German Society for Radiation Protection
(Gesellschaft für Strahlenschutz e.V.)

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Recommendations to Minimize Radiation Risk by Internal Exposure in Japan

The German Society for Radiation Protection (Gesellschaft für Strahlenschutz) and the information service Strahlentelex have considered the necessity to limit radiation risk originating from intake of radionuclides with food in Japan after the nuclear disaster at Fukushima NPP. Based on experiences after the Chernobyl disaster we did the calculations given below and give the following recommendations:

1. Because of the current high load of radio-Iodine Japanese people should refrain from eating salad, leafy vegetables and edible wild herbs for the time being.

2. The basis for estimates of health effects being uncertain, we must recommend that no food with a concentration of more than 4 Becquerel of the leading radionuclide Cesium-137 per kilogram shall be given to infants, children and adolescents.
Grown-ups are recommended to eat no food over 8 Becquerel per kilogram of the leading nuclide Cesium-137.

3. Japanese citizens action groups and Japanese foundations should consider establishing independent measuring stations to control food in Japan for radionuclides and to publish the results measured. Europe and the USA should consider the best way to support such initiatives in Japan.

Considerations and Calculations

The calculations given below are based on the valid German Radiation Protection Ordinance.

In the long run ingestion of radionuclides via food is the most important path of radiation exposure after a nuclear disaster. The organ dose for the thyroid gland after intake of just 100 grams of spinach with a load of 54 000 Becquerel Iodine-131 per kilogram, as it was found in Japan recently, amounts to[1]

20 milliSievert thyroid gland dose for an infant (up to 1 year of age)[2]
19.4 milliSievert thyroid gland dose for a young child (1 to 2 years of age)[3]
11.3 milliSievert thyroid gland dose for a child from 2 to 7 years of age[4]
5.4 milliSievert thyroid gland dose for a child from 7 to 12 years of age[5]
3.7 milliSievert thyroid gland dose for an adolescent from 12 to 17 years[6]
2.3 milliSievert thyroid gland dose for a grown-up (older than 17 years)[7]

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[1] Amount of intake in kg x radioactivity concentration in Bq/kg x dose coefficient according to German Federal Ministry of Environment Directive of July 23, 2001, in Sv/Bq = dose in Sv; 1 Sv = 1000 milliSievert. E-6, for example, is a bureaucratic way of writing the correct mathematical term of 10^{-6} = 0.000 001
[2] 0.1 kg x 54 000 Bq/kg x 3.7 E-6 Sv/Bq = 20 milliSievert
[3] 0.1 kg x 54 000 Bq/kg x 3.6 E-6 Sv/Bq = 19.4 milliSievert
[4] 0.1 kg x 54 000 Bq/kg x 2.1 E-6 Sv/Bq = 11.3 milliSievert
[5] 0.1 kg x 54 000 Bq/kg x 1.0 E-6 Sv/Bq = 5.4 milliSievert
[6] 0.1 kg x 54 000 Bq/kg x 6.8 E-7 Sv/Bq = 3.7 milliSievert
[7] 0.1 kg x 54 000 Bq/kg x 4.3 E-7 Sv/Bq = 2.3 milliSievert

According to the German Radiation Protection Ordinance of 2001, § 47, an organ dose limit for the thyroid gland of 0.9 milliSievert per year is allowable under conditions of normal operations of nuclear facilities. To eat only 100 grams of this highly contaminated spinach from Japan will exceed this limit by several times. Under conditions of a nuclear emergency an organ dose to the thyroid gland of 150 milliSievert is considered allowable according to § 49 of the German ordinance. This corresponds to a so-called effective dose of 7.5 milliSievert.[8]

For this reason we recommend that people in Japan refrain from eating salads, leafy vegetables and edible wild herbs for the time being.

Iodine-131 has a half-life of 8.06 days. After the nuclear facilities at Fukushima have burnt themselves out and stopped emitting radioactivity into the environment, 7 half-lives or a little less than 2 months will have to pass, before Iodine-131 has reduced to less than 1% of the original amount. In other words, of 54 000 Becquerel there will remain about 422 Becquerel after about 57 days, and only after 16 half-lives or 129 days the original amount will have dwindled to less than 1 Becquerel.

Radionuclides with a longer half-life

Of particular interest in the long run are radionuclides with longer half-lives, such as Cesium-134 with a half-life of 2.06 years, Cesium-137 with a half-life of 30.2 years, Strontium-90 with a half-life of 28.9 years and Plutonium-239 with a half-life of 24 400 years.
Usually, the radionuclide inventory of fuel rods after 2 years of burning is in the following proportions:
Cesium-137 : Cesium-134 : Strontium-90 : Plutonium-239 = 100 : 25 : 75 : 0.5.
The Chernobyl fallout, however, was characterized by 2 parts of Cesium-137 for 1 part of Cesium-134. From measurements published so far in Japan, the parts of Cesium-137 and Cesium-134 in the fallout are roughly the same. The parts of Strontium-90 and Plutonium-239 remain to be ascertained, since a sufficient number measurement results may take some time. The MOX-fuel of Fukushima Dai-ichi will contain more Plutonium, but presumably not all of it will be blown out into the environment. In past nuclear disasters Strontium fell down with the fall-out earlier, and therefore is found in lesser concentrations at farther distances from the disaster site. The following calculation presupposes a proportion of
Cesium-137 : Caesium 134 : Strontium-90 : Plutonium-239 = 100 : 100 : 50 : 0,5 in Japan.
Taking into account the average yearly rates of consumption given in Annex VII, Table 1 of the German Radiation Protection Ordinance of 2001, consumption of food and drink with an unchanging contamination of 100 Bq Cesium-137(Cs-137), 100 Bq of Cesium-134 (Cs-134), 50 Bq Strontium-90 (Sr-90) and 0,5 Bq Plutonium (Pu-239) per kilogram will lead to the following effective doses per year:

6 milliSievert effective dose per year for an infant (up to 1 year of age)[9]
2.8 milliSievert effective dose per year for a small child of 1 or 2 years of age[10]
2.6 milliSievert/year effective dose for a child of 2 to 7 years of age[11]

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[8] According to the German Radiation Protection Ordinance, Annex VI, Part C 2, the thyroid gland is given a weight of only 5% for the reason, that cancer of the thyroid gland is alledged to be easily operable.
[9] 325.5 kg/year x [100 Bq/kg x (2.1E-8 Sv/Bq Cs-137 + 2.6 E-8 Sv/Bq Cs-134) + 50 Bq/kg x 2.3 E-7 Sv/Bq Sr-90 + 0.5 Bq/kg x 4.2 E-6 Sv/Bq Pu-239] = 6 milliSievert/year.
[10] 414 kg/year x [100 Bq/kg x (1.2 E-8 Sv/Bq Cs-137 + 1.6 E-8 Cs-134) + 50 Bq/kg x 7.3 E-8 Sv/Bq Sr-90 +0.5 Bq/kg x 4.2 E-7 Pu-239] = 2.8 milliSievert/year

3.6 milliSievert/year effective dose for a child of 7 to 12 years of age[12]
5.3 milliSievert/year effective dose for an adolescent of 12 to 17 years[13]
3.9 milliSievert/year effective dose for a grown-up older than 17 years[14]

According to § 47 of the valid German radiation protection ordinance, under normal operating conditions of nuclear facilities individual persons may be exposed to a contamination of 0.3 milliSievert per year by emissions of these facilities into the air or the water. This limit is transgressed when you have to consume food and drink with a load of 100 Becquerel per kilogram of the leading radionuclide Cesium-137 exclusively. Therefore, to abide by the limit of 0.3 milliSievert per year the limits for the intake of food and drink must be lowered accordingly. That means a maximum of:

5.0 Becquerel Cesium-137 per kilogram for infants up to 1 year
10.7 Becquerel Cesium-137 per kilogram for small children of 1 to 2 years of age
11.5 Becquerel Cesium-137 per kilogram for children of 2 to 7 years of age
8.3 Becquerel Cesium-137 per kilogram for children of 7 to 12 years of age
5.7 Becquerel Cesium-137 per kilogram for adolescents of 12 to 17 years
7.7 Becquerel Cesium-137 per kilogram for grown-ups

Given several uncertainties in the data basis for risk assessment we must recommend that infants, children and adolescents be given no food or beverages with a contamination of more than 4 Becquerel of the leading radionuclide Cesium-137 per kilogram.
We recommend that grown-ups refrain from consuming food and beverages with a contamination of more than 8 Becquerel per kilogram of the leading radionuclide Cesium-137.

If 100 000 people are each exposed to such a dose of 0.3 milliSievert per year, the International Commission on Radiation Protection (ICRP) calculates, that approximately 1 or 2 of them will die of cancer later on, in addition to cancer deaths by other causes. Independent evaluations of the data of Hiroshima and Nagasaki question the ICRP's assessment[15], and prove that the figure may be higher by 10 times, that is about 15 later cancer deaths per year for 100 000 persons exposed to a dose of 0.3 milliSievert per year. If the dose is higher, cancer mortality may rise proportionately.

By convention, these calculations take into account only deaths by cancer. Non-fatal cancers as well as other diseases, the number and severity of which is increased by irradiation, are not considered in this modelling of risk.

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[11] 540 kg/year x [100 Bq/kg x (9.6 E-9 Sv/Bq Cs-137 + 1.3 E-8 Sv/Bq Cs 134) + 50 Bq/kg x 4.7 E-8 Sv/Bq Sr-90 + 0.5 Bq/kg x 3.3 E-7 Sv/Bq Pu-239] = 2.6 milliSievert/year
[12] 648.5 kg/year x [100 Bq/kg x (1.0 E-8 Sv/Bq Cs-137 + 1.4 E-8 Sv/Bq Cs-134) + 50 Bq/kg x 6.0 E-8 Sv/Bq Sr-90 + 0.5 Bq/kg x 2.7 E-7 Sv/Bq Pu-239] = 3.6 milliSievert/year
[13] 726 kg/year x [100 Bq/kg (1.3 E-8 Sv/Bq Cs-137 + 1.9 E-8 Sv/Bq Cs-134) + 50 Bq/kg x 8.0 E-8 Sv/Bq Sr-90 + 0.5 Bq/kg x 2.4 E-7 Sv/Bq Pu-239] = 5.3 milliSievert/year
[14] 830.5 kg/year x [100 Bq/kg x (1.3 E-8 Sv/Bq Cs-137 + 1.9 E-8 Sv/Bq Cs-134) + 50 Bq/kg x 2.8 E-8 Sv/Bq Sr-90 + 0.5 Bq/kg x 2.5 E-7 Sv/Bq Pu-239] = 3.9 milliSievert/year
[15] Nussbaum RH, Belsey E, Köhnlein W: Recent Mortality Statistics for Distally Exposed A-Bomb Survivors: The Lifetime Cancer Risk for Exposure under 50 cGy (rad). Medicina Nuclearis 1990. 2,151-162.