



**NDAWG**  
National Dose Assessment Working Group

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*Radiological Assessment Exposure  
Pathways Checklist (Common and Unusual)*

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The views presented in this paper are those of the authors in consultation with members of NDAWG. They represent the views of the majority of members of NDAWG but do not necessarily reflect the views of the organisations from which the members are drawn.





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## **1 Introduction**

- 1.1 The Euratom Basic Safety Standards (BSS) Directive 1996<sup>[1]</sup> (Article 14) requires member states to ensure that doses arising from the exposure to ionising radiation do not exceed specified dose limits. The Government and Devolved Administrations have also Directed the Environment Agency<sup>[2]</sup> and the Scottish Environment Protection Agency (SEPA)<sup>[3]</sup> to have regard to specified dose constraints.
- 1.2 In the UK, 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.
- 1.3 Radiological Assessments are undertaken to determine doses from such authorised discharges of radioactive waste to the environment and to ensure that the doses remain within dose limits or dose constraints as appropriate. Assessments may be undertaken prospectively to estimate doses from future discharges or retrospectively to estimate doses received by actual discharges.
- 1.4 The Environment Agency, SEPA, Department of Environment in Northern Ireland, National Radiological Protection Board (NRPB) and the Food Standards Agency have jointly established principles for the prospective assessment of doses to members of the public<sup>[4]</sup>.
- 1.5 This paper provides a checklist of exposure pathways which might commonly be found around most sites making authorised discharges to the environment. It also provides a checklist of less common, or unusual exposure pathways. These pathways were identified as a result of an Environment Agency R&D project<sup>[5,6]</sup>.
- 1.6 When undertaking radiological assessments, the relevance of these exposure pathways should be taken into account.

## **2 Common Exposure Pathways**

- 2.1 A checklist of common exposure pathways and a general indication of the significance of the exposure pathways is provided in Table 1. These exposure pathways are listed under the following release routes:
  - Air
  - Freshwater (rivers, lakes, etc)
  - Coastal waters or estuaries
  - Sewer and sewage treatment works
  - Ground and groundwater
  - Direct radiation

## **3 Unusual Exposure Pathways**

- 3.1 A checklist of unusual exposure pathways and a general indication of the significance of the exposure pathways is provided in Table 2. These exposure pathways are listed under the following release routes:

- Air
- Freshwater (rivers, lakes, etc)
- Coastal waters or estuaries
- Sewer and sewage treatment works
- Ground and groundwater
- Disposal to landfill site
- Process operations on site

## 4 Feedback

- 4.1 NDAWG would be grateful to have your feedback of any new unusual pathways which you may identify during radiological assessments to update this paper. Please see the 'contact us' details on the NDAWG website (<http://www.ndawg.org/>).

## 5 References

1. Council Directive 96/29/Euratom of 13 May 1996 *Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionizing Radiation*. Official Journal of the European Communities, L159, Volume 39, 29 June 1996.
2. The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000.
3. The Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000.
4. Environment Agency, Scottish Environment Protection Agency, Northern Ireland Department of Environment, National Radiological Protection Board and Food Standards Agency (2002). Authorisation of Discharges of Radioactive Waste to the Environment. Principles for the Assessment of Prospective Public Doses. [www.environment-agency.gov.uk/business/444304/444637/ras/452235/](http://www.environment-agency.gov.uk/business/444304/444637/ras/452235/).
5. AEA Technology (2001). Investigations into Unusual Pathways of Transfer of Radioactivity to the Environment from Nuclear Sites; AEA Technology Contract paper AEAT/ENV/R/0677.
6. Environment Agency (2001). Investigations into Unusual Pathways of Transfer of Radioactivity to the Environment from Nuclear Sites. National Compliance Assessment Service Technical Report NCAS/TR/20001/012.

**Table 1 Common exposure pathways checklist**

Release route / Radiation Source	Exposure pathway type	Exposure pathway	Significance (H, M or L)
Air	Inhalation of air	Inhalation of radionuclides in plume	H/M
		Inhalation of resuspended radionuclides	L
	External radiation from immersion	External radiation from immersion in plume	L (H for noble gases)
	External radiation from ground	External radiation from deposited radionuclides on soil/grass etc	H
	Consumption of food and water	Consumption of milk, milk products, beef, lamb, pig, poultry, offal, green vegetables, root vegetables, fruit and cereal containing radionuclides incorporated following deposition on soil and grass	H
		Consumption of water containing radionuclides following deposition on to water sources	L
	Inadvertent ingestion	Inadvertent ingestion of soil containing radionuclides	L
	Transfer through skin	Transfer of mobile radionuclides in plume directly through skin	L
Freshwater (rivers, lakes etc)	External radiation from ground	External radiation from radionuclides incorporated into sediments (houseboat dwellers, fishing, swimming, canoeing, dog walking by rivers etc)	M
	Consumption of food and water	Consumption of drinking water containing radionuclides	M
		Consumption of freshwater fish containing radionuclides	H
		Consumption of milk, milk products, beef, lamb and offal containing radionuclides incorporated through animals drinking water	L
		Consumption of green vegetables and root vegetables containing radionuclides incorporated following use of water for irrigation	L

**Table 1 Common exposure pathways checklist (cont)**

Release route / Radiation Source	Exposure pathway type	Exposure pathway	Significance (H, M or L)
Freshwater (rivers, lakes etc) (cont)	Inadvertent ingestion	Inadvertent ingestion of sediment containing radionuclides	L
	Transfer through skin	Transfer of mobile radionuclides directly through skin	L
	External radiation from immersion	External radiation from immersion in water during (swimming, canoeing etc)	L
	Contaminated items	External irradiation of skin from handling fishing equipment.	L
Coastal waters or estuaries	Inhalation of air	Inhalation of radionuclides in seaspray	L
	External radiation from ground	External radiation from radionuclides incorporated into sediments (houseboat dwellers, bait digging, fishing, playing on beaches)	H
	Consumption of food	Consumption of fish, shellfish and seashore plants (eg samphire, laverbread) containing radionuclides	H
	Inadvertent ingestion	Inadvertent ingestion of sediment containing radionuclides	L
		Inadvertent ingestion of seawater containing radionuclides	L
	External radiation from immersion	External radiation from immersion in water during (swimming, yachting, surfing, water skiing, windsurfing etc)	L
	Contaminated items	External irradiation of skin from handling fishing equipment (eg fishing nets, lobster pots)	L
	Transfer through skin	Transfer of mobile radionuclides directly through skin	L



**Table 1 Common exposure pathways checklist (cont)**

Release route / Radiation Source	Exposure pathway type	Exposure pathway	Significance (H, M or L)
Sewer and sewage treatment works	External irradiation from process	External irradiation from sewage and sludge containing radionuclides	H
	Inhalation of air	Inhalation of radionuclides in resuspended sewage or sludge at sewage treatment works	L
		Inhalation of radionuclides in resuspended sludge during spreading or in soil	L
	Inadvertent ingestion	Inadvertent ingestion of sewage or sludge containing radionuclides at sewage treatment works	L
		Inadvertent ingestion of sewage or sludge containing radionuclides during spreading or in soil	L
	External radiation from ground	External irradiation from sewage and soil during and after spreading process	M
	Consumption of food and water	Consumption of milk, milk products, beef, lamb, offal, root vegetables and cereal containing radionuclides incorporated following spreading of sludge on land	H
Ground and groundwater	Consumption of food and water	Consumption of drinking water containing radionuclides	M
		Consumption of green vegetables and root vegetables containing radionuclides incorporated following use of water for irrigation	M
Direct radiation	External irradiation from process	External radiation from process activity on site (eg nearby habitation, dog walking around site)	H

**Table 2 Unusual exposure pathways checklist**

Release route / Radiation Source	Exposure pathway type	Exposure pathway
Air	Inhalation of air	Fire/burning - Forest fires, agricultural burning, fell fires, bonfires, stubble burning, peat burning, charcoal production, burning animal carcasses (but not too any great extent), barbecue smoke
		Other Plant derived - Spores and pollen, herb tobaccos, vegetation die back, aromatherapy products (eg lavender, geranium)
		Other animal derived - Resuspended animal slurry, production of detritus from animal skins, methane production, grooming horses
	Inadvertent ingestion	Extreme soil consumption (in particular children - pica), chalk
	Consumption of food and water	Wildfoods/freefoods – Fungi, berries, elderberries, blueberries, rosehips, orchard fruit, home brewing, wild sicily, nettles, nuts, dandelions, herbs, sorrel, wild strawberries, distillation, pheasant, other game, wood pigeon, ostrich farms, emus, rabbits, deer, goat milk, sunflower oil, homeopathic medicines, herbs, seeds (eg sunflower)
		Radionuclides in silage and compost, lawn cuttings to compost, falling leaves to compost
		Unusual contamination routes - Deer consuming lichen, mineral additives to animal diet, growbags, moss eaten by cows, plants used to produce drinks, growing mushrooms on animal waste products, soil ingestion by animals
		Rainwater for drinking, Water butts, rainwater irrigation of crops, Water recycling systems, Acid rain (C-14 labelled)
	External radiation from immersion	Bathing in rainwater, bathing in contaminated water
	External radiation from ground	Routine sampling

**Table 2 Unusual exposure pathways checklist (cont)**

Release route / Radiation Source	Exposure pathway type	Exposure pathway
Air (cont)	Contaminated items	Plant derived - Burrs (eg on animals), biofuels, flowers, xmas trees, paper residues, leaf mould, plants grown for making clothing, thatching, moss (eg in hanging baskets)
		Animal derived - Bird / rabbit droppings, cow or sheep dung, production of liquid manure from sheep dung, bloodmeal, recycled agricultural products (eg milk), animal products for making clothing, swarming (ants, bats, bees, insects humans looking after feral animals, mosquitoes, pigeons starlings), humans feeding birds
		Other - Building materials (timber, bricks, slates, etc), grain silos, geotechnics, cutting of turf (revealing high concentrations in soil)
Freshwater (rivers, lakes etc)	Inhalation of air	Resuspension from lake and river water surfaces
		Resuspension from surface run-off
	Consumption of food and water	Surface runoff used for drinking water, animal drinking water supplies (different to human supply)
		Watercress, eels, frogs, fish farms, otters, spawning grounds (eg salmon)
	External radiation from ground	University research (eg sieving sediment samples), routine sampling, quarrying, gravel extraction, retrieval of stolen cars from quarries, production of aggregate, revealing beds of dry water bodies
	Direct into body	Dialysis using contaminated water, tattoos, mosquitoes

**Table 2 Unusual exposure pathways checklist (cont)**

Release route / Radiation Source	Exposure pathway type	Exposure pathway
Coastal waters or estuaries	Inadvertent ingestion	Sand (eg beach), sediment
	Inhalation of air	Smoking of fish, Items dissolved in water (eg radon, SO <sub>2</sub> , CO <sub>2</sub> )
	Consumption of food and water	More unusual sea derived foods include fish pate, seashore plants, duck, geese, wild fowl, game pate, waders, geese, wild fowl, whales, sharks, seals, porpoise, sprats, seamice
		Minor food products etc - fish oils, sea salt, algenates, health foods, calcium supplements, iron haemoglobin supplements, medical preparations, colouring and flavouring agents, fishmeal, natural candles
		Unusual contamination routes - Aquatic flora near discharge points (eg kelp, seamice, seaweeds), seaweed as fertiliser/compost, grazing estuaries (both tidally and occasionally inundated pastures), fish meal
	External radiation from ground	Activities near discharge points (eg mud walking, diving, fishing), mud-bathing, importation of contaminated turf, interactions with the pipeline(s), university research (eg sieving sediment samples), routine sampling, land reclamation (eg salt marshes), dredging operations (off coast, estuaries), natural erosion of surfaces to reveal regions of high concentration
	Contaminated items	Animal derived - seagulls, shellfish, lugworm, lobsters, microbe coverage on flora (eg seaweed), corals at the end of discharge pipes, lugworms, razor shells, guano
		Contaminated paint from the hulls of boats, sea spume, tar, flotsam, drift wood, fishing equipment, reeds for matting etc, artefacts from fishing, beach combing (eg with metal detectors), snagged anchors (ie boats), treasure hunts (eg from shipwrecks), plastic bottles washed up, mud on clothing, pottery manufacture, sediment on dredgers
Sewer and sewage treatment works	Inhalation of air	Resuspension of animal slurry following grazing on sludge treated pasture
		Methane and carbon dioxide etc from sewage treatment works

**Table 2 Unusual exposure pathways checklist (cont)**

Release route / Radiation Source	Exposure pathway type	Exposure pathway
Ground and groundwater	Consumption of water	Mineral waters, breaching of barriers with tritiated water, rainwater mobilising activity from roof (eg from congregating seagulls, resuspended dust, electrostatic attraction, mosses in gutters, caesium absorption by roofing materials, water wells
Disposal to landfill site	Contaminated items	Leachates
Process operations on site	Inhalation of air	Welding fumes from site, decommissioning activities producing aerosols (eg cutting up structures), mining and milling (eg USA, Canada etc), fugitive dust emissions, cooling towers (incl microbes)
	External radiation from ground	Flood damage washing material off-site
	Contaminated Items	Animal derived - Animal contaminated on site and human contact with animal and animal detritus (eg pets, feeding birds, looking after feral animals), bird / rabbit droppings, transfer of contamination (eg ants, badgers, bats, bees, cats (feral and domestic), deer, dogs, ferrets, foxes, frogs, hares, insects, mice, mink, moles, mosquitoes, newts, pigeons, rabbits, rats, rodents, shrews, snakes, squirrels, starlings, stoats, voles, weasels
		Plant derived – Tumbleweed
		Other – Metal particles (eg swarf), gasket particles (rubber, other), filter bed particles (eg sand), boots, shoes, clothing, stationery, pens (eg sucking the ends), injection of contaminated material in medical procedure, handling stolen contaminated plant or equipment (eg tools, paint brushes etc), contaminated materials (eg packing) blown off site, historic waste, use of decommissioning materials for roads etc, failure to monitor properly waste materials leaving the site, contamination of transport equipment
	Direct into body	Organisms living in and around process operations (eg ponds) - mosquitoes, snake bites