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Assessment of Compliance with the Public Dose Limit

Principles for the Assessment of Total Retrospective Public Doses

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Contents

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INTRODUCTION

1. The Euratom Basic Safety Standards (BSS) Directive 1996 [Ref 1] (Article 14) requires member states to assess regularly the total of all contributions of exposure to ionising radiations to reference groups of the public from practices subject to the Directive (ie, practices involving a risk from ionising radiation). Directions on the Environment Agency (EA) and Scottish Environment Protection Agency (SEPA) [Refs 2, 3] require these Environment Agencies to ensure that the sum of doses to reference groups of the public do not exceed the dose limits specified in the BSS, in discharging their functions in relation to the disposal of radioactive waste under the Radioactive Substances Act 1993. Equivalent legislation is being developed for Northern Ireland [Ref 4].

2. The Radioactive Waste Policy Group of the Department for Environment, Food and Rural Affairs (Defra) has recommended that the Environment Agencies (ie, EA, SEPA and Environment and Heritage Service, Northern Ireland) should take the lead on assessing and reporting on compliance with dose limits.

3. This NDAWG paper describes principles which should be applied in the assessment of total retrospective doses.

BACKGROUND

4. Collaborative studies involving the EA, FSA, NII, CEFAS and SEPA have been undertaken to develop a methodology for assessing total retrospective doses [Ref 5, 6]. A previous joint NRPB, MAFF and HMIP study has also been undertaken to assess total doses from all exposure pathways around nuclear sites [Ref 7].

5. NRPB contributed to European Commission guidance on the assessment of public doses arising from the operation of nuclear installations under normal conditions [Ref 8].

6. In 2000 the FSA organised a Consultative Exercise on Dose Assessment. One of the outcomes was support for work on methodologies for the assessment of total dose [Ref 9].

SCOPE

7. The scope of this paper is to provide principles for assessing total retrospective doses from authorised discharges of radioactivity into the environment and regulated direct radiation for comparison with the public dose limit.

8. In general, un-enhanced naturally occurring radioactivity, accidental discharges (both in the UK and from overseas) and radioactivity in food imported from other countries are excluded from the scope of these assessments. However, doses from these sources could be assessed in a similar manner.

PRINCIPLES

Transparent assessments

9. The Radioactive Waste Management Advisory Committee (RWMAC) have stated that *"An openly declared and consistent method of dose calculation should be sought"* [Ref 10].

10. Total retrospective assessment methods should be transparent, by being clear and readily understandable. To achieve this, total retrospective assessment methods and their underpinning data should be made publicly available in a suitable form such that another party can repeat the assessment.

Principle 1	**Total retrospective dose assessment methods and data should be transparent.**

Members of the public and population groups

11. Principles relating to members of the public and population groups have been established for the assessment of prospective doses to members of the public [Ref 11]:

- Workers who are exposed to discharges of radioactive waste, but do not receive direct tangible benefits from the organisation making the discharge, should be treated as if they are members of the public for the purpose of determining discharge authorisations.
- The mean critical group dose should be assessed for the purpose of determining discharge authorisations.
- Doses to the most exposed age group should be assessed for the purposes of determining discharge authorisations.

12. These principles have similar applicability to the retrospective assessment of doses to members of the public.

13. Doses to individuals are compared with dose limits and constraints. The Euratom Basic Safety Standards Directive 1996 [Ref 1] defines separate limits for workers and members of the public. The Basic Safety Standards Directive [Ref 1] defines members of the public as:

"individuals in the population, excluding exposed workers, apprentices and students during their working hours and individuals during the exposures referred to in Article 6(4)(a), (b) and (c)" (these articles relate to medical exposures).

14. The Ionising Radiations Regulations [Ref 12, 13] defines dose limits for employees, where the employer is undertaking work with radiation, as well as dose limits for 'other persons'. 'Other persons' includes employees who do not normally work with radiation and members of the public. The Approved Code of Practice for the Ionising Radiations Regulations [Ref 14] states that radiation employers should take particular steps to restrict the exposure of any employees who would not normally be exposed to ionising radiation in the course of their work. The dose control measures should make it unlikely that such persons would receive an effective dose greater than 1 millisievert per year. This is the dose limit for 'other persons', which includes members of the public.

15. Employers working with radiation are required to assess the dose to the employees under the Ionising Radiations Regulations [Ref 12, 13]. It is the responsibility of the Environment Agencies to assess total retrospective doses to members of the public and ensure that they are below the public dose limit. However, for certain groups of workers there is a need to include them in the assessment of total retrospective doses made for members of the public.

16. Workers who enter a site from which a radioactive discharge is being made (eg, employees, contractors, employees on a co-located site) should be provided with information, where necessary, on their exposure arising form radioactive discharges. The Ionising Radiations Regulations [Ref 12, 13] requires employers to co-operate (by exchanging information, etc) where work involving ionising radiation of one employer can give rise to the exposure of an employee of another employer. Therefore, it is not considered necessary to include these workers in the assessment of total retrospective doses made for members of the public.

17. There is another group of workers who may be exposed as a result of discharges of radioactive waste to the environment, but do not work directly with ionising radiation themselves and thus may be regarded as not normally working with ionising radiation. These workers and their employer may not be familiar with the requirements of the Radioactive Substances Act 1993 and the Ionising Radiations Regulations [Ref 12, 13]. This group of workers include farmers, sewage workers and fishermen. It is appropriate that these workers should be treated as if they are members of the public for the purpose of assessing and reporting total retrospective doses.

18. If total retrospective doses to these workers are assessed as being greater than the public dose limit, then consideration will need to be given to ensuring that the radioactive waste and radiation protection arrangements are appropriate.

Principle 2	**Workers, who are exposed to discharges of radioactive waste, but do not work directly with ionising radiation and are therefore not normally exposed to ionising radiation, should be included in the assessment and reporting of total retrospective doses to members of the public.**

19. The purpose of retrospective assessments is to determine compliance with the annual dose limit. Since this is an annual limit, doses should be assessed each year, normally on the basis of a calendar year.

20. The Euratom Basic Safety Standards Directive 1996 [Ref 1] requires doses to be assessed for reference groups of members of the public. Reference groups are defined as "a group comprising individuals whose exposure to a source is reasonably uniform and representative of that of the individuals in the population who are the more highly exposed to that source". This definition of a reference group is broadly equivalent to that of a critical group and the draft Statutory Guidance to the Agency [Ref 15] confirms that the reference group can be taken to be the same as the critical group.

Principle 3	**The mean critical group dose should be assessed for the purpose of assessing compliance with the dose limit.**

21. It is generally adequate to consider four age groups, fetus, 1 y old infants, 10 y old children and adults. Data are available to assess doses to these age groups [Refs 1, 16, 17]. All these age groups should be considered where they are known to be present in the population affected by the radioactive waste discharges. However, it

may be appropriate to rely on previous or similar assessments to identify the key age groups for which doses need to be assessed. NRPB will be publishing guidance to clarify when fetal doses should be assessed [Ref 18].

Principle 4	**Doses to the most exposed age group present in the affected population should be assessed for the purpose of determining compliance with the dose limit.**

Sources and exposure pathways

22. All relevant exposure pathways should be included in the assessment of doses for comparison with the dose limit (ie, doses arising from historical and current discharges of radioactive waste and direct radiation exposure from the source) [Ref 15]. However, the effort applied in the assessment should be proportional to the dose. Where the total critical group dose is <0.3 mSv/y then sources and exposure pathways which contribute a dose of greater than 0.02 mSv/y may be regarded as significant. Past experience of critical group dose assessments for radioactive waste discharges in the UK [eg, Refs 7 & 19], indicates that if the critical group dose arising from just a single source is less than 0.3 mSv/y, it is extremely unlikely that the dose limit would be exceeded once other sources are included. If the total dose is approaching 1 mSv/y, then sources and exposure pathways which contribute a dose greater than 0.01 mSv/y may be regarded as significant.

23. The recommendations of ICRP [Ref 20] suggest that contamination arising from accidental discharges may be treated as an intervention situation rather than a practice (which is the planned use of radioactive substances, including discharges). The dose limit, as defined in the Euratom Basic Safety Standards Directive [Ref 1], applies only to practices. Therefore both ICRP and the Euratom Basic Safety Standards Directive indicate that doses to the public arising from past accidents are not normally compared with the dose limit for members of the public.

24. However, monitoring of food and the environment will result in the detection of radionuclides arising both from past accidents and from authorised discharges, which in some cases will be difficult to separate. Thus, where monitoring data are used to assess doses from historical discharges, the contribution from past accidents may be included. It is acceptable to compare this to the dose limit where this contribution is small or doses are well below the dose limit. However, the contribution from past accidents may need to be determined if this is not the case.

25. There will be a need to take account of significant sources of authorised discharges from other countries, in particular European countries. Monitoring of food and the environment will provide results which will include any contribution from authorised releases from other countries.

Principle 5	**All significant sources and exposure pathways of authorised historical and current radioactive waste discharges and direct radiation from sources subject to control should be assessed and the total dose compared with the dose limit.**

Realistic assumptions

26. Article 45 of the Euratom Basic Safety Standards Directive [Ref 1] requires that the assessment of doses to 'reference groups' should be made as realistic as possible.

This requirement has been included in the Directions to the Environment Agency and SEPA [Ref 2, 3] and equivalent legislation being developed for Northern Ireland [Ref 4]. Also, the draft statutory guidance to the Environment Agency [Ref 15] states that "*Prospective doses should be estimated and retrospective doses should be calculated, using the best available science on the health and environmental effects of radiation, and on realistic assumptions of the reasonable behaviour and dietary patterns of representative members of the public who might be exposed to the radiation caused by discharges*".

27. Assessments are made more realistic through the use of site specific data, including monitoring data, modelling parameters and habits data. Although it is clear that retrospective assessments should be realistic, there is also the need to ensure that the effort spent on undertaking assessments is proportionate to the magnitude of the dose being assessed. It might be appropriate to undertake assessments making generic assumptions (eg, on population habits data), rather than using detailed site specific data, where doses are low. A similar principle was established for the assessment of prospective doses [Ref 11]. A threshold of 0.02 mSv/y was selected, above which a more realistic assessment should be considered. The same principle should apply to retrospective assessments.

Principle 6	**Where estimates of the total critical group dose exceed 0.02 mSv/y, the assessments should be critically examined and, where appropriate, more realistic assumptions made.**

Monitoring versus modelling

28. Where positive results (ie, not limit of detection data) are available from monitoring programmes and attributable to authorised releases of radioactive waste, then these data will be the most preferred for assessing retrospective doses.

29. However, monitoring data inevitably has a number of gaps and other limitations:

- Results at limits of detection may be considerably higher than actual environmental concentrations of radionuclides and lead to cautious/pessimistic assessment of doses.
- Monitoring is usually conducted for a limited range of the most significant radionuclides for a selected range of environmental media, food types and locations. Thus, there will be gaps or incompatibilities between what radionuclides are discharged; what is measured in the environment and food; and data on the consumption and occupancy habits of exposed members of the public.
- For certain key radionuclides it will not be possible to easily differentiate between authorised and non-authorised discharges (eg, accidents). The non-authorised discharges may make a significant contribution, if not dominate, the environmental and food concentrations.
- Monitoring of external radiation can be difficult to distinguish from background and will include contributions from direct radiation, radiation from deposited radionuclides and radiation from radionuclides in a plume. It can be difficult to differentiate between these components and double-counting can occur if modelling and monitoring are used to assess the contribution from these different sources.

30. Retrospective assessment studies may be used as a feedback mechanism to enhance and improve monitoring programmes to help address these limitations.

However, in certain circumstance, it may be possible to use existing monitoring data to reduce the impact of the limitations:

- Statistical techniques may be used to examine the distribution of a collection of limit of detection data (collected over different times and/or locations) and infer an expected mean value [eg, Ref 21].
- Data from previous years may be extrapolated (by averaging, or trending) to the current year if there are data gaps.
- Gaps in monitoring results for particular species or locations may be estimated from monitoring results for other species and locations. However, expert judgement and a cautious approach might be required. This approach might complement a modelling approach as discussed below.

31. In some cases there may be little or no monitoring data and attempts to extrapolate monitoring results from other sources may not be satisfactory to address this situation. In general, monitoring is not undertaken around non-nuclear sites (eg, hospitals, incinerators, etc) as it is not cost effective or proportionate to do so.

32. Modelling can be used to provide or enhance monitoring data as follows:

- Providing more realistic concentrations of radionuclides in the environment and food where monitoring results are at the limit of detection.
- Filling gaps in monitoring data (eg, radioactive noble gas concentrations in air, authorised radionuclides which have not been monitored in seafood).
- Estimating current concentrations arising from historical authorised releases.

33. Modelling may be undertaken from releases or from intermediate monitoring data (eg, radionuclide activity concentrations in water, sediment, soil and grass). Wherever possible models should be validated against measured environmental concentrations, for example at a site with higher discharges.

34. The need to derive more realistic environmental and food concentrations through extrapolation of existing monitoring data or modelling is only important where the doses are significant. Where the dose to the critical group from using results at limits of detection exceeds 0.02 mSv/y, this should prompt the need to derive more realistic data.

35. Where there are data gaps, then expert judgement based on previous assessment experience will be required to determine whether this missing dose would contribute more than 0.02 mSv/y to the critical group dose. If this is the case then derivation of data by modelling or extrapolation of existing monitoring data should be considered.

36. Past assessments [eg, Refs 7 & 19] have shown that if the critical group dose arising from just a single source is less than 0.3 mSv/y, it is extremely unlikely that the dose limit would be exceeded once other sources are included. Therefore, if the total critical group dose exceeds 0.3 mSv/y, then a careful re-examination of the realism of data derived from monitoring and modelling will be required.

Principle 7	**Positive monitoring results should be used, where available, for assessing total retrospective doses. Results at limits of detection and data gaps should be enhanced with more realistic data (eg, derived from extrapolation of monitoring data or modelling) where the dose from limit of detection data or dose from data gaps could exceed 0.02 mSv/y.**

Critical groups and their habits

37. The critical groups should be identified so as to be consistent with ICRP and NRPB advice. In Publication 43 [Ref 22] ICRP states "*The* [critical] *group should be representative of those individuals in the population expected to receive the highest dose equivalent; the group should be small enough to be relatively homogeneous with respect to age, diet and those aspects of behaviour that affect the doses received*." ICRP recommends that *"the critical group would not consist of one individual nor would it be very large for then homogeneity would be lost. The size of the critical group will usually be up to a few tens of persons"*.

38. ICRP Publication 43 [Ref 22] also advises that the degree of homogeneity in the critical group depends on the magnitude of the mean dose in the group as a fraction of the relevant source upper bound (or constraint). If that fraction is less than about one tenth, a critical group should be regarded as relatively homogeneous if the distribution of individual doses lies substantially within a total range of a factor of ten, ie, a factor of about three on either side of the mean. At higher fractions, the total range should be less, preferably no more than a factor of three.

39. NRPB has advised that where the 'normal behaviour' of only one or two individuals results in them being more highly exposed than any other individuals, then the critical group might comprise only these one or two individuals [Ref 23].

40. Where previous retrospective assessment have indicated that public doses are a relatively significant proportion of the dose limit, then habits surveys provide the most realistic means of identifying candidate critical groups and their habits. In other situations, generic UK habits data may be relied upon [eg, Ref 24].

41. The traditional selection of the critical group has relied upon expert judgement, with common groups being as follows:

- Fishermen.
- Bait diggers.
- Farming families.
- Local residents with small holdings, allotments, etc, to produce some of their own food.
- Sewage treatment workers.
- Anglers.

42. It is necessary to test the habits data for each of these groups to ensure that the groups are homogenous. Methods have been reviewed [Ref 25] and the commonly applied method is broadly to constrain the critical group to those members whose habits data are greater than one third of the maximum consumption or occupancy rate. The mean of the habits data for the group is then used for assessment purposes.

43. The FSA, EA, NII and CEFAS are now collaborating in the management of integrated habits surveys which will capture consumption and occupancy habits across a wide range of terrestrial and marine food types and locations in England and Wales. SEPA and the NII are considering a similar arrangement for Scotland. It is anticipated that results from these surveys will be available in a published form.

44. The provision of integrated habits data provides the opportunity to ensure that critical groups are selected which are homogenous with respect to dose as well as habits.

Principle 8	**Critical groups should be selected so that the habits and the doses of the members of the group are homogeneous within a factor of three.**

45. Habits surveys are generally undertaken about every 5 years, although for some sites more frequent reviews are carried out (eg, annually). A new habits survey can give rise to a step change in habits data and consequently in assessed doses. Since the public expect a rise in dose to be directly linked to a rise in discharges, this can lead to a lack of transparency of the meaning of the assessment results.

46. CEDA concluded that it would be acceptable to adopt five year rolling averages of habit data to smooth out such step changes [Ref 9]. This approach may be followed for total retrospective dose assessments.

Collective dose assessment

47. Collective dose is the sum of doses received by members of the exposed population from all significant exposure pathways from a given source. Radionuclides with long radioactive half-lives, such as carbon-14, can give rise to doses over extended periods of time, long after a release has stopped. To account for this the annual individual doses to the exposed population are summed over various time periods following the year of release. If doses are summed over all time then the quantity is known as the collective dose or collective dose to infinity. If doses are summed up to a specified time, then the quantity is referred to as a truncated collective dose (eg, collective dose truncated at 500 years). Collective dose was defined by ICRP [Refs 20 & 26] and described as a measure of the total detriment associated with a specific source or practice.

48. There is no legal limit for collective doses. Instead, collective doses are normally used to prospectively assess different process or discharge/disposal options (eg, for the abatement of discharges). However, retrospective assessments of collective dose are sometimes made [Refs 27, 28, 29]. These may be used to compare the collective dose from different periods of historical operation.

49. The International Atomic Energy Agency (IAEA) has presented dose criteria which are considered sufficiently low that doses arising from sources or practices that meet these criteria may be exempted from regulatory control. One of the criteria is that collective dose should be less than about 1 man Sv per year of practice [Ref 30, 31].

50. The document on assessment of prospective doses to members of the public [Ref 11] provides a commentary on how to assess collective doses and over what timescale they should be assessed for the purpose of authorising discharges. A timescale of 500 years has been selected for prospective assessments.

51. Retrospective assessments of collective dose may be undertaken to assess the collective dose into the future from a historical discharge. In this case, it is appropriate that collective doses should be assessed over a timescale of 500 years in the same manner as prospective assessments.

Principle 9	**Where collective doses are retrospectively assessed for the populations of UK, Europe and the World, they should be truncated at 500 y.**

Variability and uncertainty

52. When assessing doses a series of assumptions has to be made, notably about the identification and behaviour of the critical group but also about the transfer of radionuclides in the environment. Such assumptions will be based on local surveys and measurements to some extent but there will still be differences between different groups of people depending on their behaviour. This is considered through the process of selecting the critical group but the estimated mean dose to the critical group is within a distribution of possible doses.

53. There are two aspects to this distribution referred to as the uncertainty and the variability. The uncertainty reflects the amount of knowledge about the system being investigated and relates to how accurately the dose can be estimated: for example, how well are all of the parameter values in the calculation of doses known? The variability refers to the genuine differences that occur both in radionuclide transfer in different environments and between individuals within a group; for example, differences in how much of a particular food they eat or where they spend their time. This topic is discussed in more detail in Reference 32 and a number of studies have been carried out by the NRPB, FSA and EC to investigate uncertainty and variability [eg, Refs 19, 33 and 34].

54. A recent study carried out for the Environment Agency by NRPB [Ref 35] investigated the variability in the radiation doses and risks received by critical groups. The study looked at the spread on the distribution of prospective doses to critical groups from authorised discharges from the Sellafield and Sizewell nuclear sites. The spreads on the dose distributions as represented by the ratios between the 5^{th} and 95^{th} percentile were estimated. The ratios were generally between 3 and 5 depending on the group and site considered. For retrospective studies it is possible to consider the ranges of environmental measurements and on individual behaviour from habits surveys [for example, see reference 36].

55. Ideally the uncertainty should be assessed quantitatively as part of the retrospective dose considering the possible range in all of the input parameters. However, this is time consuming and is not necessary in many instances if doses are low and well below dose criteria. Instead uncertainty and variability should be reviewed to establish how much caution has been applied at each stage of an assessment. Consideration need only be given to this, if the estimated dose has exceeded 0.02 mSv/y and a more refined assessment has been made (see Principle 6). The review can be qualitative or semi-quantitative, or more rarely could be a full probabilistic uncertainty analysis. The review should consider:

- The accuracy of the discharge data.
- The use of representative radionuclides and assumptions about physical and chemical form of the discharge.
- Measurements of radionuclides in environmental materials, particularly when close to detection limits.
- Environmental modelling (eg, atmospheric dispersion, marine dispersion, transfer through foodchains).
- Selection of exposure locations and source of food production.
- Selection of habits (food intakes and occupancy).
- Dosimetric data used.

Principle 10 **Where the assessed total critical group dose exceeds 0.02 mSv/y, the uncertainty and variability in the key assumptions for the dose assessment should be reviewed.**

56. This review should provide confidence that the dose limit is unlikely to be exceeded for the discharges which have been made to the environment. It will also indicate whether there has been an undue level of caution applied in the assessment.

SUMMARY AND CONCLUSIONS

57. Ten principles have been established for the assessment of total retrospective doses to members of the public from authorised discharges of radioactive substances. The purpose of assessing retrospective public doses is to assess compliance with the public dose limit. The principles cover the following:

- Transparent assessments.
- Workers who may be treated as members of the public.
- Dose assessed to the critical group.
- Dose assessed for the most exposed age group.
- All significant sources and pathways included.
- Use of more realistic assumptions if dose exceeds 0.02 mSv/y.
- Preference to use monitoring results, but recognising that missing data or results at detection limits may need to be supplemented with extrapolated or modelled results.
- Homogeneity of habits and dose.
- Collective dose truncated to 500 years.
- Need to review uncertainty and variability.

58. These principles should be used by the Environment Agencies when discharging their responsibility of ensuring that the sum of doses arising from the authorised disposal of radioactive waste does not exceed the public dose limit.

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