Annex U: Long term consequences of a nuclear emergency

Deposition of radioactive contamination in the environment

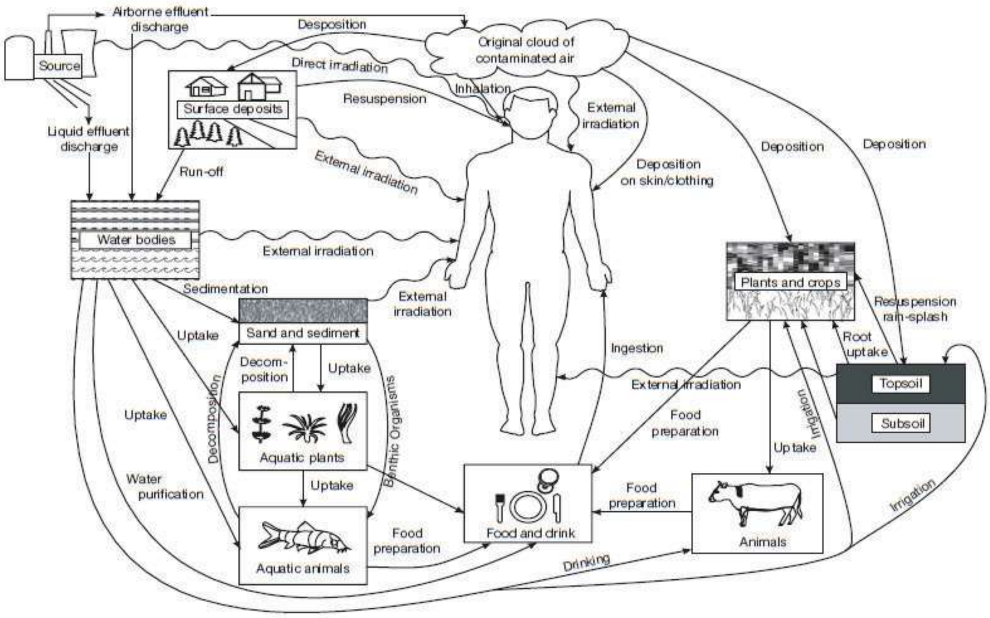
1. Following an atmospheric release, deposited radioactivity will be present as surface contamination. Its distribution will be affected by the properties of the contamination and the action of environmental process such as weathering. Material may be found on the surfaces of buildings, roads, open spaces in inhabited areas, on land used for food production and in lakes, reservoirs and the marine environment.

2. Levels of radioactivity on the ground are likely to decrease with distance from the release point. The distribution of radioactivity will be affected by the terrain, human activities, building structures, as well as weather conditions. For example, greater levels of deposition on the ground may be expected where it has rained. Additional factors such as type of radionuclide, its chemical form, soil type or media on which the contamination is deposited, as well as weathering effects (such as rainfall, erosion and resuspension) can change and redistribute the contaminated material over time. The time and rate of change can vary greatly.

Exposure pathways

3. Radioactive contamination in the environment may lead to a range of exposure pathways resulting in radiation exposures to people. Different exposure pathways are important at different times following a release. When the release of radioactivity is on-going, people affected by the plume receive a direct external radiation exposure, as well as an internal exposure from breathing in radioactive materials.

Figure 3.Exposure pathways for members of the public as a result of discharges of radioactive material to the environment[6]



[6] From IAEA Safety standards for protecting people and environment. Environmental and source monitoring for the purposes of radiation protection. Safety Guide No RS-G-1.8

4. The main potential exposure pathways in the medium to long term are:

- External irradiation from radioactivity deposited in the environment;
- Breathing in resuspended radionuclides; and
- Consumption of contaminated foods.

Factors affecting radiation exposures

5. The importance of the various exposure pathways and radionuclides depends on the type of environment being considered. For example; residential, non-residential, recreational, food production system or drinking water supplies. Identifying the main exposure pathways for a given environment assists in identifying the areas where remediation efforts are most likely to produce significant reductions in doses.

6. Once deposited in the environment, radiation exposures will be dependent on many factors, including:

- **The levels of contamination**
    - Levels of radioactivity on the ground are likely to decrease with distance from the release point. However, wash out during rainfall or snowfall may lead to 'hot spots' of deposition on the ground.
- **The type of radioactivity (radionuclides) present**
    - An airborne release of radioactivity arising from an emergency is likely to be dominated by iodine-131 and caesium-137 which are products of the nuclear fission of uranium. The thyroid gland produces hormones containing iodine. The body cannot distinguish between radioactive iodine-131 (half-life 8 days) and stable iodine, the gland which absorbs and stores iodine containing compounds will disproportionately be affected by the radiation, especially in infants and children. In the longer term, exposure may give rise to thyroid cancer. Iodine tablets distributed in the vicinity of nuclear power plants are intended to saturate the thyroid with stable iodine to prevent uptake of the radioactive form.
    - Caesium-137 (half-life 30 years) is present in the form of salts which are highly soluble in water. This means that caesium-137 ions are readily taken up into food stuff grown in contaminated areas and into the body.
    - For nuclear emergencies involving alpha-emitting radionuclides, such as plutonium-239, inhalation of resuspended (contaminated) material is the primary concern.
- **Radioactive half lives**
    - The rate of radioactive decay is determined by the half-life – the time taken for the amount of radioactivity to reduce by half. Radioactive half-lives can vary between fractions of a second to millions of years, so at any location, the amount of radioactivity present will change over time in line with the radioactive half-life.

- In general, the longer the half-life, the longer the radioactivity will persist in the environment with the potential to deliver a radiation exposure. However, it doesn't necessarily follow that radionuclides with longer half-lives are more of a problem for recovery than radionuclides with shorter half-lives. The most challenging materials are likely to be those with intermediate half-lives, for example, caesium-137, with a half-life of around 30 years. A material with a half-life of a million years is actually not very radioactive because it decays very slowly. However, one with a short half-life decays faster and produces a bigger dose.

- **Mobility of radioactivity in the environment**
    - The length of time a radionuclide presents a health hazard is not simply a matter of its physical half-life. For exposures arising from contaminated food, the speed at which the material is absorbed and immobilised in the environment may be more important.
    - For the most part, the contamination will begin as surface contamination and will generally be uniformly distributed, decreasing in concentration with distance from the incident. However, the uniformity of the initial deposition will be affected by weathering effects such as rainfall, wind, erosion and resuspension as well human activities such as farming activities and vehicle movement which can change and redistribute the contaminated material over time.   The redistribution can greatly vary according to the radionuclide and where it has been deposited.
    - Some radionuclides are more mobile than others in the environment. For example following deposition radiocaesium is highly soluble in water and is susceptible to erosion and run off before becoming immobilised in soils. Strontium on the other hand is, in most forms, relatively mobile and can move down the soil column and into ground waters with percolating water.
- **Time since the release**
    - Generally, in the absence of protective countermeasures, the exposure rate would be highest immediately after deposition. Exposures will reduce over time as the radionuclides migrate from exposed surfaces, for example - by the action of water. However, it is possible that subsequent increases in exposure rate could occur due to the movement of radionuclides into closer proximity with people.
    - Time since release is an important factor affecting exposures from materials with short half-lives. For example, iodine-131which has a half-life of 8 about days. Within a month – which is approximately four half-lives, the concentration will be 16 times lower.
- **The amount of time people spend in the proximity of contamination**
    - The longer the exposure time the greater the radiation dose.
- **Activities undertaken in the contaminated area**

- For planned activities that are particularly prone to raising dust, for example, workers carrying out some decontamination measures or for farmers or others working on the land, it is important to consider the resuspension pathway for all types of deposited radionuclides.

- **Measures in place to manage exposure**
    - For example, restrictions on the sale and marketing of contaminated foods, restricting access to contaminated areas and undertaking clean-up of inhabited areas.

Impact on health and well-being

7. Any exposure to radiation is thought to increase the long term risk of cancer. In most situations, the risk to health is proportional to the amount of radiation dose that someone receives. It is not generally possible to distinguish between cancer that is caused by low level radiation exposure and cancer from other causes.

8. Exposure to high doses of radiation in short bursts can cause illness in addition to the long term cancer risk. The severity of the effects will depend on the type of radiation, the amount of exposure and the exposure situation. Very large exposures can kill but these occur very rarely. They will not be an issue in the recovery phase of a nuclear emergency because health protection measures will already have been implemented to prevent them. Dose assessment during the recovery phase would never involve weighing up exposures that could involve severe health effects.

9. Nuclear emergencies may also have profound psychological impacts on people[7]. These events are unique in part because of the public's intense fear of radiation. In the case of the emergencies at Chernobyl and Fukushima this has led to short, medium, and long term negative effects on health and quality of life, which has manifested itself for example in terms of depression, increased incidence of suicide, alcoholism and relationship breakdowns. There have also been heightened perceptions of social stigma attached to people who were contaminated, or even potentially contaminated, by radioactive materials. The social stigma attached to people exposed to radiation may isolate them and substantially affect prospects for successful long-term recovery.

10. The negative impact may be compounded by the disruption to normal living over prolonged periods of time. This could involve a causal event which alters the lifestyle of affected communities. For example, the seismic event that led to the nuclear emergency at the Fukushima Daiichi nuclear power plant. Disruption may also be caused by relocation of communities, restricting access to contaminated areas or efforts to remediate affected areas. The impacts on normal living, such as going to school, going to work and engaging in leisure activities, may have a significant impact on individual well-being.

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[7] Recovery from Chernobyl and other Nuclear Emergencies: Experiences and Lessons Learnt. United Nations Development Programme Bureau for Europe and the CIS, April 2013.

Impact on the food chain

11. Plants may intercept radionuclides directly on their exposed surfaces or take up contamination from soil through their roots. Animals can be exposed via inhalation or through ingestion of contaminated feed or water. In some circumstances, actions can be taken that reduce the levels of contamination in the final food products to acceptable levels. This may include washing and peeling fruit and vegetables to remove surface contamination. For meat products, ensuring a period of clean feeding prior to slaughter may allow time for contamination to reduce through natural biological processes.

12. Where food is contaminated it can lead to an intake of radioactivity over a long period of time, leading to the build-up of dose. This dose can be reduced by banning the sale of contaminated food. The limits on radioactivity in food are deliberately low to reduce radiation dose to minimal levels. This may result in a wide area being subject to food controls.

Impact on drinking water

13. Reservoirs and rivers or streams used for drinking water supplies can be affected by the runoff from contaminated areas, although dilution of the radionuclides in a large water body greatly reduces concentrations. Processes used routinely in water treatment plants to remove impurities from drinking water will also remove a wide range of radionuclides, some by up to 70 %. Insoluble radionuclides will bind with sediment in the surface water bodies and will not have a significant impact on drinking water supplies.

Impact on business, economy and infrastructure

14. Long lasting radiological contamination is likely to directly affect critical infrastructure (such as utilities, public transportation, communication systems, food and water supplies) which will impact on the local economy (such as businesses and employment opportunities) and key public services (government services, security institutions, medical facilities, financial system, public health services, and education facilities). Psychosocial impacts of the radiation would also be expected to contribute significantly to longer-term deleterious economic outcomes. There may be reluctance to purchase food and other commodities from the affected area due to the stigma associated with radiation. Inadequate economic restoration may lead to permanent outmigration (for reasons apart from health-related considerations), as residents move elsewhere to seek gainful employment, although this is very much dependent on the pre-incident economy of the affected area.