Guidance on monitoring for heterogeneous Radium-226 sources resulting from historic luminising or waste disposal sites

Final

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Contents

Glossary of Terms

ALARA	An acronym for As Low As Reasonably Achievable. See Optimisation.
Alarming criteria	Threshold above which there is a distinguishable difference in the values being measured.
Artefact	An object made by a human being one of cultural or historical interest.
BPM	Best Practicable Means to achieve a particular objective: Best – means the most effective techniques for achieving a particular objective. Practicable – indicates that the 'means' under consideration should only be selected following an optimisation process that includes consideration of the technical viability including comparable processes, facilities or methods of operation, which have recently successfully tried out and takes into account social and economic costs and benefits. Means – includes technology, disposal options, the design, build, maintenance, operation and decommissioning of facilities and wider management arrangements. (Please see SEPA guidance 'Satisfying the ALARA requirement and the role of Best Practicable Means, SEPA, May 2012' for more details: http://www.sepa.org.uk/media/101545/satisfying_the_alara_requirement_and_the_role_of_best_practicable_mean.pdf)
Background counts	Background counts refer to the amount of local background radiation measured. Background radiation is the ubiquitous ionising radiation that people are exposed to, including natural and anthropogenic sources. Natural background radiation varies depending on location and altitude due to underlying geology and cosmic interactions.
Becquerel (Bq)	The International System of Units (SI) of activity equal to one nuclear transformation (disintegration) per second.
Change of use	A change in the 'Use Class' of the land as defined by The Town and Country Planning (Use Classes) (Scotland) Order 1997 that will require planning permission under the Town and Country Planning (Scotland) Act 1997.
COMARE	Committee on Medical Aspects of Radiation in the Environment.
Confidence of detection	The assessed value for which an observed effect will be recorded e.g. a 50% confidence of detection will mean there is an equal chance or detection and non-detection.
Current use	As defined in Environmental Protection Act 1990: Part IIA Contaminated Land Statutory Guidance: Edition 2, May 2006,

	Paper SE/2006/44: any use which is currently being made, or is likely to be made, of the land and which is consistent with any existing planning permission (or is lawful under town and country planning legislation). See Statutory Guidance: Edition 2 for full definition.
Integration time	The period of time (typically in seconds) over which counts of radioactive emissions detected by the instrument are collected.
Millisievert (mSv)	The sievert (symbol: Sv) is the International System of Units (SI) derived unit of equivalent radiation dose, effective dose, and committed dose. 1 mSv = 0.001 Sv.
Optimisation	The principle of ensuring that radiation exposures are as low as reasonably achievable (ALARA) in the given circumstances. Optimisation is a key principle of radiation protection recommended by the International Commission on Radiological Protection (ICRP) and incorporated into UK legislation.
Particle	A physically small radioactive source which, other than its radioactive properties, is difficult to distinguish to that of the surrounding sediment.
Practice	A human activity that can increase the exposure of individuals to radiation from an artificial source, or from a natural radiation source where natural radionuclides are processed for their radioactive, fissile or fertile properties, except in the case of an emergency exposure.
RCLEA	Radioactive Contaminated Land Exposure Assessment methodology https://www.gov.uk/government/publications/rclea-software-application
Reasonable Grounds	The conditions that SEPA must satisfy in order to justify inspecting land, namely that: a) A substance arising from a past practice, past work activity, or radiological emergency has been identified as present in, on or under the land; b) Receptors have been identified in, on or under that land; and c) It is SEPA's opinion that it is possible that the identified contamination may cause lasting exposure giving rise to radiation doses exceeding those set out in Chapter A of The Radioactive Contaminated Land (Scotland) Regulations 2007 Statutory Guidance (SG/2009/87 http://www.gov.scot/Publications/2008/03/31102033/0).
Source	A radioactive object which can include particles and artefacts.
Statutory Guidance	Environmental Protection Act 1990: Part IIA Contaminated Land Statutory Guidance: Edition 2, Paper SE/2006/44 as amended by Environmental Protection Act 1990: Part IIA Contaminated Land, Radioactive Contaminated Land (Scotland) Regulations

2007 Statutory Guidance 28 May 2009 SG/2009/87 http://www.gov.scot/Publications/2006/06/05131212/0

1.0 Introduction

1.0.1 The Scottish Environment Protection Agency (SEPA) is the regulator in Scotland under both the Radioactive Substances Act 1993 (RSA 93), the Radioactive Contaminated Land (Scotland) Regulations 2007 (Part IIA RCL) and is a competent authority under the Basic Safety Standards Directive (96/29/Euratom) (BSSD). The requirements of this legislation have a bearing on land with radioactive contamination which is being considered under the Planning regime and land with radioactive contamination where the land use will remain the same and is being considered under Part IIA.

1.0.2 Under Part IIA RCL it is SEPA's responsibility to prioritise the inspection of land that it has Reasonable Grounds to believe may meet the criteria specified in the Statutory Guidance for RCL and could be designated formally as Part IIA Radioactive Contaminated Land.

1.0.3 The Local Authority (LA) is the lead authority under the Town and Country Planning (Scotland) Act 1997. Under the Planning regime SEPA has statutory responsibilities in relation to Part IIA Radioactive Contaminated Land and the regulation of radioactive wastes under RSA 93. There is no formal requirement for the LA to consult SEPA on all plans to develop land containing radioactivity or where radioactivity is suspected. However, LAs should take into account government policy (Ref. 1 and 2) regarding radioactive contamination and not permit any development which would result in additional radiation exposure of greater than 0.3 mSv per year. Changing how land contaminated with anthropogenic radioactive contamination is used may increase the exposure of people using the land in the future and is considered a 'practice'. As such LAs should consider consultation with SEPA on relevant applications. Whilst recognising that it is the responsibility of the Planning Authority to determine planning applications, SEPA recognises that some LAs may feel the need for support and guidance to assist them in the decision making process where land with potential radioactive contamination is being considered.

1.0.4 This document provides guidance to aid LAs and contractors in undertaking what SEPA considers to be current best practice for radiological walkover surveys concerning gamma emitting radionuclides, specifically radium 226, under Part IIA and also under the Planning regime in Scotland. It is SEPA's experience radium 226 is the most common contaminant due to historic practices.

1.0.5 Due to the differences in legislation concerning radioactive contaminated land across the UK, use of this guidance outside of Scotland would require consultation with the relevant LA and environment agency. Use of this guidance with respect to other radionuclides (i.e. alpha and beta emitting radionuclides) is unlikely to be applicable and requires a different approach.

1.0.6 The criteria for land in current use and for land where a change in use is proposed are different:

Current land use, as defined by the Part IIA RCL Statutory Guidance (Ref. 1):

1. SEPA should regard significant harm as being caused to human beings when lasting exposure gives rise to a dose in a year to an individual exceeding one or more of the following:

   (a) an effective dose of 3 mSv;
   (b) an equivalent dose to the lens of the eye of 15 mSv;
   (c) an equivalent dose to the skin of 50 mSv averaged over any $1cm^2$ area of skin, regardless of the area exposed.

2. Where:

   (a) in a single exposure event, the potential effective dose would be greater than 100 mSv; or
   (b) contact with contamination would result in a potential absorbed dose to the skin greater than 10 Grays in an hour;

SEPA shall regard the possibility of significant harm as significant, irrespective of the probability of radiation dose being received.

1.0.7 Where 1 relates to homogeneous contamination and 2 relates to point source heterogeneous contamination.

Change in use: 1 mSv/yr limit with a 0.3 mSv/yr constraint (Ref. 2).

For the full criteria please refer directly to References 1 and 2.

1.0.8 This means that the quality of surveying and the associated Limit of Detection (LoD) needs to be significantly greater for a change in land use than that for current land use i.e. quality of surveying is better if there is a lower LoD.

1.0.9 This document, as guidance to LAs and contractors, covers both scenarios; Chapter 2 presents SEPA’s position on what is current best practice for walkover surveys for radium 226 for land in its current use (i.e. being assessed under Part IIA RCL). Chapter 3 presents SEPA’s position on what is current best practice for walkover surveys for radium 226 for land where there is a proposed change of use under the Planning regime. Annex 1 detail’s what SEPA consider best practice with regard to the requirements for monitoring equipment.

1.0.10 Where land is to be cleaned-up on a voluntary basis rather than as a result of proposed redevelopment or because it has been identified as Radioactively Contaminated Land under the Part IIA regime, the selection of clean-up criteria is a matter for the land owner in consultation with any other relevant stakeholders. In this case selection of clean-up criteria will be driven by their reasons for cleaning up the site, e.g. to make an area safe to work in, to remediate the site so it is suitable for development or to attempt to clean-up the site to such an extent that all possible future liabilities are removed.

1.0.11 Landowners and their contractors often seek assurance from SEPA that their proposed clean-up will remove all future liabilities. However, in practice this can rarely be assured (e.g. it is difficult to prove that all buried contamination has been located and removed). Therefore, SEPA can only offer advice on what the regulatory position is in relation to any radioactivity remaining in or on the land and how it would be considered in the future.

1.0.12 The publication of this document does not constrain SEPA's regulatory independence in any way nor provide any reassurance, indication or guarantee that SEPA will or will not exercise any of its functions in any particular way. SEPA may update, vary or withdraw this guidance at any time.

2.0 Walkover Surveys for heterogeneous Radium-226 for Land in Current Use or Investigation under Part IIA

2.0.1 For land being considered under Part IIA where contamination may be present but not confirmed, a basic radiological survey can provide the necessary information to evaluate whether further works are likely to be required. Although it is accepted that no monitoring programme is certain to detect all sources present, a basic survey will give some confidence to the conclusions of a desk study review. Monitoring for land in its current use should reflect that use; however, for typical situations monitoring should be targeted to detect radioactive sources within 10-20cm of the soil surface as it is only those which are likely to be encountered by the public.

2.0.2 NOTE: For areas undergoing redevelopment where deeper disturbance depths may occur, e.g. digging of foundations, although following the approach detailed in Section 3 of this guidance can be useful, early engagement with SEPA can allow a common understanding of the requirements for each particular site as further work in addition or in replacement of that detailed in section 3 may be appropriate. This guidance is not applicable to situations where remediation is required and unrestricted use envisaged. Equally for high activity sources other techniques may be more suitable. Where greater confidence is required or a change in land use is envisaged SEPA is willing to discuss with landowners/developer to determine the appropriate requirements.

2.1 SEPA Recommendations for Land in Current Use

2.1.1 As general guidance, for land remaining under its current use SEPA would advise a walkover survey for Ra-226 to be conducted to detect 20 kBq of radium to a depth of 100 mm with a 95% probability of detection using appropriate instrumentation with suitable transect spacing typically of no greater than 1m (ideally approaching 0.5m) and a walking speed of no greater than 1m/s. In these situations the limit of detection (LoD) for Ra-226 sources using a suitable instrument can be around the criteria specified in the COMARE 15th report (Ref. 3) i.e. 20 kBq of radium to a depth of 100 mm with a 95% probability of detection[1]. It is noted that the interpretation of the monitoring data (often in the form of alarming criteria) either real time or post monitoring will determine the confidence of detection together with the effects of local background. Where greater confidence is required or lower activity sources are required to be detected SEPA can provide site specific guidance.

2.1.2 In order to interpret the data there will be a need to relate monitoring data to dose rates, potential activity and hazard from radioactive sources. This interpretation is out with this monitoring guidance. In the event that potential sources have been found by the monitoring survey, further works may be required including both field and laboratory measurements and a full dose

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https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/312674/COMARE_15th_Report.pdf

It is noted that the interpretation of the monitoring data (often in the form of alarming criteria) either real time or post monitoring will determine the confidence of detection together with the effects of local background.

assessment. Please note that this guidance relates to point source, heterogeneous contamination and as such RCLEA is not appropriate for undertaking dose assessment.

3.0 Walkover Surveys for heterogeneous Radium-226 sources where there is a Proposed Change in Use.

3.0.1 For land where a change in use is envisaged and requires planning permission and the potential for radium contamination exists or where radium contamination has already been identified on site, there is a need for further work to characterise the contamination and ensure that the in the context of optimisation all exposures shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account in line with Government policy (Ref. 2) and RCL Statutory Guidance (Ref. 1). SEPA considers the appropriate dose constraint for change of use is that appropriate to a practice: 0.3 mSv per annum.

3.0.2 For land where there is limited information on radioactive contamination or previous uses of radioactive substances or no monitoring has previously been undertaken a desk study will inform potential areas for examination which could then be supplemented by a walkover survey with a minima criteria as specified in Annex 1, however, consideration should be given to improving LoD through adjustment of one or more of the variables which affect the LoD as discussed in Annex 1.

3.0.3 For land where previous monitoring has been undertaken the robustness of the walkover survey findings should be considered against the suggested approach set out in Annex 1, as well as the nature of the change in use.

3.0.4 The nature of the development on the site will inform whether further work needs to be required. For example, if the land use change constitutes additional material being added to site and no excavation is required, provided the area had been monitored according to the recommendation in Annex 1, and no contamination was detected, no further work would be required.

3.0.5 However, if disturbance of the land or excavation were to occur (for example to dig foundations to a depth of 0.5m), even if a walkover has been carried out, with the recommended criteria in Annex 1, further work would still be required. This is needed to monitor the wastes arising, as contamination may exist which would exceed the criteria appropriate to a practice (0.3 mSv/yr) at depths beyond the capability of the detection equipment. Monitoring of such wastes can be performed by surveying detectors or a range of hand held instrumentation.

3.0.6 For removal of waste offsite either as ‘free release’ or disposal to a landfill site, instruments and their use should give confidence that the waste has been appropriately consigned. For material remaining on site, to which the public could have access, instrumentation and monitoring technique must be chosen to allow the confident detection of sources which could deliver doses of 0.3 mSv/yr. Confidence in detection of such sources is both a product of the efficiency of the detector and the methodology used.

3.0.7 As outlined in paragraph 1.6 the criteria for land in current use and for land where a change in use is proposed is different. For the full criteria please refer directly to references 1 and 2.

3.0.8 These differing criteria mean that the quality of surveying and the associated LoD for a change in land use needs to be significantly greater than that for current land use. However, the principle of ALARA (As Low As Reasonably Achievable) also requires to be applied. This effectively means for current available techniques the basic walkover survey indicated in Section 3.1 should be optimised to improve the LoD where possible. For intrusive works other monitoring methodologies and instrumentation can be used to allow detection of sources which pose a hazard greater or equal to 0.3 mSv/yr. SEPA recognises that detection of Ra-226 sources which could deliver such doses is highly problematic and a bespoke practical approach using BPM needs to be adopted in these situations. In these situations SEPA would welcome early discussion with regard to monitoring requirements and criteria in advance of any works.

3.0.9 To ensure such works are undertaken to the appropriate criteria, planning conditions should be attached to any planning application where radium contamination could be present, such as former luminising sites, clock factories and airfields. The DEFRA (Department for Environment, Food & Rural Affairs) Industry Profile for Industrial Activities which have used Material Containing Radioactivity should be consulted (Ref. 4). SEPA can also provide guidance on appropriate wording for such conditions see Section 3.2.

3.1 SEPA Recommendations for Land under a Change of Use

3.1.1 As general guidance, for land where a change in use is planned, SEPA would expect a walkover survey for Ra-226 to be conducted using appropriate instrumentation with suitable transect spacing typically of no greater than 1m and a walking speed of no greater than 1 m/s as an absolute minima. The applicant should optimise the system used to maximise the detection probability of radium sources at the site and although operator performance should have been established in advance, lower speeds and closer transect spacing approaching 0.5 m/s and 0.5 m respectively should be the aim of monitoring in areas where a change of land use is envisaged. Where intrusive works are undertaken a range of hand held instrumentation is available and selection and analysis of this instrumentation should be based on a requirement to detect contamination which could deliver doses of 0.3 mSv/yr.

3.2 Wording for Suspensive Planning Conditions

3.2.1 For sites where radium 226 contamination is potentially present from historic practices and a change of use is proposed SEPA suggests a separate condition from that relating to conventional contamination be used.

3.2.2 In line with Model Planning Conditions, the addendum to circular 4/1998, The Use of Conditions in Planning Permissions as referenced in Planning Advice Note 33 Development of Contaminated Land (Ref.5) draft wording is presented here for the investigation stage and also for the remediation and validation stages:

3.2.3 *That, prior to commencement of any development works, a Radiological Walkover Survey report shall be submitted for the consideration of the planning authority and shall be carried out to a methodology submitted and approved in consultation with SEPA. The survey shall be completed in* *accordance with The Radioactive Contaminated Land (Scotland) Regulations 2007 (as amended). Any wastes arising shall be addressed in accordance with the Radioactive Substances Act 1993 and Radioactive Substances (Exemption)(Scotland) Order 2011.*

3.2.4 *That, where recommended by the Radiological Walkover Survey report, a detailed remediation strategy shall be submitted for the written approval of the planning authority. The development shall not commence until the planning authority has approved the Radiological Walkover Survey and any associated remediation works in writing. Prior to the occupation of the development a validation report confirming that all necessary remediation works have been undertaken shall be submitted for the written approval of the planning authority.*

3.2.5 SEPA are able to assist the LA, where required, with wording for conditions as the above draft text may not be suitable for every planning application.

4.0 Remediation and Compliance with RSA 93

4.1 Regulatory position for radioactive contamination in situ

4.1.1 Undisturbed contamination remaining in situ is neither regarded as radioactive material which is being kept or used, nor is it regarded as radioactive waste as defined in RSA 93. However, SEPA recognise that the classification of a substance as radioactive waste is independent of the applicability of the contaminated land and the planning regimes. These regimes may still impose controls on such contamination if necessary.

4.2 Regulatory position for excavated soil with radioactive contamination

4.2.1 Background levels of radium-226 often exceed 0.01 Bq/g, the level which it would fall within scope of RSA 93. It can be difficult to distinguish radium-226 from a past practice and that which is naturally present. As a consequence, SEPA will not treat soils excavated from historic luminising sites as radioactive waste unless they contain concentrations of radium that are demonstrably above the local background level. In determining what is demonstrably above background, the practicability of monitoring should be taken into account. Thus it is essential that any works undertaken provide a robust assessment of background.

4.2.2 An application for a RSA 93 authorisation to accumulate and dispose of radioactive waste must be applied for and granted. Please see our website for further information: http://www.sepa.org.uk/regulations/authorisations-and-permits/application-forms/

4.3 Segregation and characterisation of waste

4.3.1 SEPA expects that Best Practicable Means (BPM) is used to segregate and characterise any wastes arising from land remediation. SEPA will take action against inappropriate averaging of waste which is designed solely to ensure that exemption or out of scope values are met. In the case of land containing discrete radioactive items, best practice would be to develop a monitoring protocol that is capable of identifying and removing radioactive items from bulk soil. This facilitates appropriate sentencing and management of waste in accordance with the waste hierarchy e.g. minimising radioactive waste generation. We note that there is a need to optimise the process of segregation and consideration of ALARA and are happy to discuss optimised segregation.

5.0 References

1. The Radioactive Contaminated Land (Scotland) Regulations 2007 Statutory Guidance 28 May 2009

2. Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom, Defra, DTI and the Devolved Administrations, 26th March 2007, particularly paragraph 40 of Annex 1: Supplementary Notes to the Policy Statement

3. COMARE 15th Report 2014

4. Department for Environment Food and Rural Affairs, Industry Profile, Industrial Activities Which Have Used Materials Containing Radioactivity, March 2006

5. Planning Advice Note 33 Development of Contaminated Land, Scottish Government

Other Relevant Legislation and Guidance

The Radioactive Contaminated Land (Scotland) Regulations 2007

Environmental Protection Act 1990: Part IIA Contaminated Land Statutory Guidance: Edition 2, May 2006, Paper SE/2006/44

Radioactive Substances Act 1993

The Radioactive Substances Exemption (Scotland) Order 2011

Basic Safety Standards Directive (96/29/Euratom)

SAFEGROUNDS Good practice guidance for the management of contaminated land on nuclear-licensed and defence sites, Version 2, CIRIA W29, 2009

Satisfying the ALARA requirement and the role of Best Practicable Means, SEPA, May 2012

Town and Country Planning (Scotland) Act 1997

Annex 1 Instrumentation and Methodology Applicable to Part IIA and Planning

Walkover surveys for radium contamination are limited by instrument, time and methodology which all contribute to the overall performance and the cost of the works. This section describes the factors which influence the performance of walkover surveys.

The work carried out by SEPA at Dalgety Bay and the advice given by the Committee of Medical Aspects of Radiation in the Environment (COMARE) (Ref.3) have provided criteria which are linked to the potential health effects of radioactive contamination. The performance of monitoring instruments is influenced by a number of factors which should be optimised. COMARE recommend that walkover surveys (for land in its current use, i.e. where no redevelopment is planned) should be undertaken with a detector system with a detection limit of, or better than, 20 kBq of radium to a depth of 100 mm with a 95% probability of detection. SEPA consider this to be current best practice for land being investigated under Part IIA RCL.

The factors considered in this Annex should enable surface walkover surveys to achieve the criteria specified in the COMARE recommendation (dependent on the site specific context).

NOTE: For areas undergoing redevelopment where deeper disturbance depths may occur, e.g. digging of foundations, aspects of this Annex may not be appropriate. This Annex is not applicable to situations where remediation is required and unrestricted use envisaged. Equally, for high activity sources other techniques are more suitable. Where greater confidence is required or a change in land use is envisaged, SEPA can provide site specific guidance.

A1.1 Instrumentation

There are a number of commercially available suitable instrumentation which are capable of providing sufficient sensitivity in relation to the COMARE criteria. These include, but are not limited to:

- 3”x3” NaI;
- 6”x1” NaI; and
- 2”x2” BGO (Bismuth germanate)

As an example a 3” x 3” sodium iodide (NaI) detector represents a relatively large crystal detector which is commercially widely available and capable of detecting the gamma rays from the decay of radium-226 (Ra-226) and some of its progeny. Although larger NaI crystal detectors are available together with other types of crystal (e.g. High Purity Germanium (HPGE)), these are more expensive and can be problematic for use over uneven ground. It is also worth noting that as the volume of the detector increases so do the background counts seen by the detector, making any excess gamma rays ‘seen’ by the crystal which are from a low activity source close to the surface potentially more difficult to discriminate. For deeply buried high activity sources, such larger systems would be much more suitable for detection.

SEPA recognise that new systems and software may exist or is likely to be developed in the future which would provide similar or better detection capability.

Monitoring instruments can be sensitive to particular energies of radionuclides. However, NaI detectors can be constructed to collect all gamma-ray emissions and the energy range can be sampled either by gating or reporting of specific energy ranges to focus the analysis for the emissions of interest (e.g. a particular energy range). Storage of the spectra for each data sampling interval (a timescale over which the emissions were collected - typically one second) will allow post monitoring examination of the data windows for one of the primary daughter radionuclides of radium Bismuth-214 (Bi-214) (with account made for potential drift) and will aid the examination of the data.

During monitoring the use of a discriminating detector, which can differentiate between differing types of gamma emitting radionuclides, will aid interpretation and minimise analysis costs. For example, the increased total counts for a given location could be due to either a Ra-226 source or naturally present potassium-40 (K-40) from buried bricks, the use of such a detector can differentiate between these two radionuclides.

If required, SEPA can discuss the suitability of instrumentation with the LA or contractors directly.

A1.2 Speed

The speed of monitoring influences how likely it is that any sources present will be detected or missed. For a source sitting on the ground surface, the more rapid the speed of the detector over the source, the less number of gamma rays from any radioactive source will interact with the crystal, making any excess ‘counts’ more difficult to resolve from background levels. Thus, a slower speed is more effective.

A1.3 Integration Time

The sampling period for counting the integration time is critical to allow comparison of background to potential sources. Such a time period needs to be sufficiently long to reduce the variation in background count rates, but sufficiently short so that the time period where excess counts are present is not diluted to such an extent it is difficult to determine it from background. As the integration time is linked to the proportion of time where the detector is influenced by the source, it is also directly linked to the speed of monitoring. The integration time needs to be considered for the activity and location of the contamination. For instance, a low activity particle on the surface might be missed in the long count time case, but for a more deeply buried more radioactive source a longer count time may be more useful. It is noted that for gross counting (where all the energy emissions are counted) it becomes slightly more complicated due to potential collimation.

A1.4 Transect Spacing

Walkover surveys typically involve coverage of the entire survey area using transects. Although full coverage of the entire area under the width of the detector would be an ideal situation, it is often unrealistic and impracticable given time and resource constraints. Thus, some spacing between transects is necessary. As the distance between transects increases so the probability of detection of sources off centre from the detector decreases. At distances of over 2m transect spacing the probability of detection for sources of activities recommended by the COMARE 15th report (Ref.3) are unlikely to be detected[2]. However it is also impractical in the field to ensure consistent transect spacing of less than around 0.3m. A reasonable transect spacing of between 0.5 to 1m often presents a practical option which retains confidence in the detection of any sources close to the surface but offset from the transect line. Additional transects perpendicular to the initial transects will aid confidence in detection capability. Consideration can also be given to closer spacing where an observable increase in the count rate occurs.

A1.5 Height of detector

The height of the detector above the ground surface is a further consideration in monitoring technique. A consistent monitoring height and knowledge of detector performance will assist with interpretation of gathered data. Calibration of detectors against a known source activity to a standard depth for the density of the ground medium (i.e. soil, clay or sand) will aid interpretation of data.

A1.6 Data Analysis

Monitoring data needs to be capable of being interrogated in real time or logged with an associated GPS location such that, post monitoring, the data can be interrogated and the location of any anomalies identified. Logging of the data with a GPS location is the preferred option as it allows demonstration of the area monitored and other issues such as transect spacing and speed of monitoring to be checked. In order to be of value, the GPS log should be of sub metre precision and consistent in its accuracy. To permit detailed examination of the data, the data can be provided in its entirety in a format which can be loaded onto a GIS tool (e.g. in .csv file).

A1.7 Background

The capability of a walkover survey to detect Ra-226 sources close to the surface is dependent upon the factors outlined above, but these variables are also compounded by the effect of natural background levels of radium in the environment. Where these are consistent over the monitored area, the capability of detection is significantly greater than areas where greater fluctuation of background count rate (both spatially and temporally) occurs. Shorter integration times will increase the variation in background count rates. In situations where background significantly fluctuates, greater confidence can be achieved by changes in one of the variables of the monitoring regime (e.g. reduction in transect spacing, reduction in speed or increased detector size). All monitoring environments will have a natural level of background radioactivity present, including the gamma rays emitted from this natural radioactivity (including radium) from the decay of uranium and potassium. A gamma detector can detect all gamma emissions within a given energy range. The detector will collect both the background emissions together with any emissions from the gamma emitting radionuclide of concern. The number of gamma emissions contributing from the background radioactivity is both temporally and spatially variable.

Homogenous environments, such as a deep sandy beach, will have largely consistent background levels; whereas, in areas where bedrock are near to or at the

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[2] The COMARE 15th Report on Radium at Dalgety Bay, Section 8 – Implications for other sites reported "In accordance with the recommendation of the COMARE Contaminations Working Group, surveys of the area should be carried out using a detector system with a detection limit of, or better than, 20 kBq of radium to a depth of 100 mm with a 95% probability of detection".

surface, the background may vary significantly between the deep sand and bedrock areas. The total count rate (counts per second (cps)) contributing to background for any given point is a reflection of the composition of the substrate. For example, a soil with high uranium (Uranium 238) content will have a higher background than one without. Equally, surveying over buried brick buildings will result in a higher background than environments where no bricks are present.

It is the relative change in the count rate which affects the confidence in detection of a radioactive source rather than the background level itself. For example, if the background is stable at 300 cps ± 10 cps and a source is present resulting in an excess count of 50 cps the confidence of detection will be similar to that in a lower background environment where the count rate is 150 cps ± 10 cps as the detector is 'looking' for an excess of 50cps. However, in environments where the background is highly variable, even where the background total count is relatively low the confidence is significantly lower (e.g. detecting an excess 50cps would be problematic in a background environment which varies from 120 to 180 cps i.e. mean 150cps ± 30cps).

To address this, zoning can be helpful when monitoring in areas where the spatial background varies; i.e. breaking up the areas into similar background 'zones' each having a given background and range which is smaller than the total range for the site. Thus, background variability across the site can be considered in advance of monitoring. Alternatively, the data could be divided following monitoring into suitable zones if significant variation of background is evident. Monitoring of an adjacent area as a control site can also help to assess local background and interpretation of the data.

A1.8 Calibration

Calibration can allow greater confidence to be provided in the validity of the data output. However, if the total count rate approach is taken where the entire energy range of the gamma emitting radionuclides is included, calibrations will provide little added value as there is no discrimination between radionuclides.

If the spectra can be examined, or windows have been established for Ra-226, or in most situations its daughter Bi-214, these can be directly compared to a calibration by assessing the energies of the counts against a standard reference.

It is notable that unless the distance and any possible shielding of the source is known, estimates of activity of Ra-226 from a walkover survey should be taken with extreme caution. If a discriminating detector is used, these generally require to be calibrated against an appropriate source on an annual basis.

Calibration of the detection capability of any instrument and its effectiveness is aided if consideration is made of the specific density of materials which may be shielding the source (e.g. sand vs concrete) together with the potential confounding effects of geometry and natural levels of radionuclides within the spectra selected.

A1.9 Limit of Detection

The Limit of Detection (LoD) for detecting the presence of a Ra-226 source is the lowest activity which can be confidently detected (often expressed as 95% confidence) in a given situation. The LoD is dependent upon all of the aforementioned variables, together with the activity and depth of the source (and by implication the distance from source to detector) and any shielding effect of the substrate, if the source is not at the surface. The overall effect all of these variables have on detection limit is complicated. However, the following can assist in deriving an acceptable detection limit:

- The confidence of detection for a source on the surface is greatest directly under the detector and diminishes until the mid-point between two transects.
- For sources buried at depth the confidence of detection diminishes with increasing depth and the associated increased shielding of the source.
- Sources buried at depth and offset from the detector have the lowest confidence in detection.

As the probability of detection is directly related to the number of excess ‘counts’ seen by the detector, the probability of detection increases for increasing activities (assuming the effect of self-shielding is negligible). Thus, confidence and probability of detection is greatest for higher activity sources at surface under the path of the detector and lowest for lower activity sources buried at depth at maxima offset from the detector.

To improve the confidence in detection of sources from any survey supplementary transects can be run perpendicular to the initial transects. This would minimise the possibility of ‘missed’ sources.

For areas where multiple radioactive sources exist which are located close to each other, consideration should be made of how to optimise the resolution of such sources. SEPA can provide advice upon on a case by case basis.

A1.10 Monitoring Results

Monitoring data can be collected to allow retrospective interpretation. This will also provide a demonstration that the area under consideration has been monitored to a given standard. Appropriate interpretation of the data is important as it is this that will give confidence as to whether radioactive sources have been detected or otherwise. The contractor can be asked to provide information to support the performance of the monitoring system to aid interpretation (e.g. that a 20kBq source at 10cm (and by inference sources of higher activity at deeper depths) will produce an excess count rate to the operator’s detector of 200cps at maxima offset). The data can then be interrogated to examine locations where the recorded count rate was background + 200cps (with account made for variation in emissions).