review.
- Where the BSSD value is lower than the current EPR value, the potential impact from an increase in the scope of regulation needs to be considered.
- Where the BSSD value is higher than the current EPR value, the potential impact from a decrease in the scope of regulation will be considered.

Note: EPR specifies out of scope values for: solids and relevant liquids; other liquids; and gases. In contrast, the BSSD refers only to solid materials. Consequently, it is assumed that any values for other liquids and gases specified in EPR will not be changed.

FEEDBACK REQUEST FROM EDUCATION AND RESEARCH ESTABLISHMENTS AND USERS IN THE MEDICAL SECTOR

The purpose of this review is to obtain views from users in the education/research and medical sectors on the practical impacts of changing EPR as described in the preceding section. It is considered extremely important that this information is taken into account – so please take this opportunity to provide as much information as you can.

The potential changes to the out of scope values described earlier are shown in the table below.

Radionuclide	Existing out of scope value (Bq g^{-1})	Potential out of scope value (Bq g^{-1})
Carbon-14	10	1
Fluorine-18	1	10
Phosphorus-32	100	1,000
Chromium-51	10	100
Molybdenum-99	1	10
Indium-111	1	10
Iodine-123	10	100
Iodine-125	1	100
Iodine-131	1	10
Lutetium-177	10	100
Radium-226	0.01 (0.5 for NORM)	0.01 (1 for NORM)

We want to know whether any of the above changes would have an impact on your UK operations and have attached a questionnaire for you to complete. In providing your answers, please consider:

- All aspects of activities: for example keeping and use of radioactive sources, disposals of radioactive wastes and site clearance.
- Whether there are positive and negative impacts, and how large these might be. This can include financial costs or savings. Please also indicate if you consider there to be little or no impact.
- The changes within the overall context of the EPR framework. For example, if changing an out of scope value makes little impact on you because the material or waste is exempt, then please let us know.
- Whether you see any of the proposed changes as affecting the interface with any other regulations.

The project deadlines are very tight and we ask that you respond **before the end of 2015**. Responses should be sent by email to: rachel.benson@phe.gov.uk, nicola.northrop@phe.gov.uk and adam.lowe@phe.gov.uk. Otherwise, please let us know if you do not wish to be involved.

If you have any questions about the proposed changes, or simply wish to discuss these issues in more detail, please contact us.

Which radionuclides in the above table do you use at your facility?
Which radionuclides in the above table do you dispose of from your facility?
Do you currently hold a Permit, Certificate of Registration or Authorisation for this work?
If you do not hold a Permit, Certificate of Authorisation, is your waste material currently out of scope of EPR or disposed of under the Exemption regime in EPR?
How will these changes affect your facility? Can you give specific examples?
Do you consider that these changes have a positive or negative effect on your facility?
What will be the financial implications for your facility? Can you give a quantitative answer?
Do you expect these changes to cause any issues with your ability to comply with other Regulations, for example when transporting radioactive materials?

Appendix C Additional information related to decommissioning wastes at Sellafield

Sellafield Ltd provided detailed information on the additional costs related to monitoring impact and waste disposal.

C1 Monitoring impact

The clearance and exemption activities carried out on the Sellafield site are applied to materials (including items) and wastes, and are many and varied (Sellafield Ltd, 2012).

The same numerical clearance values are applied to materials and items as well as waste. This is done to ensure that all materials and items, if they were then to become waste, would still be classified as out of scope (ie non-radioactive).

There are approx. 7,000 clearance activities conducted each year (48,000 since 2009). Each of these clearance activities usually involves some level of monitoring, which is undertaken by a Suitably Qualified and Experienced Person (SQEP), in the form of a Health Physics and Safety (HP&S) monitor.

For a typical Sellafield fingerprint for clearance activities that contains 57.6% caesium-137 the detection level for out of scope for caesium-137 would reduce from 0.22 Bq g^{-1} down to 0.082 Bq g^{-1}. This would drive a change in monitoring techniques from instantaneous count-rate mode, to integrated count-rate mode, with increased count times.

Current measurement times are as short as a few minutes for small items, up to several hours for large volume bulk wastes.

Assuming an increase of approximately 0.5 hours per clearance activity, this would give 3,500 hours additional monitoring time per year. At £43 per hour tariff rate, this equates to £150,000 per year (equivalent to two additional HP&S monitors for the site).

It will also drive increased costs associated with improved instrumentation (eg sodium iodide (NaI) detectors compared with dual phosphor probes) and associated training. These additional costs are summarised in Table C1. There may also be issues associated with increased background count levels and potentially a decrease in confidence when sentencing materials, items and wastes as out of scope.

Table C1 Summary of additional set up and ongoing costs of operational activities at Sellafield as a result of the proposed changes to clearance values

Activity	Additional set up costs (£ k)	Additional ongoing costs (£ k)	Total (£ k)
Instrumentation – NaI detectors	600	-	600
Training – 2 hours per HP&S monitor	30	-	30
Monitoring	-	150	150
Total additional costs			780

C2 Costs for waste disposal

The volumes of waste from future decommissioning of the Sellafield site are covered under waste stream 2D148, and are currently estimated at 2.8 million m^3.

The current assumptions are that 80% of these materials will either be clean, or classified as out of scope of EPR, based on reported information (Sellafield Ltd, 2012).

It is very difficult to assess the actual impact on these future arisings, but an evaluation of waste clearance activities, has shown that approximately 80% of wastes which were characterised (by Facility Characterisation) in 2013/14, were classified as out of scope.

Further evaluation of these waste arisings and the associated ‘bulk activity assessment’ results, has allowed a theoretical comparison with clearance values included in the BSSD (derived from RSG1.7). This has allowed the extraction of the sum of fractions (SoF) value used in the classification process, along with the contribution from caesium-137 (Bq g^{-1}). As the clearance value for caesium-137 is 10 times lower in RSG1.7 compared with EPR11 (based on RP122), and the contribution from carbon-14 and radium-226 can be considered to be insignificant, then the impact of each project can be estimated from:

$$SoF(RSG1.7) \sim SoF(EPR2011) + (9 * Cs137)$$

For each project arising classified in 2013/14, an assessment has been made to see if the material which was out of scope under EPR11, would be out of scope with the adoption of the RSG1.7 values. Within the wastes classified in 2013/14, 13,880.6 m^3 out of a total of 17,461.6 m^3 was out of scope.

The adoption of RSG1.7 value for caesium-137 would have reduced the amount classified as out of scope by 2,397.9 m^3. This would be an approximate reduction from 80% down to 65% of the arisings. This change of 15% can be used to estimate the impact of the adoption of RSG1.7 clearance values on future decommissioning wastes from Sellafield.

Using the currently estimated arisings of 2.8 million m^3, an assumed density of 1.75 tonnes m^{-3}, and an estimated disposal charge of £900 per tonne of waste, for disposal as HV-VLLW to an off-site specified landfill, then the impact is of the order of £700 million.

However, this work is based on all characterisation projects completed in 2013/14, which are considered to be non-conservative, in relation to broad front decommissioning of the Sellafield site.

Characterisation projects have supported a whole range of work across the Sellafield site, the majority of which has not supported front line decommissioning activities. As decommissioning progresses on the site, the characterisation and waste clearance activities will be more challenging, as work is undertaken closer to the higher hazard radioactive materials, which have been processed and stored on the Sellafield site.

In order to assess this, the characterisation projects were considered further, to make a judgement about their applicability to future decommissioning activities. This reduced the list of projects and the total waste arising to about 7,200 m^3 (roughly 40% of the material).

From this refined list, approximately 60% of the waste (about 4,000 m^3) was determined to be out of scope under the existing EPR11 framework. The amount of waste which would be considered out of scope with the adoption of RSG1.7 values was reduced to around 1,700 m^3 (approximately 25% of the material), implying that the change would impact on about 35% of future arisings.

Based on this analysis, the impact of the clearance values included in the BSSD (which are derived from publication RSG1.7) to future decommissioning arisings from the Sellafield site (2D148), could be significantly higher than the 15% derived above. It could be up to two or three times higher. This would then give a range of potential impacts of 15% (lower), 30% (realistic) and 45% (upper bound). The financial impact would be £700 million, £1,300 million and £2,000 million respectively.

The impact of the proposed change to the BSSD (utilising RSG1.7 values) is therefore estimated to be in the range £1,300 million ± £700 million.

Appendix D Derivation of out of scope values for carbon-14, caesium-137 and radium-226

An explanation of the derivation of the values in EC RP122 and IAEA RS-G-1.7 for carbon-14, caesium-137+ and radium-226 is given below. Much of the text is taken from the *Comparative Study of EC and IAEA Guidance on Exemption and Clearance Levels* EC RP157 (European Commission, 2010).

D1 Carbon-14

In considering carbon-14, EC RP157 concludes that the reason for the reduction in the carbon-14 activity concentration value is the very conservative modelling adopted for the exposure pathway from water with the assumption being that activity leaches from landfilled solid waste into an aquifer used for drinking water. EC RP157 states that ‘Differences may be caused by the fact that the water pathway is limiting in IAEA Safety Report 44 (International Atomic Energy Agency, 2005) for a small number of radionuclides that are relevant for clearance (carbon-14, iodine-129). This water pathway is based on restrictive model assumptions and generally leads to clearance values that are too low in international comparison. The values of 1 Bq g^{-1} for carbon-14 and of 0.01 Bq g^{-1} for iodine-129 provided in RS-G-1.7 are not manageable in routine clearance measurements.’

Some of the conservative assumptions used in the IAEA report are:

- 25,000 m^3 of material is buried in landfill
- The entire radionuclide inventory is available for migration (into groundwater)
- A conservative partition coefficient is chosen
- There is no dilution of the aquifer with groundwater and there is no further dispersion or diffusion within the aquifer

It is accepted within the IAEA report that generic modelling of the water pathway is difficult. Factors affecting the leaching of surface contamination from a landfill into a drinking water well require assumptions about the quantity of material disposed of, its location and hydrogeology. However, the pathway was included in spite of this difficulty.

The exclusion of the water pathway leads to an exemption value of 10 Bq g^{-1}, which is consistent with the existing value within EPR.

D2 Caesium-137

For caesium-137 the scenarios governing the clearance values in both documents describe the same exposure situation, but the assumptions in RP122 are slightly less restrictive than those in RS-G-1.7. The exposure parameters used in each calculation and the resulting clearance values are given in Table D1 below.

The factor of 10 difference in the end results is due to the rounding methodology causing the results to be rounded in different directions. The rounding procedure is if the calculated value lies between 3 10^{x} and 3 10^{x+1}, the rounded value is set to 10^{x+1}.

Table D1 Comparison of exposure parameters for calculating caesium-137 clearance values

Situation	RP122 Parameters	RS-G-1.7 Parameters
Person living in house built with cleared building rubble	Time of exposure: 7,000 h y^{-1} Dilution: 0.02	Time of exposure: 4,500 h y^{-1} Dilution: 0.1
Calculated value	0.38 Bq g^{-1}	0.12 Bq g^{-1}
Rounded value	1 Bq g^{-1}	0.1 Bq g^{-1}

It can be seen in the table above that the calculated values in the two reports are similar (approximately a factor of three difference) but the rounding procedure results in a factor of ten difference.

D3 Radium-226

The approach for radionuclides of 'natural origin' including radium-226 is completely different in both documents.

IAEA RS-G-1.7 starts from the assumption that radionuclides that occur in nature (potassium-40, radionuclides of the uranium-238, uranium-235 and thorium-232 decay chains) have no relevance for practices; that is any radiological levels being derived for such radionuclides need only be based on considerations pertaining to their natural occurrence. This is the reason why these radionuclides are excluded from the scenario calculations, but are based purely on considerations on the activity contents in soil and NORM. The value for all radionuclides of natural origin except potassium-40 is 1 Bq g^{-1}.

EC RP 122 (Part 1) considers potassium-40 and the radionuclides of the uranium-238, uranium-235 and thorium-232 decay chains only with respect to their occurrence as part of licensed practices. The derived levels are therefore based on scenarios as for all other radionuclides. Their abundance in natural materials or NORM is irrelevant for defining clearance values for practices. This approach leads to a significant difference between the 'artificial' radionuclides that are based on scenarios related to individual doses of 10 µSv y^{-1} and the other group of 'natural' radionuclides that are limited by values occurring in natural soil and rock, thus being related to doses of several mSv y^{-1}. This discrepancy becomes most obvious for radionuclides such as radium-226, where the clearance value based on 10 µSv y^{-1} is of the order of 0.01 Bq g^{-1} instead of 1 Bq g^{-1} as recommended in IAEA RS-G-1.7. The level is based on the ingestion scenario that takes into account only direct ingestion of material. The prolonged and intense contact of a child with the material, leading to ingestion of 100 g y^{-1}, is a very conservative assumption. For comparison, data compiled by PHE for use in assessments assumes an average intake rate for 1 year olds of 37 g y^{-1} with 44 g y^{-1} for high rates of inadvertent ingestion (Smith and Jones, 2003). An additional conservatism is the assumption that this entire quantity originates only from the cleared material in question. EC RP 113 also considers this pathway. However, in this report the material is assumed to be diluted by a factor of 10 before being consumed by the child and therefore the clearance value is a factor of 10 lower at 0.1 Bq g^{-1}.