Radioactive Substances Regulation

Authorisation of Discharges of Radioactive Waste to the Environment

Principles for the Assessment of Prospective Public Doses

Interim Guidance[1]

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Environment Agency (www.environment-agency.gov.uk)
Scottish Environment Protection Agency (www.sepa.org.uk)
Department of Environment, Northern Ireland (www.ehsni.gov.uk)
National Radiological Protection Board (www.nrpb.org)
Food Standards Agency (www.food.gov.uk)

[1] Document will be finalised once statutory guidance to the Environment Agencies on regulation of radioactive discharges is published

FOREWORD

The Environment Agency, the Scottish Environment Protection Agency and the Department of Environment, Northern Ireland (the UK 'Environment Agencies') have responsibilities for regulating major industries under environmental protection legislation. These include the nuclear industry (on nuclear licensed sites) and other organisations using radioactive substances within their processes who are all regulated under the Radioactive Substances Act 1993.

The Radioactive Substances Act 1993 provides for controls to be exercised over the keeping and use of radioactive materials and, in particular, on the accumulation and disposal of radioactive wastes. Discharges of radioactive waste to the environment are strictly controlled through authorisations granted to operators. Granting of an authorisation is subject to a number of requirements being met. One requirement is that members of the public must not receive a total dose from ionising radiation in excess of the legal dose limit as a result of discharges of radioactive waste. The impact of future discharges of radioactive waste must also be assessed against dose constraints specified by the Government.

This document has been prepared by the Environment Agencies in collaboration with the National Radiological Protection Board and the Food Standards Agency to define a set of principles and provide guidance on the assessment of public doses for the purpose of authorising discharges of radioactive waste to the environment. The document will enable radiological assessments to be produced in a consistent and transparent manner. The National Radiological Protection Board has a statutory role to give advice on the acceptability and the application in the UK of radiological protection standards recommended by international or inter-governmental bodies. The Food Standards Agency is a statutory consultee for the determination of authorisations granted to operators on nuclear licensed sites.

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INTRODUCTION

1. The Radioactive Substances Act 1993 (RSA 93) provides the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. In particular, RSA 93 requires prior authorisation for the disposal or discharge of radioactive waste to the environment. Responsibility for granting an authorisation rests with the Environment Agency in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland and the Department of Environment in Northern Ireland. For simplicity, the term 'the Environment Agencies' is used within this document to represent all three of these regulatory bodies.

2. This document sets out principles and guidance for the assessment of ionising radiation doses to the public arising from planned discharges to the atmosphere and to the aquatic environment. The results of assessments undertaken in accordance with these principles and guidance will be used as an input into the process of determining whether discharges of radioactive waste to the environment should be authorised. This document has been developed by the Environment Agencies in collaboration with the National Radiological Protection Board (NRPB) and the Food Standards Agency (FSA).

3. The **objectives** of this document are:

   - To provide guidance to Environment Agencies' officers on the assessment of public doses for the purposes of determining radioactive waste discharge authorisations, so that the approach to assessments is consistent and transparent.
   - To inform holders of RSA 93 authorisations about the Environment Agencies' approach to the assessment of public doses and thus provide guidance on the preparation of radiological assessments in support of authorisation applications.
   - To provide information to the public on the Environment Agencies' methods of conducting public dose assessments.

4. The **scope** of this document is limited to the assessment of total future doses which might be received by members of the public for the purpose of authorising discharges under RSA. It applies to **all** UK premises that are subject to authorisation under RSA 93 or would be so if Crown exemptions did not apply and covers:

   - Future discharges of radioactive waste to atmosphere.
   - Future discharges of radioactive waste to the aquatic environment, including sewers.
   - Environmental residues from historical discharges, where the residues persist into the future.
   - Future doses arising from direct radiation from the site for those members of the public also receiving doses from discharges to atmosphere or the aquatic environment.

5. Two types of dose assessment may be undertaken; a prospective assessment of doses which might be received by members of the public in the future and a retrospective assessment of doses as a result of discharges already made. Although the principles and guidance contained within this document apply to prospective assessments, much of the advice given can also be applied to retrospective assessments.

6. The document does not apply to the assessment of the impact of disposals of solid radioactive waste. Guidance already exists on the requirements for authorisation of disposal facilities on land for Low and Intermediate Level Wastes [Ref 1].

7. This document is concerned with radiological assessments for the determination of effective dose or committed effective dose, referred to as dose. Effective dose and committed effective dose are defined in the glossary and have the units of sievert (Sv). The sievert is a relatively large unit and therefore doses are usually reported as fractions of a sievert, for example, millisievert (mSv), one thousandth of a sievert, or microsievert (μSv), one millionth of a sievert. Doses may be assessed for individual members of the public and also the sum of all doses to all the individuals in an exposed population, referred to as collective dose. The unit of collective dose is the man-sievert (manSv). Other terms used in this document are described in the glossary.

BACKGROUND

8. The Environment Agencies have recognised the need for guidance on the methods to be used in assessing prospective public doses to ensure that such assessments are consistent and transparent. This is supported by one of the UK Government's advisory bodies, the Radioactive Waste Management Advisory Committee (RWMAC), who have made the following comments [Ref 2]:

   - "*It is not unusual for three different sets of dose calculations to be carried out (ie by the operator, one of the Environment Agencies and the Ministry of Agriculture, Fisheries and Food (MAFF)* [now the Food Standards Agency (FSA)] *and for these to result in three different estimates of dose*".
   - RWMAC "*expressed concern about the pessimistic, often grossly pessimistic, assumptions made in these dose calculations". "Using grossly pessimistic assumptions in dose calculations is not, in the RWMAC's view, a sound basis for decision making".*
   - "*An openly declared and consistent method of dose calculation should be sought*".

9. A further need for guidance on dose assessment has arisen since May 2000 with Directions to the Environment Agency and SEPA [Ref 3, 4] requiring these regulators to ensure that legal dose limits and defined dose constraints are not exceeded. These Directions implement requirements of the Euratom Basic Safety Standards Directive 1996 [Ref 5]. Equivalent legislation is being developed for Northern Ireland [Ref 6] .

10. The predecessor organisation to the Department for Environment, Food and Rural Affairs (DEFRA) and the Department of Health consulted on draft Statutory Guidance to the Environment Agency on the Regulation of Radioactive Discharges into the Environment from Nuclear Licensed Sites [Ref 7] during 2000/2001. This Statutory Guidance, once published, will provide the general principles and guidance on how discharge authorisations should be determined by the Environment Agency in England. It includes high-level principles and guidance for assessing the radiological impact of discharges from nuclear sites which have been taken into account in developing this document. Similar guidance is expected from the Welsh Assembly Government for

Wales and the Scottish Executive for Scotland. There is no requirement for such guidance in Northern Ireland since there are no nuclear installations.

11. DEFRA, the Scottish Executive, the National Assembly for Wales and the Department of Environment, Northern Ireland are developing guidance for non-nuclear users of radioactivity [Ref 8]. Guidance on dose assessments and reference to this document will be included.

12. The Euratom Basic Safety Standards Directive 1996 [Ref 5] and the draft Statutory Guidance [Ref 7] require the Environment Agencies to make realistic assessments of the doses to reference groups of members of the public. This requirement for realistic assessment is a key principle which has been addressed within this document.

13. The FSA organised a Consultative Exercise on Dose Assessment (CEDA) in October 2000 [Ref 9] to initiate a wider debate on assessment methods and to improve their transparency. A key recommendation from CEDA was to establish a National Dose Assessment Working Group (NDAWG) to bring together representatives from the regulators, other government agencies, industry, non-governmental organisations and independent experts. This working group has now been formed and is expected to facilitate improvements in the consistency and transparency of dose assessments.

Radioactive Waste Management Policy

14. The current UK Government Policy on the management of radioactive waste is defined in Cm 2919 [Ref 10]. However, the UK Government in conjunction with the Devolved Administrations is currently consulting on a revised policy for the management of solid radioactive waste [Ref 11]. Also a number of parts of Cm 2919 will be replaced by the Statutory Guidance to the Environment Agency [Ref 7] and in Scotland by Statutory Guidance to SEPA. Government policy emphasises the duty of the Environment Agencies to ensure that the regulatory framework is properly implemented. It has the principal aims of ensuring that:

    - radioactive wastes are not unnecessarily created;
    - such wastes as are created are safely and appropriately managed and treated;
    - they are then safely disposed of at appropriate times and in appropriate ways;

    so as to safeguard the interests of existing and future generations and the wider environment, and in a manner that commands public confidence and takes due account of costs.

15. This is similar to the fundamental principle of IAEA [Ref 12], consistent with the concept of sustainable development, that:

    "*Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today*".

16. The UK radioactive waste management policy and regulatory framework is underpinned by international recommendations made by the International Commission

on Radiological Protection (ICRP) and national recommendations made by NRPB on radiation protection principles and criteria. The most recent formal recommendations are provided in ICRP Publication 60 [Ref 13] and the NRPB's formal advice to the Government in its 1993 Board Statement on the 1990 Recommendations of the ICRP [Ref 14]. ICRP Publication 77 [Ref 15] provides specific guidance on the disposal of radioactive waste. For practices involving the use of radioactive substances (eg medical diagnostics and treatment or nuclear power generation), the system of protection recommended by ICRP and NRPB is based on the following principles:

- no practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes (the **justification** principle);
- in relation to any particular source within a practice (eg an individual hospital with a nuclear medicine department or an individual nuclear power station), the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA). This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgements (the **optimisation** of protection);
- the exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of the risk in the case of potential exposures (individual dose and risk **limits**). These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible to control by action at the source (eg as a result of incidents or accidents) and it is necessary to specify the sources to be included as relevant before selecting a dose limit.

17. Government Ministers have a responsibility to determine whether particular practices are justified and draft regulations have been prepared to make this a statutory responsibility. In Scotland, the Scottish Executive has taken the view the first consideration of the issue of justification should remain with SEPA until proposed legislative changes remove this duty.

18. These principles of radiological protection are aimed primarily at the protection of humans. The ICRP has previously stated that the standard of environment control needed to protect humans will ensure that other species will not be put at risk [Ref 13]. However, ICRP is currently reviewing its position with respect to the protection of the environment. The Environment Agencies recognise the importance of protecting species in the environment other than humans and are supporting International and European initiatives to develop a framework for protecting the wider environment. Ultimately, this may lead to additional principles and guidance for the assessment of doses to non-human species. Interim methods and data are provided in an Environment Agency R&D report [Ref 16].

19. The Government, in conjunction with the Devolved Administrations, has finalised the UK Strategy for Radioactive Discharges 2001-2020 [Ref 17]. This aims to implement the OSPAR Strategy for radioactive substances which was agreed by Ministers of the

Signatory countries (known as 'Contracting Parties') at Sintra, Portugal in 1998. The objective of the OSPAR strategy is to prevent pollution of the North East Atlantic maritime area through progressive and substantial reductions in discharges, emissions and losses of radioactive substances. The ultimate aim is to achieve, by the year 2020, additional concentrations in the marine environment, above historic levels, which are 'near background' for naturally occurring radioactive substances and 'close to zero' for artificial radioactive substances.

Regulatory Framework

20. The Radioactive Substances Act 1993 provides the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. Under Section 13 of RSA 93, no person may dispose of radioactive waste unless it is in accordance with an authorisation issued under the Act, except where the waste is excluded from control under the Act or exempted from provisions of the Act by an Exemption Order. In addition, premises occupied by the Crown for defence purposes are exempt from the Act. However, discharges from these premises are made in accordance with approvals which apply the same standards as authorisations. The Environment Agencies are responsible for determining applications for authorisations made by producers of radioactive waste and for reviewing those authorisations on a regular basis.

21. The Euratom Basic Safety Standards Directive [Ref 5] provides for the implementation of the 1990 recommendations of ICRP [Ref 13] within the European Union. Many of the Directive's provisions are implemented by the Ionising Radiations Regulations [Ref 18, 19] and with respect to the control of radioactive waste has been implemented within England, Wales and Scotland through Regulations amending RSA 93 [Ref 20, 21] and Directions to the Environment Agency and SEPA [Ref 3, 4]. Regulations to implement the Euratom Basic Safety Standards Directive are currently being made in Northern Ireland. The principal aims of the Directions are to require the Environment Agencies to ensure, when exercising their duties and functions under the RSA 93, that:

- All public ionising radiation exposures from radioactive waste disposal are kept ALARA.
- The sum of the doses arising from such exposures does not exceed the individual public dose limit of 1 mSv a year.
- The individual dose received from any new discharge source since 13th May 2000 does not exceed 0.3 mSv a year.
- The individual dose received from any single site does not exceed 0.5 mSv a year.

22. The Nuclear Installations Inspectorate (NII) within the Health and Safety Executive (HSE) is responsible for regulating sites licensed under the Nuclear Installations Act 1965 [Ref 22] and is a statutory consultee in the process of determining authorisations. On sites for which a nuclear site licence has been granted by the NII, commonly referred to as 'nuclear sites', the accumulation of radioactive wastes are regulated via conditions attached to the licence. The HSE regulates the exposure of workers using radioactive substances under the Ionising Radiations Regulations [Ref 18, 19] (undertaken by the NII on nuclear sites).

23. There are a number of advisory bodies involved in the regulatory process. On 1 April 2000, the Food Standards Agency (FSA) became responsible to Government for providing advice on food safety, including the safety of radionuclides in food. FSA is a statutory consultee in the process of determining authorisations for nuclear sites and its advice is sought for the determination of authorisations for other premises. The FSA conducts radiological monitoring of food in England, Wales and Northern Ireland and its results are published annually, jointly with the radiological monitoring of food and the environment undertaken in Scotland by SEPA [Ref 23, 24 & 25]. FSA publishes food monitoring data on its web site.

24. The National Radiological Protection Board has a statutory role to give advice on the acceptability and the application in the UK of standards recommended by international or inter-governmental bodies. The functions of the Board are to give advice, to conduct research and to provide technical services in the field of protection against both ionising and non-ionising radiations.

25. Other advisory bodies involved in the regulatory process include:

- The Radioactive Waste Management Advisory Committee (RWMAC) – An independent body of experts drawn from a wide range of backgrounds including nuclear, academic, medical, research and lay interests. It is responsible for providing a source of independent advice to government on matters of civil radioactive waste management.
- The Committee on Medical Aspects of Radiation in the Environment (COMARE) – Created in 1985 to assess and advise the Government on the health effects of natural and man-made radiation in the environment and to assess the adequacy of the available data and the need for further research.

Radiological Protection Criteria for Public Exposure

26. The following criteria are discussed in this section and illustrated in Table 1:

- Dose Limits.
- Site and Source Dose Constraints.
- Optimisation at low doses.

Table 1 Summary of Radiological Protection Criteria for Public Exposure

Criteria	Quantity	Doses to be Included in Assessments Against Criteria					
		Source of Radiation for Site Considered			Other Sources of Radiation (Excluding Medical and Natural)		
		Historical Discharges	Future Discharges	Future Direct Radiation	Historical Discharges	Future Discharges	Future Direct Radiation
Dose Limit	1 mSv/y	✓	✓	✓	✓	✓	✓
Site Constraint	0.5 mSv/y		✓	(a)			
Source Constraint	0.3 mSv/y (max)		✓	✓			
Optimisation at low doses:							
'Threshold of Optimisation' [Ref 10]	0.02 mSv/y		✓	✓			
Potentially 'of no Regulatory Concern'(b) [Ref 7]	≤0.01 mSv/y		✓	✓			

(a) The derivation of this UK specific constraint strictly excludes consideration of future direct radiation.
(b) For example, permitting exemption of certain practices.

Dose Limits

27. Legal dose limits are set out in the Euratom Basic Safety Standards Directive [Ref 5] and implemented in the UK through the Ionising Radiations Regulations [Ref 18, 19] (IRR 99). Doses to members of the public from all controlled sources (excluding occupational and medical exposure) are limited to 1 mSv in a calendar year. In addition, the Environment Agency and SEPA have been directed, when exercising their functions under RSA 93, to ensure that doses to members of the public from discharges of radioactive waste are limited to 1 mSv per year for England, Wales and Scotland [Ref 3, 4]. Equivalent legislation is being developed for Northern Ireland [Ref 6].

28. Although, ICRP has recommended [Ref 13] that doses arising from artificial radioactivity already in the environment should not be included when making comparisons with the dose limit, NRPB has recommended [Ref 26] that it is appropriate in the UK to include such doses when making comparisons with the dose limit. The Environment Agencies, NRPB and FSA consider that the dose from direct radiation should also be included when comparing with the dose limit.

29. The recommendations of ICRP [Ref 13] 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 5], 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. 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 is used to assess doses from historical discharges, the contribution from past accidents may be included and will inevitably be compared with the dose limit for the public.

Dose Constraints

30. The NRPB considers that there is a need for prospective constraints to assist in the optimisation of radiological protection of new facilities and have recommended that the constraint on dose to members of the public for a single new radioactive discharge source should not exceed 0.3 mSv/y [Ref 14]; options for disposal of radioactive waste that imply doses higher than the dose constraint should be rejected. The Government has stated in Cm 2919 that a maximum constraint of 0.3 mSv/y should be used when determining applications for discharge authorisations from a single new source, defined as "*a facility, or group of facilities, which can be optimised as an integral whole in terms of radioactive waste disposals*". This constraint is referred to as a source constraint. The Environment Agency and SEPA have been directed to ensure that doses to members of the public from discharges of radioactive waste from any source from which radioactive discharges are first made on or after 13th May 2000, do not exceed 0.3 mSv per year [Ref 3, 4]. Equivalent legislation is being developed for Northern Ireland [Ref 6].

31. Cm 2919 states that the Environment Agencies will consider whether lower constraints should be defined for radioactive waste disposals from different applications, both nuclear and non-nuclear, for the purpose of authorisations under RSA 93. The draft Statutory Guidance to the Environment Agency [Ref 7] states that this Agency is to set dose constraints for new or existing facilities not exceeding the 0.3 mSv/y source constraint.

32. Following advice from the NRPB, the UK Government has accepted that, in general, existing facilities should be able to operate within a constraint of 0.3 mSv/y. However, it is recognised that in some cases a realistic assessment of doses might suggest that the facility could not be operated within this constraint. In these cases the operator will need to demonstrate that the doses resulting from the continued operation of the facility are as low as reasonably achievable and within dose limits.

33. Prior to the review of policy on the management of radioactive waste (Cm 2919), the UK Government had operated a site target of 0.5 mSv/y as part of its system of dose limitation for radioactive discharges. Under the re-structuring of the nuclear power industry, ownership at four power stations has been split between the company owning or operating a Magnox station and that owning or operating an Advanced Gas-Cooled Reactor (AGR) or Pressurised Water Reactor (PWR). To provide reassurance that standards are not being relaxed as a result of restructuring, a site constraint of 0.5 mSv/y has been set [Ref 3, 4]. This will apply to the aggregate exposure from a number of sources with contiguous boundaries at a single location, irrespective of whether different sources on the site are owned or operated by the same or by different organisations. Another example of a split ownership site is that of URENCO and BNFL at Capenhurst.

34. The 0.5 mSv/y site constraint applies to doses arising from future exposures from discharges and not from exposures arising from direct radiation. This was clarified in the 1996 decision document for the AGR and PWR nuclear power station applications and was accepted at the time by the Department of the Environment [Ref 27].

35. Neither the source nor the site constraints, however, are limits. If it is found on the basis of environmental measurements and current understanding of population habits that the dose is in excess of either constraint, then it should be clearly demonstrated that doses are within limits and as low as reasonably achievable.

Optimisation at Low Doses

36. The risks that people are prepared to accept and the degree to which risk is perceived vary considerably from individual to individual. The HSE has conducted a considerable amount of work on tolerable and acceptable levels of risk, culminating in the publication of The Tolerability of Risk from Nuclear Power Stations (TOR) [Ref 28], originally issued in 1988 and updated in 1992. More recently the HSE has published a document on 'Reducing Risks, Protecting People' [Ref 29] which extends the principles in the Tolerability of Risk document to other industries. The HSE recognised that there was an upper limit beyond which a risk would be intolerable, regardless of the benefit which society derived from the activity involved, and a lower level, below which the risk was negligible in comparison with other risks people run in their daily lives and therefore broadly acceptable. The area in between is where the risk is tolerable only if is as low as reasonably practicable (ALARP).

37. In Cm 2919, the Government introduced a threshold or lower bound on optimisation for radioactive waste discharges, similar to the lower level defining broadly acceptable risk in TOR. The value for this threshold was set at 0.02 mSv/y, which is consistent with the HSE's Safety Assessment Principles for new nuclear facilities [Ref 30]. Taking the internationally accepted assumption that any dose, no matter how small, has the potential to cause harm, a dose of 0.02 mSv/y can be broadly equated to an annual risk of death of about one in a million per year. For comparison, the annual average UK dose from natural radiation is 2.2 mSv/y, the average dose from a single chest X-ray is 0.02 mSv/y and the typical dose from a return transatlantic flight due to cosmic radiation is 0.07 mSv/y [Ref 31].

38. If exposures are calculated to be below 0.02 mSv/y, the regulators are advised in Cm 2919 that they should not seek to secure further reductions in the exposure of members of the public, provided they are satisfied that the operator is using the best practicable means to limit discharges. The regulators need to ensure that discharges are properly controlled and monitored and the radiological assessments submitted to them by the operator are valid.

39. These policy requirements relating to the threshold of optimisation within Cm 2919 were not implemented in UK law through the Direction placed on the Environment Agencies [Ref 3, 4]. However, the Government has stated in the UK Strategy for Radioactive Discharges 2001-2020 that as a result of reductions in radioactive discharges, there will be a progressive reduction of human exposure to ionising radiation [Ref 17]. It is expected that members of a "local critical group" of the general

public in the UK will be exposed to a dose of no more than 0.02 mSv a year from authorised radioactive discharges to the aquatic environment from 2020 onwards.

40. The draft Statutory Guidance to the Environment Agency [Ref 7] notes that there is widespread international agreement that doses to members of the public of the order of 0.01 mSv/y or less are sufficiently low to be of no regulatory concern. However, all doses to members of the public, including those below 0.01 mSv/y remain subject to the ALARA requirement under directions placed on the Environment Agency and SEPA [Ref 3, 4]. This is achieved primarily through the application of best practicable means to limit and control authorised discharges of radioactive waste to the environment.

GENERAL DOSE ASSESSMENT PRINCIPLES

Nuclear Sites and Other Premises Discharging Radioactive Waste

41. Radioactive waste discharges are made from premises such as hospitals, research establishments, universities and industry (the so called 'non-nuclear sites') as well as from the nuclear industry. The radionuclides discharged from non-nuclear sites generally have short radioactive half lives compared with the radionuclides discharged from nuclear sites. Also, the quantity of activity discharged from many non-nuclear sites is much less than the nuclear industry. However, some non-nuclear sites do discharge radionuclides with longer radioactive half-lives, such as tritium and carbon-14, and a few non-nuclear sites make discharges which exceed those from some of the smaller nuclear sites.

42. The requirements of the Euratom Basic Safety Standards Directive 1996 [Ref 5] make no distinction between nuclear and non-nuclear sites. It is the magnitude of the dose and hence risk which is important. Thus, the assessment principles within this document apply equally to nuclear and non-nuclear sites. However, it is expected that many non-nuclear sites will be able to undertake a simple source assessment to demonstrate that the doses arising from the discharges from the site are sufficiently low to be acceptable for regulatory purposes.

Members of the Public and Population Groups

43. Doses to individuals are compared with dose limits and constraints. The Euratom Basic Safety Standards Directive 1996 [Ref 5] defines separate limits for workers and members of the public. Definitions of a member of the public are provided in both the Basic Safety Standards Directive [Ref 5] and the Ionising Radiations Regulations [Ref 18, 19], which for the former reads:

    "*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).

44. This definition would strictly exclude farmers, sewage workers, fisherman etc from being considered as members of the public during their working hours. The view of the Environment Agencies, NRPB and the FSA is that where such workers do not receive direct tangible benefits from the organisation discharging radioactive waste to the environment (eg employment by that organisation) then these workers should be treated as if they are members of the public for the purpose of authorising the discharges. The dose limit and dose constraints for members of the public would then apply to these groups. The HSE has supported this view for the purposes of authorising discharges.

45. In general, workers entering a site from which a radioactive discharge is being made (eg employees, contractors, employees on a co-located site) will be receiving tangible employment benefits from the site and will also have been informed of the hazards involved. The Ionising Radiations Regulations [Ref 18, 19] 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. Thus, it

would not be appropriate for these workers to be treated as members of the public for the purpose of authorising discharges.

Principle 1	**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.**

46. Because it is not practicable to assess doses to each individual member of the public, the 'critical group dose' approach is used. The critical group is intended to be "*representative of those individuals in the population expected to receive the highest dose*" [Ref 32]. ICRP has recommended that the mean dose to members of this group can be compared with the public dose limit and with the public dose constraint [Ref 13, 32]. This dose is referred to in the remainder of this document as the critical group dose.

47. The Euratom Basic Safety Standards Directive 1996 [Ref 5] 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 7] confirms that the reference group can be taken to be the same as the critical group.

48. In Publication 43 [Ref 33] 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*".

49. NRPB endorsed the use of the critical group for assessing doses to members of the public for comparison with the dose limit and the dose constraint and gave interim advice on critical group methods for these purposes [Ref 26]. NRPB has also 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. What constitutes normal or realistic behaviour is considered later, in the section on identifying critical groups.

50. It is recommended that critical group doses are assessed for the purposes of comparison with source constraints, site constraints and dose limits, in the process of determining discharge authorisations.

Principle 2	**The mean critical group dose should be assessed for the purpose of determining discharge authorisations.**

51. It should be assumed that all members of the population could be exposed, thus the most affected age group should be selected. This will depend upon the radionuclides discharged and the environment around the source.

52. However, it is generally sufficient to consider three age groups, 1 year old infants, 10 year old children and adults. Although well established data are available to enable doses to be assessed for other age groups of infants and children these groups are representative of the range of habits, physiology and sensitivity to radiation of all children and infants. All three age groups should normally be considered in an assessment even if habit surveys indicate that there are no people of that age in the location of interest. Assessments of fewer age groups may be made if there is adequate evidence to support this decision (eg assessment of doses to adult sewage workers).

53 Doses to human embryos and fetuses are currently subject to clarification by the ICRP. The ICRP has recently published dose factors for the embryo and fetus from intakes of radionuclides by the mother before and during pregnancy [Ref 34]. ICRP and NRPB are currently reviewing when and where such dose factors should be applied.

Principle 3	**Doses to the most exposed age group should be assessed for the purposes of determining discharge authorisations.**

Assessment Criteria and Exposure Pathways

54. All relevant future exposure pathways should be included in the assessment of doses for comparison with the source constraint (ie doses arising from the future discharges of radioactive waste from the source and future direct radiation exposure from the source) [Ref 7].

55. The doses arising from future discharges of radioactive waste from a site (but not future direct radiation) should be assessed for comparison with the site constraint. Doses arising from exposure to radionuclides in the environment from historical discharges are not included in the comparison with the source or site constraint, but are included in the comparison with the dose limit (see Principle 5).

Principle 4	**Critical group doses to be assessed for comparison with the source constraint and, if appropriate, the site constraint should include all relevant future exposure pathways.**

56. If there are additional significant future exposure pathways as a result of other sources of radioactive discharges, direct radiation or accumulation of radionuclides in the environment from historical discharges (ie discharges prior to current year), then it will be necessary to undertake an assessment for comparison with the dose limit for members of the public. The draft statutory guidance to the Environment Agency [Ref 7] states "*when calculating doses, full account should be taken of all sources of radiation, not just the discharges under immediate consideration, and the assessment should include any dose arising in the environment from historical activity as well as current practice*".

57. Past experience of critical group dose assessments for radioactive waste discharges in the UK [eg Refs 35 & 36], indicates that if the critical group dose for 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.

Principle 5	**Significant additional doses to the critical group from historical discharges from the source being considered and doses from historical and future discharges and direct radiation from other relevant sources subject to control should be assessed and the total dose compared with the dose limit of 1 mSv/y.**

Realistic and Cautious Assumptions

58. Prospective assessments require assumptions to be made regarding the behaviour of radionuclides in the environment and the habits of people who may be exposed to those substances. One approach is to make a cautious assessment using simple cautious assumptions to ensure that the dose is very unlikely to be underestimated. In general, assessment assumptions are simplified by using generic critical groups and associated generic behaviour or habit data which is used to determine their exposure. Cautious assessments are designed to ensure that the calculated doses will be an overestimate of those that would actually be received for a given discharge of radionuclide or level of activity concentration in the environment.

59. An alternative approach is to make a realistic or best-estimate assessment of doses using knowledge and data for known population groups around the site of interest (ie a site specific assessment). The aim is to be as close as possible to the actual doses that would be received from discharges at the proposed future limits, by making efforts to be as comprehensive and accurate as possible.

60. Article 45 of the Euratom Basic Safety Standards Directive [Ref 5] 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 3, 4] and equivalent legislation being developed for Northern Ireland [Ref 6]. Also, the draft statutory guidance to the Environment Agency [Ref 7] 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*".

61. The NRPB has previously given formal advice [Ref 26] that when dose assessments are made for comparison against dose constraints:

"*Where the application of dose constraints will influence the operating regime of a controlled source, it is important that assessments provide estimates of doses that are as realistic as practicable (as opposed to over estimation or under estimation), otherwise operational decisions may be taken which result in much smaller doses to members of the public, but with higher costs and possibly higher doses to workers than would be the optimum. This requirement for realism applies at all stages of the dose assessment,*

including estimates of discharges and levels of direct irradiation, the modelling of pathways by which individuals are exposed, and the assumptions made concerning the location, habits and characteristics of those exposed".

62. For the purposes of setting discharge authorisations, future doses from discharges at the proposed limits have to be assessed. As indicated, this means that various assumptions have to be made, for example about the composition and behaviour of the critical group in the future. It is common practice to start with relatively cautious generic assumptions and then refine these assumptions, as appropriate, to take account of more realistic site specific exposure pathways and habit data.

63. NRPB has recommended that where generalised derived constraints (GDCs) [Ref 37, 38] are used as a cautious means of demonstrating compliance with the maximum dose constraint, then further investigation should be carried out if the assessed doses are above an implied dose level of 0.1 mSv/y, corresponding to 30% of the GDC. Further investigations would include consideration of site specific factors, the source of the activity and the length of time for which the situation is likely to persist.

64. The Euratom Basic Safety Standards implies that all assessments should be realistic and the policy of the UK Government and its Devolved Administrations is that there should be progressive reductions in discharges and hence doses [Ref 17]. Thus the Environment Agencies and the FSA consider that further investigation and use of more realistic data should be undertaken when doses exceed a few tens of microsieverts per year (ie 0.02 mSv/y). Doses above 0.02 mSv/y are implicitly of regulatory concern [Ref 7] and they will not be consistent with the Government's expectation that from 2020 onwards doses from discharges to the aquatic environment will be less than 0.02 mSv/y [Ref 17]. It is expected that cautious assessments of critical group doses for many small users of radioactive substances would result in estimated doses that are less than 0.02 mSv/y.

65. It is important to recognise that a distinction cannot easily be drawn between a cautious assessment and a realistic assessment. Assessments will have a number of assumptions which will vary in their degree of caution or realism. The Environment Agencies, NRPB and FSA recognise that some caution will be required in prospective assessments. When undertaking such assessments, sufficient caution should be retained to provide confidence that actual doses received from all sources of radiation by a representative member of the critical group will be below the dose limit. However, the level of caution between doses assessed prospectively and those assessed afterwards (ie retrospectively) should not exceed a factor of about ten, unless this is due mainly to the difference between actual discharges and discharge limits. The level of caution that has been applied may be assessed as a result of an investigation into the uncertainty and variability in an assessment.

Principle 6	**Where estimates of the critical group dose exceed 0.02 mSv/y, the assessments should be refined and, where appropriate, more realistic assumptions made. However, sufficient caution should be retained in assessments to provide confidence that actual doses received by a representative member of the critical group will be below the dose limit.**

66. The Environment Agencies will confirm that the dose limit for members of the public has not been exceeded by undertaking retrospective assessments after the discharge has occurred, mainly using the results of environmental monitoring. Programmes of regular monitoring are carried out by the Environment Agencies, Food Standards Agency (FSA) and the site operator and reported annually (eg Ref 25, 39, 40).

Accumulation in the Environment

67. For assessments of individual dose, it is appropriate to take account of accumulation of radionuclides in the environment, usually by undertaking the assessment for the year in which the highest critical group dose is likely to occur. This ensures that future generations are afforded the same level of protection as the current generation. Assuming no change in discharge limits, the highest critical group dose is generally predicted to occur during the last few years of discharges from a plant/site. Once discharges cease or are reduced significantly, the highest environmental activity concentrations near the discharge point generally start to decline. An accumulation time-scale of 50 years is usually selected for new plants and for plants/sites where it is difficult to specify a closure date. For plants, which are unlikely to be replaced or replaced with plants having significantly lower discharges, then it may be appropriate to limit this to the lifetime of the plants. Where radionuclides build-up to an equilibrium level more quickly in the environment, then a shorter time-scale may also be adopted.

68. Generally, the highest radionuclide concentrations in the environment, from a given site, tend to decline following a reduction in discharges. A key exception is where there is in-growth of a daughter radionuclide from its parent (eg americium-241). The effect of a reduction in discharges is clearly demonstrated in the Irish Sea around Sellafield. Discharges from Sellafield of many radionuclides, including radiocaesium and isotopes of plutonium have declined by a factor of 100 or more between the mid 1970s and present day [Ref 41]. Following the discharge reductions, concentrations of these radionuclides in sea water, sediments and marine organisms in the Irish Sea have also generally declined [Ref 23, 24 & 25]. The decline commenced at the time or shortly after the reduction in discharge occurred. Where there is relevant information available about the accumulation and other reasonably foreseeable effects in the environment, which are likely to have significant implications for the doses which might be received, this should be considered in radiological assessments.

69. Environmental models (eg for the marine environment) are generally sufficiently well developed to be able to provide estimates of future average environmental concentrations for key radionuclides over time-scales of about 50 years with a reasonable degree of confidence.

Principle 7	**The assessment of critical group doses should take account of accumulation of radionuclides in the environment from future discharges.**

Critical Groups and their Habits

70. There are two broad approaches to the identification of critical groups. The first method identifies the critical group for a particular controlled source by carrying out localised surveys. The alternative method uses a generalised approach that leads to the specification of a generic critical group perhaps based on national or regional survey data.

71. The important factor is that the characteristics of the critical group are applicable to the time period over which doses are assessed and the time period for which the dose assessment will apply. For prospective assessments of critical group doses relating to the authorisation of radioactive waste discharges, annual doses are required for comparison with the dose constraints and dose limits. Also, the assessment needs to be applicable over the period of time before the authorisation is reviewed, about every 4-5 years for nuclear sites.

72. To afford future generations the same level of protection as the current generation, it is assumed that the habits observed for the current generation continue to occur in the future. However, there is also a need to take account of possible changes of habits in the future over the relevant time period. The draft statutory guidance [Ref 7] states that "*the Environment Agency should not exclude from consideration any pattern of behaviour that a reasonable person might adopt, whether or not anyone actually engages in such behaviour at a given time*". This is a continuation of the same policy documented in Command 2919 [Ref 10]. The Environment Agencies, NRPB and FSA recognise that prospective assessments should consider possible changes of habits and location of critical groups, whilst being as realistic as possible [Ref 42].

73. The difficulty is in balancing this requirement with the one for the assessment of doses to be realistic over a future time period of about 5 years. In practice, an acceptable way to proceed is to make plausible assumptions based on habits and behaviour observed currently or in the recent past. The habits and behaviour may be based on general observations, those for the site in question or those for similar sites. It may be appropriate to consider activities that happened at a location in the recent past (say 5 years) even if they do not currently occur. If a significant dose is delivered over a short time period as a result of a particular pattern of behaviour, then this pattern of behaviour should be adopted in assessments if it is sustainable over several years.

74. For generic habits to be realistic they should be reasonably foreseeable and be sustainable over the period until the next review of the authorisation (typically 5 years). Inevitably, expert judgement will be required to decide whether it is plausible to assume that habits observed at another site could occur in the future at the site in question.

75. The future habits assumed for a critical group should not be influenced by the potential exposures to be received (ie it should be assumed that members of the critical groups are unaware of the potential exposures). However, it is not necessary to consider

exposures resulting from actions that would lead to a breach of UK law (including statutes, common law and bylaws). For example, occupation of land that would involve trespass does not need to be considered. Also, deliberate actions taken by members of the public with the prime intention to cause themselves to receive radiation exposures should not be included in these dose assessments.

Principle 8	**The realistic habits adopted for the critical group should be those which are actually observed year on year at the site, or at similar sites elsewhere, either currently or in the recent past. Sustainable habits leading to greater exposure, that are reasonably foreseeable over the period until the next review of the authorisation (about 5 years), should be considered.**

76. Many critical group habits will be supported by particular land use or infrastructure requirements (eg allotments or small holdings for supply of food produce; appropriate anchorage, road access and, usually, mains services power supplies for houseboat owners). The capacity of the infrastructure, land or region of sea to support the critical group for a period of about 5 years is particularly important for the provision of food. When deciding upon where local food might be produced in the future, it is important that there is sufficient land or marine area to allow the production of all the food types assumed to be consumed by the critical group.

77. Where a change of land use or provision of infrastructure is considered for the critical group then this should be reasonably foreseeable over the time period of the authorisation (about 5 years) and be sustainable year on year. Where planning applications have been made involving a change in land use, then it would be expected that this would be taken into account in an assessment. However, it would not be appropriate to include unconstrained speculation on planning applications which have not been made.

78. Changes in agricultural practice (eg introduction of milk production) which allow consumption of food not currently produced should be considered within future critical group habits, unless it can be demonstrated that factors such as the soil type or climate preclude a particular agricultural practice.

Principle 9	**Land use and infrastructure should have sufficient capacity to support the habits of the critical group. Any changes to land use and infrastructure should be reasonably foreseeable over the period until the next review of the authorisation (about 5 years) and be sustainable year on year for them to be considered.**

79. Some specific examples of the identification of future critical group habits are given below:

- A holiday cottage is identified as being at a location which would lead to the highest doses. Under its present use, there will be no single group of individuals who will be exposed continuously throughout the year. However, it is reasonably foreseeable that the cottage could be sold over the next 5 years and a single group of individuals take up residence.

- A badly derelict farmhouse is at a location which would lead to the highest doses. If there are no current plans to renovate the property, then it is not considered to be reasonably likely that the building could be renovated to achieve occupation on a continuing basis over the next 5 years.
- There is a derelict plot of land near to an urban hospital with a large nuclear medicine department. It would not be reasonably likely for that plot of land to be converted to a small holding from which a family source all their food (milk, meat, vegetables and fruit) on a sustainable basis over the next 5 years. However, it would be appropriate to assume residents grow their own fruit and vegetables within their gardens.
- An estuary with contaminated sediments, currently has little occupation. Generic occupancy habits on these sediments should be used which will provide a cautious estimate of public dose based on activities such as bait digging or dog-walking. It is possible that such habits could arise during a 5 year time period even if they are not observed at present. For house-boat dwelling, to be considered as likely over this time period, there would need to be a recent history of such occupancy habits, or an appropriate provision of facilities and adequate physical characteristics (eg protection from storm conditions in respect of house-boat owners) to enable the habits to be adopted.
- A beach close to a military establishment is fenced-off from public access and warning notices are displayed (eg MOD firing range). The habits of dog walking or bait collection etc on such a beach are considered to be contrary to UK law and thus such exposure should not be included.

OVERVIEW OF DOSE ASSESSMENT PROCESS

80. A staged approach to the assessment of critical group doses is advised (see Figure 1) which implements the principles in the previous section. The first stage (Initial Source Assessment) would be to make a simple and cautious assessment of the critical group dose. If the resulting critical group dose is less than the 0.02 mSv/y (see Principle 6), then no further assessment would be warranted for the purpose of authorising the discharge of radioactive waste to the environment.

81. Where the cautious critical group dose exceeds 0.02 mSv/y, then a detailed assessment will be required with the following stages:

- **Detailed Source and Site Assessment -** To determine critical group doses for comparison with the source and site constraints and the dose limit.
- **Short Term Release Assessment** - To determine acceptability of short term release limits, where appropriate.
- **Collective Dose Assessment** - To provide an assessment of the population doses for different discharge/disposal options.
- **Variability and Uncertainty Assessment** - To establish how much caution has been applied at each stage of the assessment.

INITIAL SOURCE ASSESSMENT

82. A simple and cautious assessment can be made by utilising dose per unit release factors based on generic assumptions. The assessment should consider direct radiation where it is known from monitoring or the type of process being operated that direct radiation dose-rates above background levels can or will be measured at the site perimeter. Dose per unit release factors will be developed by the Environment Agencies, but could be developed by other organisations.

83. Further guidance on simplified dose assessments for non-nuclear sites has also been provided by NRPB [Ref 43]. In addition, NRPB has published Generalised Derived Constraints [Ref 37, 38] which have been produced using cautious generic assumptions and therefore may be used to make an initial source assessment. The GDCs give the annual discharge for particular radionuclides which if they are not exceeded are unlikely to result in a critical group dose greater than 0.3 mSv/y (ie the maximum source constraint). If the discharges are greater than $1/15^{th}$ of the appropriate GDC for a single radionuclide, a detailed assessment will be necessary.

DETAILED SOURCE AND SITE ASSESSMENT

84. The general steps for a detailed and hence more realistic assessment of the critical group dose for a particular source or site are as follows (see Figure 2):

- **Identify / Quantify Source Term -** The amount of each radionuclide released, its chemical form (if important) and the mode of release.
- **Model Radionuclide Transfer in the Environment -** Estimate activity concentrations and dose-rates arising from the discharged radionuclides in environmental media such as air, water, sediment, soils and foods.
- **Determine Exposure Pathways -** Identify the relevant exposure pathways to people from the activity concentrations and dose-rates in environmental media.
- **Identify Critical Habits and Data for Exposure Pathways** – Identify those habits and behaviours together with the associated habit data that could lead to exposure of people through all relevant pathways. Examples of habit data include intake rates of particular foods and the time spent at particular locations.
- **Identify Candidate Critical Groups from Realistic Combinations of Critical Habits** – A number of groups should be identified for a particular source with a combination of habits both critical and average for the different exposure pathways. This identification should be based on local knowledge and plausible assumptions.
- **Estimate Doses for Candidate Critical Groups –** Calculate doses for each group for all relevant exposure pathways. This should include identification of the most important exposure pathways and radionuclides in terms of their contribution to the overall dose.
- **Identify the Critical Group –** This is the candidate critical group expected to receive the highest mean dose.
- **Total Dose** - Calculate the additional dose arising from historical discharges from the site being considered and the dose from historical and future discharges and direct radiation from other sources subject to control to enable comparison of the total dose with the dose limit.

85. Methods and guidance for the detailed assessments of doses from all exposure pathways [Ref 44] and via the food chain [Ref 9, 42, 45] are available.

Identify / Quantify Source Term

86. For the purpose of determining authorisations it is assumed that the discharges are at the authorisation limits. These might be the limits proposed by the Environment Agencies or the limits applied for by the operator. Actual discharges are likely to be lower than the authorised limits and sometimes an additional assessment is carried out to determine the doses from the likely level of discharges.

87. Discharge authorisations contain discharge limits for specific radionuclides and, commonly in the past, for groups of radionuclides with the same type of activity (eg total alpha activity or total beta activity). Assessments of doses can only be carried out on a radionuclide specific basis and so where limits for groups of radionuclides remain, it is necessary either to split the discharge for the groups of nuclides between the radionuclides known to be discharged or to use a 'representative' radionuclide. Thus, in some circumstances, it might be cautious to assume that plutonium-239 is representative of total alpha activity or caesium-137 is representative of total beta activity. However, in most cases it is more realistic to adopt a site specific approach based on the radionuclides known to be discharged from the site. In cases where a discharge authorisation is being set for a new facility, the assumed radionuclide composition will have to be based on a knowledge of the processes that will be undertaken or from considering discharges from similar facilities already in operation.

88. In some cases the chemical form of the discharged radionuclide can have a significant effect on the radiation doses. The operator will be required to provide information on specific or general chemical form, particularly when it is important in the dose assessment (eg organic or inorganic form of radionuclides).

Model Radionuclide Transfer in the Environment

89. A variety of models and data are required to predict the transfer of radionuclides through the environment and the resulting doses to people. It is important that any models used are robust and fit for the purpose. Measures should have been taken to ensure that the models are valid. This means that the models should have been tested to ensure that they are behaving as intended and where possible they should be compared with measurement data to ensure that they are an adequate representation of reality. For authorisation purposes it is normally adequate to use generic models and parameter values although occasionally there may be sufficient evidence to warrant using a site specific value for a particular parameter. Empirical models may also be used which relate environmental activity concentrations to discharges, although care has to be taken due to the accumulation of radionuclides in the environment.

90. Authorisations are mainly concerned with routine discharges and it is assumed that discharges are continuous over a year. Where this is not the case and a significant proportion of the authorised limits are utilised in a short time period, say a few days (eg depressurisation of gas cooled reactors or iodine-131 discharges to sewer from thyroid treatment at a hospital), then short term releases will need to be assessed (see later section on Short Term Releases).

91. Although the dose assessment is carried out for a year's discharge there is the possibility that radionuclides will build up in the environment from continuous discharges over more than one year. Account should be taken of this in the modelling (see Principle 7), usually by assuming that the discharge continues for 50 years with the dose assessed for the final year of discharge.

92. There are a number of environmental dispersion and dose assessment models available. The Environment Agencies make no specific recommendation on model application, but require any model to be appropriate for the application. The European Union code system, PC-CREAM [Ref 46] is a suitable model for many applications. The code is based on a methodology for assessing the radiological consequences of routine releases published by the European Commission [Ref 44]. It should be noted that currently PC-CREAM does not have a model for the assessment of doses to sewage workers as a result of discharges to sewer. Also, it cannot be used directly to assess the impact of the disposal of sewage sludge to land, where the sludge contains radionuclides. Alternative models for the assessment of doses from discharges to sewer are available [Ref 43, 47] and a further model is being developed by the FSA.

Atmospheric Discharges

93. For releases to atmosphere, models are required to estimate activity concentrations in air and the subsequent deposition of radionuclides to the ground. Further models are then required to predict the transfer of radionuclides through terrestrial foodchains, the behaviour of radionuclides deposited on the ground and, where relevant, the resuspension of radionuclides from the ground back into the air.

94. The model used to predict activity concentrations in the air and on the ground should take account of the effective particle size of the radionuclides, the effective release height, the range of meteorological conditions that occur in the course of a year, wet and dry deposition as well as radioactive decay. All significant routine radioactive releases of radionuclides to atmosphere are filtered, generally using High Efficiency Particulate in Air (HEPA) filters. The filters generally trap all particles with an activity mean aerodynamic diameter of greater than 1 μm. The model used will need to be appropriate for the remaining discharged particle size range.

95. The meteorological conditions should be appropriate for the site in question and should preferably be averaged from several years of data. Such data may be available for the site itself or from nearby meteorological stations. The atmospheric dispersion model also needs to take into account the height of the release, the effects of nearby buildings and any plume rise due to the thermal buoyancy and/or momentum of the released material. Gaussian plume dispersion models [Ref 48] are currently still acceptable for public dose assessment purposes, although new generation dispersion models (eg ADMS [Ref 49], AERMOD [Ref 50]) are available.

96. It is common practice to a use a generic model for the transfer of radionuclides through terrestrial foodchains. In such models similar foods are grouped together for modelling purposes, for example green vegetables and root vegetables are considered rather than specific crops such as cabbage or carrots. In most cases it will be acceptable to use generic parameter values for the foodchain model. However, if extensive measurements

have been made close to the site then it may be appropriate to use site specific values for particular parameter values. The PC-CREAM code contains a farmland model for undertaking such modelling and the FSA uses its own model, SPADE [Ref 51].

97. For modelling the resuspension of radionuclides deposited on the ground two approaches are possible. The first uses a resuspension factor to relate the ground deposition to the activity concentration in air while the second uses a dust loading approach [Ref 44]. Resuspension factor models can take account of the ageing process for deposited activity, including weathering of the deposit and migration into deeper soil layers. The dust loading model is particularly appropriate for scenarios in which the concentrations of radionuclides in soil or dust have arisen from processes other than atmospheric deposition (eg sewage sludge conditioning of land) or there are higher than normal dust loadings in air (eg due to agricultural activities).

98. A model may also be required to calculate external radiation exposures from radionuclides in the passing cloud and deposited radionuclides. The latter should allow for the downward migration of radionuclides in the soil as well as the build up of activity due to continuous deposition. Dose-rate factors per unit air concentration or deposition rate are available [Ref 44, 52] and are provided in PC-CREAM data files.

Aquatic Discharges

99. Radioactive wastes may be discharged to a freshwater, estuarine or marine environment. In the UK there are also discharges of radionuclides to the sewer system from hospitals, universities and research establishments and a few nuclear sites.

100. Radionuclides discharged to water bodies are dispersed due to general water movements and sedimentation processes. Much depends on the local characteristics of the receiving environment and it is not possible to have a totally generic model for these releases. For example, for rivers information is required on the size of the river and its flow rate. Models are required to predict the activity concentrations in water and in sediment. From these data activity concentrations in aquatic foods, such as fish and crustacea, can be estimated together with external radiation doses from exposure to sediments.

101. In assessing doses to the candidate critical group, the highest activity concentrations and hence doses will generally arise close to the discharge point. However, there is the possibility of exposures arising from further afield, for example where drinking water is abstracted or where there is a major fishery. Freshwater may be used for irrigation of agricultural land and then the transfer of radionuclides to the terrestrial foodchains needs to be considered. The models discussed above for releases to atmosphere can also be used to derive concentrations of radionuclides in food, where the source of radionuclides is via irrigation water. For discharges to the marine environment exposures may also arise from radionuclides in sea spray being blown onto land and inhaled.

102. When assessing discharges to sewers, it is necessary to model the transfer of the radionuclides to the sewage works and their subsequent release into the environment. At the sewage works the doses to workers need to be estimated from external irradiation as well as inhalation and inadvertent ingestion. Radionuclides could be discharged from the sewage works with the treated effluent, to rivers or coastal waters, where the models

discussed above would be required. In addition radionuclides may be associated with the sewage sludge which is disposed of in various ways including its use as a land treatment and disposal by incineration. Appropriate models are then required for the transfer of radionuclides through terrestrial foodchains and for atmospheric releases (as discussed previously).

Determine Exposure Pathways

103. The relevant exposure pathways depend on the radionuclides discharged and the particular circumstances. The following pathways should normally be considered although calculations will not necessarily be carried out for them all for all cases:

- Internal irradiation following inhalation of radionuclides in the air either following releases to atmosphere or following the resuspension of radionuclides from the ground or in seaspray.
- External gamma irradiation from radionuclides in environmental media including air, soil and sediments.
- External radiation direct from the site of interest.
- Internal irradiation following the ingestion of radionuclides in terrestrial and aquatic foods and drinking water.
- Internal irradiation following inadvertent ingestion (eg soil, sediment or seawater).
- External beta irradiation from exposure due to radionuclides in environmental media.
- Internal irradiation from direct absorption of radionuclides through the skin (eg tritium).

104. Where unusual pathways relating to authorised discharges exist at a site then they should be included in the assessment.

Identify Critical Habits and Data for Exposure Pathways

105. Particular habits and behaviours which could lead to exposure of people through the pathways outlined above should be identified. This may be accomplished through local knowledge, commissioning of habit surveys or by reference to generic studies of such critical habits.

Atmospheric Discharges

106. The key exposure pathways are inhalation, irradiation from deposited activity and consumption of food. The radiation exposures will depend on the concentrations of radionuclides in air and on the ground around the site resulting from the discharges. This depends in turn on the location of the discharge points, the effective height of the release and the atmospheric conditions.

107. For inhalation of radionuclides in the plume, locations with the highest air concentration are required while for external irradiation from deposited material it is the highest ground deposition that leads to the highest exposures. Locations for assessment might include homes, places of work or places for leisure (eg dog walking, fishing). Only occupation of existing buildings need be considered. It is not normally necessary to consider the possibility of additional buildings being erected unless the land is within a planned development area. Where there are no planned developments, a substantial

period of occupancy in a new building is unlikely during the course of the authorisation period.

108. Account should be taken of the degree of shielding offered by the building, to reduce the external irradiation exposure, and also occupancy of the building. Generic occupancy data is available for time spent at home by different age groups [Ref 53], detailing time spent indoors and outdoors in the garden. If the building is a workplace only, then assuming occupancy during working hours only is sufficient (eg 2000 hours per year, Ref 53). The combination of occupancy and shielding may mean that the nearest building to the source is not the location for the most exposed group.

109. For discharges to atmosphere it is also necessary to include the transfer of radionuclides to terrestrial foods and their subsequent ingestion by people. The areas of land currently used for agricultural production or where it is reasonably foreseeable that food production could occur, over the period until the next review of the authorisation, need to be identified. The assessment will be concerned with those agricultural areas where the deposition from atmosphere is highest. It is possible for people to grow vegetables in their gardens and so it is reasonable to assume that any house nearby could have vegetables growing. It is important to consider the intake of products such as milk and meat from animals such as cattle and sheep that graze outdoors for significant periods. It is also reasonable to assume that any agricultural land nearby could be used for cattle and sheep in the future even if this is not currently the case. It is not normally necessary to consider products from pigs and poultry where they are housed inside and fed from a number of sources most of which will be some distance from the site of interest. However, it is unlikely that a house could change to become a small holding with cattle or sheep so this possibility does not need to be considered. It is also considered unlikely that someone would grow their own grain and so this possibility does not normally need to be considered. Habit surveys may be used to ascertain what food has been produced locally over a period of say the last 5 years.

110. Agricultural production occurs over significant areas and so it is unrealistic to assume that all food consumed could be produced close to the source of the discharge, unless this is shown to be the case by habit surveys. It might be cautiously assumed that a few foods could be produced over an area which has a centre at a distance of few hundred metres from a premises' boundary. However, where it is assumed that a number of different types of foods (eg milk, meat and vegetables) are produced close to the source of discharge, then it is more realistic to take account of the need for larger grazing areas, movement of livestock around a farm and rotation of crops. Thus, a distance of 500 m from the premises' boundary would be a more realistic minimum distance for the production of food, unless there is evidence to indicate that significant production occurs at a closer distance.

111. There is evidence from national and regional habit surveys that people rarely consume more than two foods at high rates [Ref 54]. In assessments where consumption rates for each food type are used, then two foods are assumed to be consumed at high rates while other foods are assumed to be consumed at average rates. The two foods chosen are those which give rise to the highest dose. If assessments utilise data-sets of actual consumption rates for individual people obtained from site specific habit surveys, then it is not necessary to make such assumptions about which foods are consumed at the highest rates. It is normally cautiously assumed that all terrestrial foods are locally

produced. The degree of caution resulting from these assumptions can be investigated as part of an uncertainty/variability review (see later).

Aquatic Discharges

112. For marine discharges, the critical habits are likely to include those persons who consume higher than average amounts of locally caught seafood (fish, crustacea and mollusca) and those people who spend a relatively large amount of time on areas of sediment or sand and so are exposed to external irradiation (this could also include handling sediment or sand). The candidate critical group for marine discharges does not necessarily live close to the source of the discharge.

113. The critical habits for discharges to freshwater may include consumption of drinking water abstracted from the freshwater, angling on riverbanks into which radionuclides have been incorporated, consumption of freshwater fish, consumption of food irrigated by the freshwater or exposure to external irradiation through employment as a sewage worker.

Direct Radiation

114. For direct radiation exposure, the critical habit will generally be living or working close to the source of radiation. As for external irradiation from deposited atmospheric discharges, factors such as occupancy and the shielding effects of buildings influence the location of the most exposed group [Ref 55]. It is only necessary to consider existing buildings for assessing direct radiation doses, for the same reasons as atmospheric discharges.

115. The Environment Agencies do not have regulatory responsibility for ensuring the control of direct radiation from nuclear sites, this being a duty of the NII. However, direct radiation exposure should be considered as an additional dose at the locations where members of the public are exposed to atmospheric and/or aquatic discharges. The Environment Agencies will liaise with the NII over the assessment of direct radiation doses from nuclear sites, including the publication of direct radiation dose-rates.

Habit Data

116. A variety of habit data are required to assess radiation doses. These include intake rates of terrestrial and aquatic foods, water and air together with occupancies of different environments, such as time spent indoors or near sediments. As discussed earlier it is possible to use generic or site specific data and the important factor is that the data are applicable over the period of the authorisation, typically 5 years. Both average habit data and higher than average habit data are required to assess doses.

117. A compilation of intake rates for a range of foods have been published jointly by the then MAFF and NRPB [Ref 56]. These data include the mean intake for consumers that could be used to represent the average and also the 97.5 percentile that can be used for the higher than average habit data. This compilation is based on national surveys and is appropriate for use where there are unlikely to be strong local differences in intakes.

118. For aquatic foods there are likely to be regional or local differences, for example between the intakes of people living in a coastal community and the UK population as a whole. Also the availability of particular seafood species, varies around the UK. Site specific habit surveys have been carried out for many years to determine the intakes of aquatic foods [Refs 23, 24, 25, 57, 58 & 59]. These surveys are available for the major nuclear sites and a range of different locations for marine, estuarine and freshwater environments. The surveys show existing or past habits and care is required in applying them to prospective authorisation assessments. It is possible to use these site specific data to obtain a more generic set of intakes for use in authorisation assessments (for example, see Reference 53).

119. Data on the habits of people living around nuclear sites in the UK have been, and are currently being, collected by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) for the Environment Agencies, Food Standards Agency and the Nuclear Installation Inspectorate on a routine basis. For terrestrial foods, there are generally less local and regional differences in intakes than for aquatic food. Therefore the use of generic intake rates for terrestrial foods [eg Refs 53 & 56] is unlikely to lead to unrealistic assessments. Where, site specific studies identify higher intake rates that are reasonably likely to continue over the period until the next review of the authorisation (ie about 5 years), then these should be used.

120. Generic and site specific data on occupancies are also available [Refs 53 & 57). As for terrestrial food intakes, generic habit data may be used, unless site specific studies identify higher occupancy rates.

121. Where site specific habit survey data are used, they should be no more than about 5 years old.

Identify Candidate Critical Groups from Realistic Combinations of Critical Habits

122. Candidate critical groups will need to be identified with particular combinations of habits, both critical and average, based on local knowledge and plausible assumptions. These combinations of habits will need to be realistic and not lead to implausible situations such as a full-time working person spending an equal proportion of the day on leisure activities or a person having an excessive calorie intake.

123. A full range of exposure pathways should be considered for each of the candidate critical groups. For example, the people who are a candidate critical group due to their direct radiation exposure from the site will also be exposed due to any atmospheric discharges and depending on the circumstances could be exposed due to the aquatic discharges. However, in most cases it is not realistic to assume that the same people are most exposed from all pathways and so a simple addition of doses attributed to different pathways is not necessarily appropriate. Instead, a combination of habits typical of average and most exposed people may be assumed. For example, members of the candidate critical group who eat locally produced terrestrial foods at higher than average rates, could be assumed to eat a proportion of locally produced aquatic foods at average rates.

124. Candidate critical groups may be located in areas remote from the site as a result of discharge to sewer or the interplay of dispersion and accumulation mechanisms in the environment. Sometimes, it may be necessary to consider candidate critical groups from different countries.

125. SEPA undertakes a programme of combined (terrestrial and marine pathway) habit surveys in Scotland which provides information on real cases of combinations of exposure pathways. The Environment Agency, Food Standards Agency and the Nuclear Installations Inspectorate are also working together on combined habit surveys to provide similar information for England and Wales. The results of these studies will be published and will form the basis for defining the common characteristics of the critical group as required by the draft statutory guidance to the Environment Agency [Ref 7].

126. Typical candidate critical groups may include the following:

- Consumers of shellfish and fish who spend time on contaminated sediments collecting shellfish.
- Fisherman who dig bait, and catch and eat fish.
- People who eat local terrestrial produce and walk dogs on a beach.
- People who eat local fish and shellfish and local terrestrial produce.
- Farmers who work outdoors close to site and eat local terrestrial produce.

Estimate Doses for Candidate Critical Groups

127. Dose coefficients are required to calculate the radiation doses arising from intakes of radionuclides into the body. A full range of dose coefficients for intakes by inhalation and ingestion have been published in the Euratom Basic Safety Standards Directive 1996 [Ref 5]. It is a requirement of this Directive that the dose coefficients are used. They are the same dose coefficients for intakes by inhalation and ingestion that have been published by ICRP [Ref 60] and by IAEA [Ref 61]. NRPB advice on the use of more appropriate dose coefficients than those provided in Euratom Basic Safety Standards Directive will be taken into account.

128. The dose coefficients relate the intake of activity (Bq) to the effective dose (Sv) and are available for a number of ages and, in the case of inhalation dose coefficients, common chemical forms for each radionuclide. If specific information on chemical form is not available then the defaults recommended in ICRP Publication 72 should be used. It is not appropriate to use the chemical form that leads to the highest dose coefficient in all cases. Based on an understanding of the processes involved, expert judgement should be used to determine the most appropriate chemical form for use in the assessment.

129. For calculating effective doses from external irradiation, standard models exist as well as compilations of dose coefficients [eg Ref 44, 52].

Identify the Critical Group

130. The term ‘critical group’ is used solely to refer to the group of people who receive the highest doses. The dose to the critical group will result from a combination of exposure pathways arising from all routes of discharge and include exposure due to direct

radiation from the site. It is not appropriate to define separate critical groups for discharges to different environmental media. This critical group dose will be compared with the source or site constraint as appropriate.

Total Dose

131. In order to make a comparison with the dose limit, significant future exposures arising from historical discharges from the site, historical and future discharges from other sites in the locality and future direct radiation from other sites will need to be added to future discharges and direct radiation from the site. Expert judgement will be required to determine those discharges and direct radiation sources which are likely be significant, but those which are likely to give rise to a dose greater than 10% of the dose arising from the source under consideration might be regarded as requiring an assessment. The critical group for total dose may be different to that assessed for comparison against the source or site constraint.

132. Modelling of the transfer of radionuclides in the environment and food-chain can be used. However, it may be possible to use the results of published retrospective assessments which utilise radiological environmental monitoring data, such as those produced by site operators [eg Ref 40], Environment Agencies [eg Ref 39], the Food Standards Agency [Ref 23, 24, 25] or the NRPB [eg Ref 35].

SHORT TERM RELEASE ASSESSMENT

133. Operational short term releases of a significant proportion of the 12-month discharge limit, can occur as a result of variations in site production, restricted nuclear medicine treatment days within hospitals or particular projects (eg decommissioning activities).

134. Critical group doses which are assessed for releases at the annual or 12-month rolling discharge authorisation limits, assume that the activity is discharged continuously and uniformly throughout the year. In practice, discharges are unlikely to be entirely uniformly continuous. Indeed, radioactive waste discharged to the aquatic environment, is generally accumulated in tanks prior to discharge which then occurs over a short period each day. Given the other uncertainties in the assessment process, the results based on continuous release are appropriate for these normal operational daily variations in discharges.

135. However, if a significant proportion of the 12-month authorisation limit was discharged operationally in a short time period, this could lead to higher annual critical group doses than that assessed for a uniform release rate over the year for the following reasons:

- Over the short time period that the release occurred, dispersion in the environment could be more localised than average dispersion over a year. This could lead to higher activity concentrations in a few parts of the environment, including areas where food is produced. In the case of discharges to atmosphere, this might be due to occurrence of meteorological conditions leading to poor dispersion (eg inversion conditions at night or during anticyclones) and the wind blowing in one direction for the duration of the release. For discharges to water, this could be a result of low flow conditions in rivers etc, such as can occur during summer months.

- For releases to atmosphere during rainfall this will lead to greater local deposition of radionuclides.
- Occupancy habits may change through the seasons. For example, swimming in the sea or angling may occur more frequently in summer.
- Food may be ready for harvesting shortly after the release leading to higher activity concentrations in the food than would have been assumed. Also, some foods (eg root vegetables and fruit) may be stored for consumption for many months after harvesting, giving prolonged exposure.

136. It should be noted that, conversely, short term releases could occur at times which would lead to lower doses (eg during winter when milk is produced by cows which are not grazing outdoors).

137. The Environment Agencies may decide to impose short term (ie daily, weekly, monthly or quarterly) notification levels or limits as a preventative measure against unacceptable doses from operational short term releases. Dose assessments for discharges at short term limits or notification levels will need to follow the same principles as those used to assess doses from discharges at limits with longer time-scales, normally annual limits. In particular, more realistic assumptions should be used if the estimated doses exceed 0.02 mSv/y.

138. The dose from operational short term discharges which might occur during a year at notification levels or limits may be compared with the source dose constraint of 0.3 mSv/y and the dose limit of 1 mSv/y. In order to do that, the assessment will need to allow for the number of short term releases which could affect a particular candidate critical group in one year. Clearly, the quantity of activity discharged for each radionuclide cannot exceed the annual limit. For discharges to atmosphere, windrose data may be taken into account. For example, if monthly limits are 20% of the annual limits for all radionuclides discharged to atmosphere it could be assumed that five discharges at the monthly limits occur in one year. However, if the percentage of time in a year that the wind blows a plume towards any particular candidate critical group is less than 20%, it can be assumed that the candidate critical groups are only likely to be affected by one short term release in a year.

139. Assumptions will also need to be made over the duration of a release, with typical periods being 30 minutes or 24 hours. The assessment will need to take account of the months or seasons for which dispersion is typically poor, crop harvesting occurs and outdoor occupancy is high. However, a realistic combination of assumptions should be selected to establish the critical group dose. Thus, for example, it would not be realistic to assume that the worst dispersion (normally in late autumn) and harvesting of crops (late summer) occur at the same time.

140. Realistic judgements will need to be made concerning the activity concentrations of radionuclides in food following a short term release. Where it is assumed that foods are harvested and then stored (eg root vegetables, frozen green vegetables, some fruit), then peak activity concentrations (taking account of radioactive decay) might be used in the assessment. However, it must be remembered that only one short term release can cause peak concentrations in these crops. Once they have been harvested, further releases should not affect these stored foods. For foods which are produced

continuously (eg milk), the time-integrated activity concentrations over a period of one year following one or more short term releases should be used.

141. Peak and time-integrated activity concentrations of radionuclides in foods following unit deposition are available [Ref 62, 63, 64]. The Environment Agencies, NRPB and FSA are undertaking work to derive and publish data for additional radionuclides and to also produce a generic methodology for the assessment of short term releases to atmosphere.

142. As with continuous discharges of radioactivity, there will be a build up of radioactivity in the environment from short term releases which occur many times throughout the lifetime of the plant. Given that environmental conditions (eg wind direction) will not be the same for every short term release, the averaging assumptions used in the assessment for discharges at the annual or 12-month limit will be applicable. This assessment will take into account build-up in the environment by using doses for the 50^{th} year of discharge. Consequently, there is no need to consider the impact of short term releases beyond a period of one year.

Principle 10	**The dose assessed for operational short term release at proposed notification levels or limits should be compared with the source constraint (maximum of 0.3 mSv/y) and the dose limit (1 mSv/y).**

143. Uncontrolled short term releases may also occur as a result of incidents or accidents. Doses arising from these uncontrolled releases are not assessed as part of the process of authorising routine discharges of radioactive waste to the environment. The doses and risks from uncontrolled releases are addressed as a requirement of the Ionising Radiations Regulations [Ref 18, 19] and, where relevant, the nuclear site licence conditions. The Environment Agencies and the Health and Safety Executive inspect operators on a regular basis to ensure that engineered and administrative protection systems are in place to minimise the likelihood and consequences of such uncontrolled releases. Radiological assessments would be carried out as part of post-accident recovery operations, but this guidance document does not strictly apply to this situation.

COLLECTIVE DOSE ASSESSMENT

144. 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, for example, 500 years, then the quantity is referred to as collective dose truncated at 500 years. Collective dose was defined by ICRP [Refs 13 & 32] and described as a measure of the total detriment associated with a specific source or practice.

145. There is no legal limit for collective doses. Instead, collective doses are normally used to assess different process or discharge/disposal options (eg for the abatement of discharges). The Environment Agencies use the outcome of collective dose

assessments for this purpose. 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 65, 66].

146. Collective dose to an exposed population of members of the public is often the result of the summation of very small individual doses to very large number of people. Thus, although the resultant collective dose may be numerically large, from the perspective of the individual the risks from the exposure may be insignificant. Both the magnitude of the individual doses and the size of the exposed population become increasingly uncertain as the time increases [Ref 67]. Also, current judgements about the relationship between a radiation dose and the consequent health effects may not be valid for future generations. For these reasons, ICRP has recommended that, generally "*forecasts of collective dose over periods longer than several thousands of years and forecasts of health detriment over periods longer than several hundred years should be examined critically*" [Ref 15]. In general, the rate of increment of collective dose is highest when discharges are occurring and begins to slow when discharges cease. Therefore, the rate of increment of collective dose will be highest in the first few hundred years.

147. It is therefore appropriate to draw comparisons of process/disposal options on the basis of truncated collective doses [Refs 68 & 69]. NRPB has previously noted that calculations of collective dose extending beyond around five hundred years into the future are of little value for estimating health effects [Ref 70, 71]. The draft Statutory Guidance to the Environment Agency [Ref 7] draws on this advice and states that collective doses should be truncated at 500 years. In estimating collective doses the population of the UK should be considered together with the populations of Europe and the World.

Principle 11 For authorisation purposes, collective doses to the populations of UK, Europe and the World, truncated at 500 y, should be estimated.

148. Estimating collective doses requires appropriate models together with information on the spatial distributions of population and agricultural production over the region of interest [Ref 44]. The code system PC-CREAM [Ref 46], for example, can be used to estimate collective doses for discharges to atmosphere and discharges to the sea. NRPB has published the results of a study to determine the radiological impact of routine discharges from UK civil nuclear sites in the mid 1990s [Ref 71]. This report gives collective doses per unit discharge for a range of radionuclides for a number of locations in the UK. These collective doses can be scaled by the actual discharges to obtain collective doses for authorised discharges. If the site of interest is not included then it is acceptable to take another similar site, preferably nearby, and to use the collective doses from there. In general, the world collective dose need only be considered for globally circulating radionuclides (eg tritium, carbon-14) as all other radionuclides will not be dispersed significantly beyond Europe. Collective doses per unit activity concentration in sewage sludge and unit production rate of the sludge are also available for some radionuclides [Ref 47].

149. By its nature, collective dose is an aggregated quantity and even in the case of collective doses truncated at 500 years, useful information for decision-making may be hidden. For example, the magnitude of the individual doses comprising the collective dose and when these doses are received are useful items of information. It can be shown that the collective dose truncated at a particular time from one year's operation of a practice is numerically equal to the maximum annual collective dose-rate if the practice operated unchanged for that time period provided all other factors remained the same [Ref 72]. Thus, division of the maximum annual collective dose by the number of individuals in the exposed population gives the highest average annual individual dose in the exposed population from operation of the practice over the particular time period. It is suggested that proposed new practices are assumed to operate unchanged for a period of not more than 500 years and that the highest average individual doses are calculated for 500 years. Individual facilities, of course, will not exist for such an extended time period; it is assumed, however, that they would be replaced by similar facilities. This assumption is considered to be consistent with the principle of sustainable development.

150. For a practice that operates for a shorter time period, the collective dose truncated at 500 years may be greater than the maximum annual collective dose, but will, in any case, be no less. In the case of existing facilities that may have been designed to meet less stringent standards than apply today and which would operate for only a limited period of time, it might be appropriate to estimate average annual individual doses from collective doses truncated at time periods much shorter than 500 years.

151. The highest annual average individual dose is a useful quantity for decision-making purposes. Taken together with estimated critical group doses, it gives an indication of the health risks to individuals in the exposed population and also allows an evaluation of the radiological implications of build-up of radionuclides in the environment.

152. In this respect, calculated average annual individual doses for a population group in the nanosievert (nSv/y) range or below should be ignored in the decision making process as the associated risks are minuscule and the contribution to total doses to individuals will be insignificant. Higher annual doses, up to say a few microsievert (μSv/y) can be considered trivial but may require some consideration particularly if at the higher end of the range. Calculated annual average individual doses in excess of these values should prompt careful consideration of the discharge options being considered.

VARIABILITY AND UNCERTAINTY ASSESSMENT

153. As previously discussed, assessments of doses necessarily entail a series of assumptions about the identification and behaviour of candidate critical groups and about the transfer of radionuclides in the environment. There will be differences between different groups of people depending on their behaviour. This is considered through the process of selecting a number of known or plausible candidate critical groups. This allows different exposure pathways and habits to be explored in a realistic manner. The estimated mean dose to the critical group is therefore within a distribution of possible doses.

154. 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 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 73 and a number of studies have been carried out by the NRPB, FSA and EC to investigate uncertainty and variability [eg Refs 36, 74 & 75].

155. A recent study carried out for the Environment Agency by NRPB [Ref 76] investigated the variability in the radiation doses and risks received by critical groups. The study looked at the spread on the distribution of 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.

156. Uncertainty and variability should be reviewed to establish how much caution has been applied at each stage of an assessment. In most cases this would be a qualitative or semi-quantitative review and might also be undertaken generically rather than on an assessment specific basis. It should include:

- Expected discharges compared with limits (ie headroom).
- Representative radionuclides (eg for other activity) and chemical form.
- Environmental modelling (eg atmospheric dispersion, marine dispersion, transfer through food chain).
- Selection of exposure locations and source of food production.
- Selection of habits (consumption, occupancy).
- Dosimetric data used.

157. The purpose of this review would be to provide confidence that sufficient caution has been retained to ensure that the dose limit is unlikely to be exceeded on the basis of a retrospective assessment (see Principle 6) and that also there has not been an undue level of caution applied in the assessment. Such a review will only be necessary when the critical group dose exceeds 0.02 mSv/y and a detailed assessment has been undertaken.

Principle 12	**Where the assessed mean critical group dose exceeds 0.02 mSv/y, the uncertainty and variability in the key assumptions for the dose assessment should be reviewed.**

CONCLUSIONS

158. This document provides guidance on the assessment of doses to members of the public for the purposes of authorising discharges of radioactive waste to the environment. The guidance has been developed by the UK Environment Agencies in collaboration with the National Radiological Protection Board and the Food Standards Agency as a result of a recognised need to ensure that the methods used in assessing public doses are consistent and transparent. The Euratom Basic Safety Standards Directive 1996, which

has been largely implemented in UK law through the Ionising Radiations Regulations [Ref 18, 19], amendments to the Radioactive Substances Act and by Directions placed on the Agencies, provides particular requirements for the assessment of public doses. Regulations to implement the Euratom Basic Safety Standards Directive 1996 are being made in Northern Ireland. In addition, the UK Government is developing Statutory Guidance on the regulation of radioactive discharges into the environment from nuclear sites. Account has been taken of the relevant UK legislation and draft Statutory Guidance in the production of this document.

159. Principles have been established which relate to the following:

- Population groups to be considered in assessments and the use of the critical group concept.
- Exposure pathways to be included for comparison of doses against the source constraint, site constraint and dose limit.
- Accumulation of radionuclides in the environment.
- The need for realistic dose assessments, based upon the selection of realistic habits, but taking account of foreseeable changes over the period until the next review of an authorisation.
- The need to assess doses from short term releases, assessment of collective doses and investigation of variability and uncertainty in the assessment.

160. A staged approach to dose assessments is recommended. An initial assessment may be undertaken using, for example, published dose per unit release factors. If the assessed dose is less than 0.02 mSv/y then no further dose assessment will be necessary. This is likely to be the case for most non-nuclear premises. Where the assessed dose exceeds 0.02 mSv/y, a more detailed and realistic site specific assessment should be carried out. Assessed doses will be compared with the source and site constraints of 0.3 mSv/y and 0.5 mSv/y respectively. Significant additional doses from historical discharges and other sources will need to be assessed and compared with the dose limit of 1 mSv/y.

161. Assessments for short term releases may be required to enable short term (eg daily, monthly or quarterly) limits or notification levels to be set.

162. Collective doses for the UK, European and world populations may be assessed to consider different process/disposal options, but should be truncated at 500 years. The variability and uncertainty in the critical group dose should be investigated to establish how much caution has been applied at each stage of the assessment and to ensure this level of caution is appropriate.

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GLOSSARY OF TERMS

Absorbed Dose Is the ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J/kg.

Committed Effective Dose The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the sievert (Sv).

Committed Equivalent Dose Is the integral of the absorbed dose-rate over time for a tissue or organ, weighted for the type and quality of the radiation by a radiation weighting factor. For adults and children the default time integration period is 50 years and 70 years respectively. The unit of committed equivalent dose is the sievert (Sv).

Direct Radiation Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.

Dose Coefficient Committed effective dose per unit acute intake. Committed doses are evaluated over 50 years for adults and from intake to age 70 years for children. Also effective dose from external irradiation due to unit activity.

Dose Constraint A restriction on annual dose to an individual from a single source or site such that when aggregated with doses from all sources, excluding natural background and medical procedures, the dose limit is not likely to be exceeded; the dose constraint places an upper bound on the outcome of any optimisation study and will therefore limit any inequity which might result from the economic and social judgements inherent in the optimisation process. Source constraints will be set by the Environment Agencies for new sources, the maximum constraint being 0.3 mSv/y. A site constraint of 0.5 mSv/y has been set by the UK Government and this applies to the aggregate exposure from a number of sources with contiguous boundaries at a single location, irrespective of whether different sources on the site are owned or operated by the same or by different organisations.

Dose Limit Maximum dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified

	period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv/y for the UK.
Effective Dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the sievert (Sv).
Equivalent Dose	Is the absorbed dose in a tissue or organ, weighted for the type and quality of the radiation by a radiation weighting factor. The unit of equivalent dose is the sievert (Sv).
Nuclear Site	A site licensed by the Nuclear Installations Inspectorate under the Nuclear Installations Act 1965 and Nuclear Installations Regulations 1971.
Practice	Human activity which can increase the exposure of people to radiation (eg medical diagnostics and treatment; nuclear power generation).
Prospective Assessment	Estimation of the doses that may be received by a critical group from future sources of radiation.
Radiation Weighting Factor	Factor used to weight the tissue or organ absorbed dose to take account of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactive Waste	Legal definitions of radioactive material and radioactive wastes are contained in Sections 1 and 2 of the Radioactive Substances Act 1993; the effect of the definitions is that radioactive waste generally includes: a. scrap, surplus or spoilt radioactive material; and b. any other waste substance or article which has become radioactive or has acquired an increased concentration of radioactivity.
Retrospective Assessment	Calculation of doses that have actually been received by a critical group.
Source	A facility, or group of facilities, which can be optimised as an integral whole in terms of radioactive waste disposals (eg an individual hospital with a nuclear medicine department or an individual nuclear power station).
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to take account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung= 0.12; bone marrow= 0.12; skin= 0.01.

LIST OF ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BPM	Best Practicable Means
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
COMARE	Committee on Medical Aspects of Radiation in the Environment
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions (responsibility for the environment has now passed to DEFRA)
FSA	Food Standards Agency
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
MAFF	Ministry of Agriculture, Fisheries and Food
NII	Nuclear Installations Inspectorate
NRPB	National Radiological Protection Board
RWMAC	Radioactive Waste Management Advisory Committee
SEPA	Scottish Environment Protection Agency

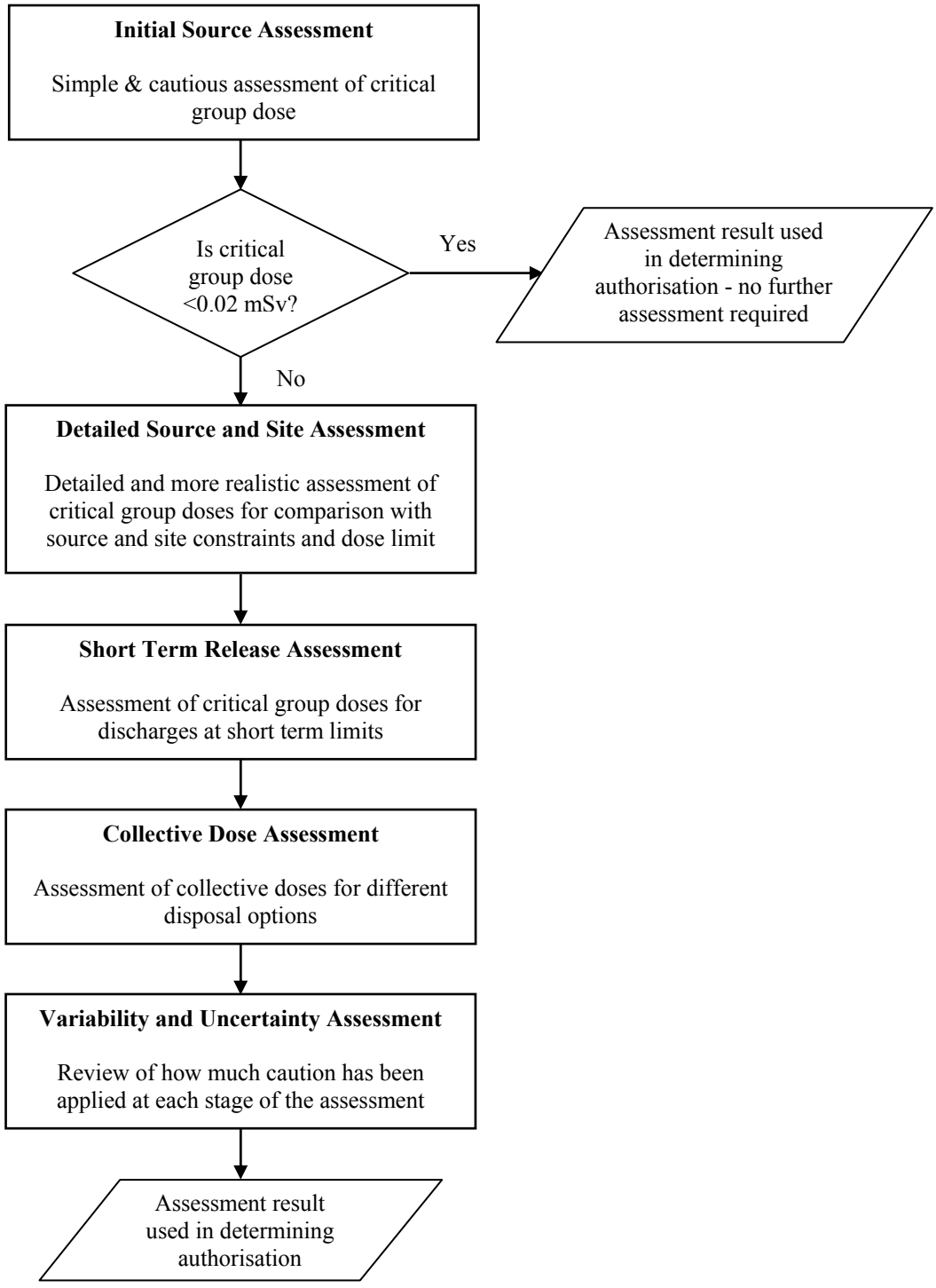

Figure 1 Stages of Dose Assessment Process

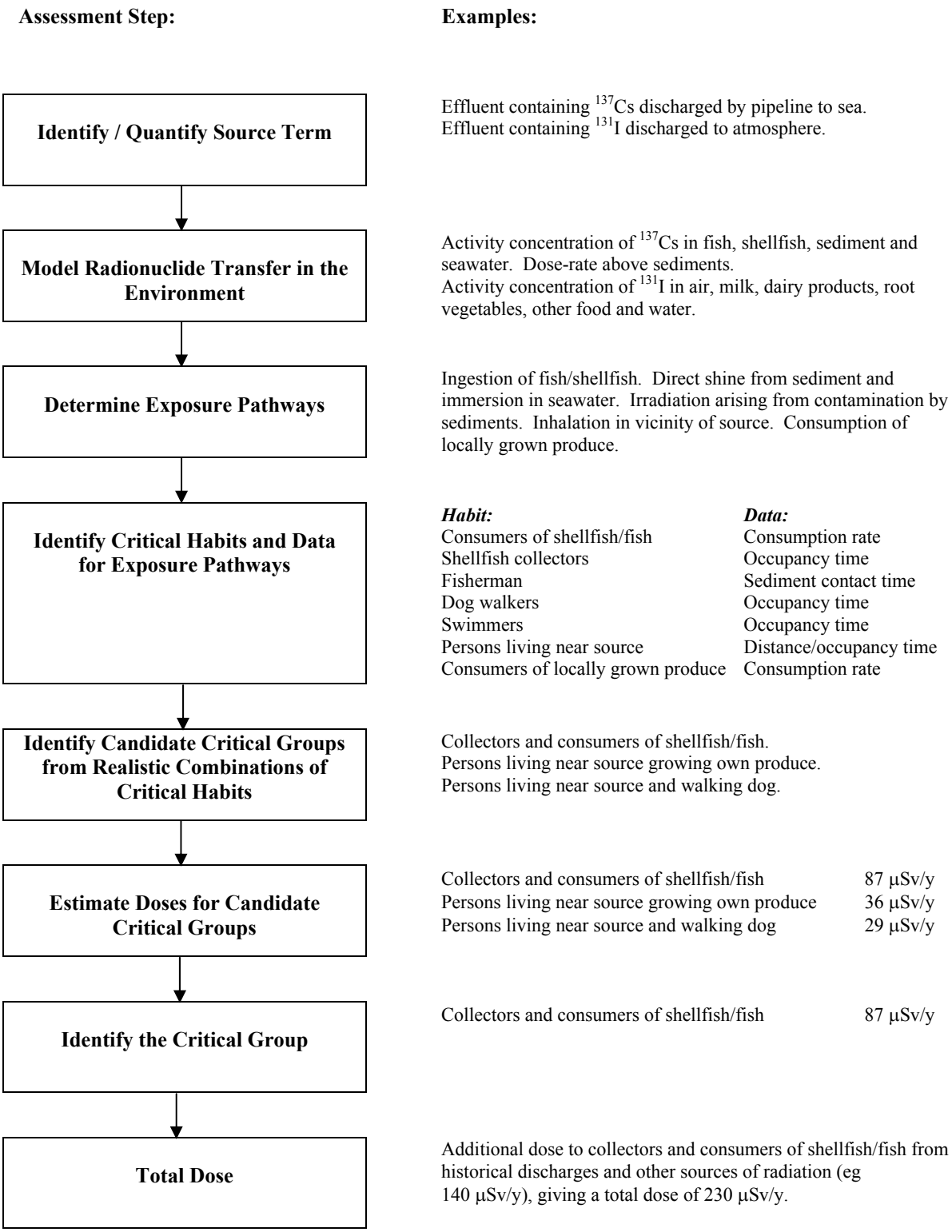

Figure 2 Detailed Source and Site Assessment