World Health Organization

Food and Agriculture Organization of the United Nations

Nuclear accidents and radioactive contamination of foods
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This document is intended to provide basic background information and not to give a complete overview. It will be updated as appropriate.

1. Introduction

Radioactive isotopes of elements (radionuclides) are naturally present in the environment, and that includes our bodies and our food and water. We are exposed to radiation (also known as background radiation) from these radionuclides on a daily basis. Radiation comes from space (i.e., cosmic rays) as well as from naturally-occurring radioactive materials (radionuclides) found in the soil, water and air. Radioactivity can be detected in food and water and the concentration of naturally-occurring radionuclides varies depending on several factors such as local geology, climate and agricultural practices.

People can also be exposed to radiation from man-made activities, including medical diagnostic intervention. Radioactivity can contaminate food after it has been discharged into the environment from industries that concentrate natural radionuclides and from civil or military nuclear operations. Whether, man-made or natural in origin, radioactive material passes through the food chain in the same way as non-radioactive material. The degree of harm to human health depends on the type of radionuclides and the length of time people are exposed to it. The amount of radiation people are exposed to varies from place to place and among individuals.

In the event of releases of radioactivity following an emergency at a nuclear power plant, land, rivers, sea and structures in the vicinity of the power plant can become contaminated with a mixture of radionuclides generated inside the reactor, also known as “nuclear fission products”. Individuals can therefore become exposed to radiation from these fission products.

2. Radionuclides in food

Background levels of radionuclides in foods vary and are dependent on several factors, including the type of food and the geographic region where the food has been produced. The common radionuclides in food are potassium-40 (^{40}K), radium-226 (^{226}Ra) and uranium 238 (^{238}U) and their associated progeny. In general, ^{40}K is the most commonly occurring natural radioisotope. In milk, for example, levels of ^{40}K measure around 50 Bq/L, and for meat, bananas and other potassium rich products, levels may measure at several hundreds Bq/kg. Other natural radioisotopes exist in much lower concentrations, and originate from the decay of uranium and thorium.

When large amounts of radioisotopes are discharged into the environment, they can affect foods by either falling onto the surface of foods like fruits and vegetables or animal feed as deposits from the air or through contaminated rainwater/snow. Radioactivity in water can also accumulate in rivers and the sea, depositing on fish and seafood. Once in the environment, radioactive material can also become incorporated into food as it is taken up by plants, seafood or ingested by animals.

Although many different kinds of radionuclides can be discharged following a major nuclear emergency, some are very short-lived and others do not readily transfer into food. Radionuclides generated in nuclear installations and that could be significant for the food chain include; radioactive hydrogen (^{3}H), carbon (^{14}C), technetium (^{99}Tc), sulphur (^{35}S), cobalt (^{60}Co) strontium (^{89}Sr and ^{90}Sr), ruthenium (^{103}Ru and ^{106}Ru), iodine (^{131}I and ^{129}I), uranium (^{235}U) plutonium (^{238}Pu, ^{239}Pu and ^{240}Pu), caesium (^{134}Cs and ^{137}Cs), cerium (^{103}Ce), iridium (^{192}Ir), and americium (^{241}Am).

The radionuclides of most concern for possible transfer to foods have been considered when setting the Codex Guideline levels described below.

Of immediate concern is iodine-131, it is distributed over a wide area, found in water and on crops and is rapidly transferred from contaminated feed into milk. However, iodine-131 has a relatively short half-live and will decay within a few weeks. In contrast, radioactive caesium which can also be detected early on, is longer-lived (Cs-134 has a half life of about 2 years and Cs-137 has a half life of about 30 years) and can remain in the environment for a long-time. Radioactive caesium is also relatively rapidly transferred from feed to milk. Uptake of caesium into food is also of long-term concern.

Other radioisotopes that could be of long-term concern if released, are strontium and plutonium. Strontium-90 has a half life of about 29 years and plutonium has a much longer half life than that (Pu-238: 88 years, Pu-239: 24100 years, Pu-240: 6564 years). However, both strontium and plutonium are relatively immobile in the environment and are of concern more locally, thus it is unlikely to cause a problem in international food trade in the immediate and medium-term.

Commodities of concern

Open-air vegetables and plants can be affected by the atmospheric release of radionuclides, resulting in radioactive contamination. Thus, radionuclides tend to be detected from leafy vegetables especially the ones with large leafy parts in the early phase after a nuclear accident. Milk is also associated with the early-phase contamination due to the rapid transfer of radioactive iodine and "relatively" rapid transfer of radioactive caesium from contaminated feed into milk.

Over time, radioactivity can also build up within food, as radionuclides are transferred through soil into crops or animals, or into rivers, lakes and the sea where fish and other seafood could take up the radionuclides. Foods collected from the wild, such as mushrooms, berries and game meat, may continue to be a radiological problem for a long time. Fish and aquatic microflora may bioconcentrate certain radionuclides, but due to the high dilution of radionuclides in water, contamination tends to be confined relatively locally.

3. Health effects

The main health concern for consumers in the long term due to high radiation exposure is development of cancer. Cancer types and target organs depend on the radionuclides.

IAEA estimates that on average, our radiation exposure due to all natural sources amounts to about 2.4 mSv a year - though this figure can vary, depending on the geographical location by several hundred percent. In Canada, the average dose due to naturally occurring background radiation is about 2 mSv per year, of which about one-half comes from the inhalation of naturally-occurring radon and its short-lived decay products. About 0.7 mSv per year, nationally-averaged, arises from cosmic and terrestrial gamma radiation. The portion of the background dose resulting from ingestion of natural radionuclides in food is about 0.25-0.4 mSv per year.

Consuming contaminated food will increase the amount of radioactivity inside a person and therefore increase their exposure to radiation, thereby possibly increasing the health risks associated with radiation exposure. The exact health effects will depend on which radionuclides have been ingested and the amount being ingested.

Examples for exposure from contaminated foods:

- Adult eating 200g spinach contaminated with 1000Bq/kg of Cs-137 resulting in 0.0026 mSv additional exposure

$$[0.2\ (\text{kg}) \times 1000\ (\text{Bq/kg}) \times 1.3 \times 10^{-5} (\text{mSv/Bq})]$$

- One-year old child consuming 0.5 L milk contaminated with 100 Bq/L of I-131 resulting in 0.009 mSv additional exposure

$$[0.5\ (\text{L}) \times 100\ (\text{Bq/L}) \times 1.8 \times 10^{-4} (\text{mSv/Bq})]$$

Radioactive iodine (I-131) in food is of immediate concern due to its rapid transfer to milk from contaminated feed and its accumulation in the thyroid gland. I-131has a relatively short half-life (8 days) and will therefore naturally decay over a short time frame. If radioactive iodine is breathed in or swallowed, it will concentrate in the thyroid gland and increase the risk of thyroid cancer. The uptake of radioactive iodine into the thyroid gland can be decreased or prevented by ingestion of non-radioactive iodine, by taking potassium iodide pills. Once the thyroid is saturated with iodine, no further iodine can be incorporated. Iodized table salt should not be used as an alternative to potassium iodide pills as it does not contain sufficient iodine to saturate the thyroid, and high salt intake may have adverse health effects.

Radioactive caesium (Cs-134 and Cs-137), in contrast to radioactive iodine, has a long half-life (Cs-134: 2 years, Cs-137: 30 years). Radioactive caesium can stay in the environment for many years and could continue to present a longer term problem for food, and food production, and a threat to human health. If caesium-137 enters the body, it is distributed fairly uniformly throughout the body's soft tissues, resulting in exposure of those tissues. Compared to some other radionuclides, caesium-137 remains in the body for a relatively short time. Like all radionuclides, exposure to radiation from caesium-137 results in an increased risk of cancer.

Other radionuclides could be of concern, depending on the nature of the nuclear accident and release of specific isotopes.

4. International standards and guidance

The Codex Guideline Levels

The Codex Alimentarius Commission (Joint FAO/WHO Food Standards Programme) has developed the guideline levels for certain radionuclides in food following a nuclear emergency (General Standard for Contaminants and Toxins in Food and Feed (GSCTFF), CODEX STAN 193-1995, page 33-37). The Guideline Levels have been first developed in 1988 and then revised in 2006 to increase the number of radionuclides covered. These Guideline Levels are applied to foods destined for human consumption and traded internationally, which have been contaminated following a nuclear or radiological emergency. If radionuclide levels in food do not exceed the corresponding guidelines levels, the food should be considered as safe for human consumption as far as generic radiological protection of food consumers is concerned.

The following text is from the GSCTFF and provides the proper context:

Scope: The Guideline Levels apply to radionuclides contained in foods destined for human consumption and traded internationally, which have been contaminated following a nuclear or radiological emergency[1]. These guideline levels apply to food after reconstitution or as prepared for consumption, i.e., not to dried or concentrated foods, and are based on an intervention exemption level of 1 mSv in a year.

Application: As far as generic radiological protection of food consumers is concerned, when radionuclide levels in food do not exceed the corresponding Guideline Levels, the food should be considered as safe for human consumption. When the Guideline Levels are exceeded, national governments shall decide whether and under what circumstances the food should be distributed within their territory or jurisdiction. National governments may wish to adopt different values for internal use within their own territories where the assumptions concerning food distribution that have been made to derive the Guideline Levels may not apply, e.g., in the case of wide-spread radioactive contamination. For foods that are consumed in small quantities, such as spices, that represent a small percentage of total diet and hence a small addition to the total dose, the Guideline Levels may be increased by a factor of 10.

Radionuclides: The Guideline Levels do not include all radionuclides. Radionuclides included are those important for uptake into the food chain; are usually contained in nuclear installations or used as a radiation source in large enough quantities to be significant potential contributors to levels in foods, and; could be accidentally released into the environment from typical installations or might be employed in malevolent actions. Radionuclides of natural origin are generally excluded from consideration in this document.

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[1] For the purposes of this document, the term “emergency” includes both accidents and malevolent actions.

General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193, page 33-37) is available in English at: http://www.codexalimentarius.net/download/standards/17/CXS_193e.pdf

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture provides advice on immediate actions to prevent and mitigate the radioactive contamination of agricultural foodstuffs when a nuclear emergency occurs in or affect your area. You will find the advice, counter measures, glossary and other relevant information at:
http://www-naweb.iaea.org/nafa/emergency/index.html

5. Analytical methods and Laboratories

Routine monitoring of the food supply is undertaken by several national authorities. For example the US FDA has published a method for the determination of Gamma-Ray Emitting Radionuclides in Foods by High-Purity Germanium Spectrometry
http://www.fda.gov/downloads/ScienceResearch/FieldScience/UCM248262.doc

After a nuclear accident monitoring the agricultural, forestry and fisheries environment and restriction of the movement and export of possibly contaminated products is an important factor. However, an implementation of such monitoring can be complex, expensive and technically demanding and require certain training and quality assurance of laboratory performance in advance.

IAEA (International Atomic Energy Agency) has established and coordinates a world-wide network of the analytical laboratories called "ALMERA network (Analytical Laboratories for the Measurement of Environmental Radioactivity)". Those laboratories in the ALMERA network would be expected to provide reliable and timely analysis of environmental samples including food in the event of an accidental or intentional release of radioactivity. ALMERA currently (April 2010) consists of 122 laboratories representing 77 countries.

- The website of ALMERA Network: http://www-naweb.iaea.org/naml/page.php?page=2244
- A full listing of the current ALMERA member laboratories can be found in the ALMERA Newsletter: http://www-pub.iaea.org/MTCD/publications/newsletter.asp?id=146
- Generic procedures for monitoring in a nuclear or radiological emergency (IAEA, 1999): http://www-pub.iaea.org/MTCD/publications/PDF/te_1092_web.pdf (File size: 28MB)
- Programmes and systems for source and environmental radiation monitoring (IAEA Safety Reports Series No.64, 2010): http://www-pub.iaea.org/MTCD/publications/PDF/Pub1427_web.pdf

6. Useful links and references

Links

FAO
Agriculture and Consumer Protection Department (Joint division for nuclear techniques)
http://www.fao.org/ag/portal/age-index/en/
http://www.fao.org/crisis/japan/en/

WHO
http://www.who.int/hac/crises/jpn/en/index.html

Canada

- Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency (Health Canada, 2000) : http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/emergency-urgence/index-eng.php

European Commission

- Maximum level of radioactive contamination in foodstuffs: http://europa.eu/legislation_summaries/food_safety/contamination_environmental_factors/l21109_en.htm

USA

- Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA, 1998): http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM094513.pdf
- Supporting Document for Guidance Levels for Radionuclides in Domestic and Imported Foods (FDA, 2004): http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/Radionuclides/UCM078341

References

- Radioactive fallout in soils, crops and food (FAO, 1989) http://www.fao.org/docrep/T0228E/T0228E00.htm

- Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear accident or a Radiation Emergency (ICPR Publication 111, 2008)

- Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency (IAEA Safety Standards Series No. GSG-2, 2011): http://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf

- Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments (IAEA Technical Reports Series No.472, 2010): http://www-pub.iaea.org/MTCD/publications/PDF/trs472_web.pdf

- Measurement of Radionuclides in Food and the Environment A Guidebook, Technical Reports Series No. 295 (IAEA Technical Reports Series No. 295, 1989), Hard copy only.

- Quantification of Radionuclide Transfer in terrestrial and Freshwater Environments for Radiological Assessments (IAEA TECDOC Series No.1616, 2009). http://www-pub.iaea.org/MTCD/publications/PDF/te_1616_web.pdf