Calculated Fatalities from Radiation

Officially Permissible Limits for Radioactively Contaminated Food in the European Union and Japan

A foodwatch Report,
based on a study by Thomas Dersee and Sebastian Pflugbeil
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In cooperation with the German Section of the International Physicians for the Prevention of Nuclear War (IPPNW)

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Foreword

Radioactivity is still escaping from the reactors in Fukushima – posing a significant threat to humans and the environment. Even though reliable information on the extent of radioactive contamination is not available, one thing is certain: the people of Japan will have to deal with contamination – in food – for decades.

The dietary intake of radionuclides such as cesium-137 after nuclear disasters like the meltdowns at Fukushima and Chernobyl represents the highest danger to human health in the long term. Officially permissible limits on the content of radionuclides in food, set with the intention of protecting the population from exposure to radiation, therefore play a very prominent role.

The nuclear disaster at Fukushima again raised the question – as did the reactor meltdown at Chernobyl – of how much protection can be guaranteed to citizens when currently permissible limits are in effect. To answer this question, foodwatch commissioned Thomas Dersee and Sebastian Pflugbeil of the German Society for Radiation Protection to compile the study found in this report.

The report is published in cooperation with the German Section of the International Physicians for the Prevention of Nuclear War (IPPNW). It includes not only the professional opinion written by Thomas Dersee and Dr Sebastian Pflugbeil of the German Society for Radiation Protection, which provides the scientific basis, but also a summary and the conclusions drawn by the organizations collaborating on this work.

The report documents that there are no ‘safe’ limits for radioactivity and that determining any permissible value limits is equivalent to making a calculated decision on the number of fatalities that can be expected from a given level of radiation exposure. With this in mind, the study concludes that current limits in Europe and Japan are irresponsibly high and consciously tolerate thousands of deaths. Even if only 5 percent of currently permissible limits on radioactive contamination were consumed in food, Germany, for example, could expect at least 7,700 of its population to die each year from the effects of radiation. This does not even take into account the secondary health consequences of chronic diseases of the thyroid and pancreas, for example.

The intention of this report is to open public debate on the existing European Union system governing the determination of permissible limits and its implications, and to counteract the ideology widely used by governments and the nuclear industry that people can be safe if allegedly scientifically established limits are set.

We at foodwatch and the German Section of the International Physicians for the Prevention of Nuclear War (IPPNW) call for a drastic reduction in current EU value limits to significantly improve health protection for the population, knowing full well that allowing any permissible limits at all means that a certain number of people will be the victims of radiation. The Japanese government is also urged to substantially lower its current value limits.

foodwatch e.V. and the German Section of the International Physicians for the Prevention of Nuclear War (IPPNW)

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Observations – and what must happen next

Permissible limits in the European Union and Japan do not protect the population and tolerate a high number of fatalities from radiation

- The dietary intake of radionuclides such as cesium-137 after a nuclear disaster poses the highest danger to human health in the long term. Officially permissible limits on the content of radionuclides in food, established with the intention of protecting the population from radiation risks, therefore play a very prominent role.

- The permissible limits currently set in the EU and Japan for radiation protection mean that the population is exposed to an unnecessarily high risk to health. If we assume that the population of Germany were to ingest food containing the current maximum limits of contamination permitted in the EU – equivalent to the limits applying to imports from Japan – children and adolescents would each be exposed to an annual effective dose of 68 millisieverts (mSv) and adults of 33 mSv. The German radiation protection legislation that governs the operation of nuclear power plants stipulates that the legally permissible limit of total exposure from all exposure pathways is 1 mSv per year for individuals. This means that if children and adolescents ingested the amount of radioactive contamination permitted by EU and Japanese regulations, they would be exposed to 68 times the German limit. Even if only 2 percent of the dietary intake were contaminated to permissible EU and Japanese limits, the annual effective dose would already be over the German limit of 1 mSv.

- Calculations based on models used by the International Commission on Radiological Protection (ICRP) show that dietary intake of the maximum amount of radioactive contamination permitted in the EU and Japan would lead to at least roughly 150,000 fatalities in Germany each year. Other calculation models reach vastly higher figures. If the entire German population were to eat foods exposing individuals to only 5 percent of the contamination currently allowed in food imports from Japan, at least 7,700 fatalities could be expected; this figure doesn’t even include the secondary consequences of a wide range of greatly varying diseases and genetic disorders.

- Other countries have to some extent set much stricter limits and thereby done more to protect human health. Even the limits in Ukraine and Belarus are much stricter and have continuously tightened over the last few years. The permissible limit for cesium-137 in milk products in Ukraine and Belarus is 100 becquerels per kilogram (Bq/kg), whereas this value stands at 370 Bq/kg in the EU and 200 Bq/kg in Japan.

Current permissible limits are contradictory and opaque

- After the nuclear disaster at Fukushima in Japan, the EU Commission put into effect parts of an already existing regulation that had been prepared in 1987 in response to the Chernobyl disaster but never used. This regulation allowed the maximum permissible limits for contamination in food imports from Japan to the EU to be much higher and less strict than the limits in effect before the Fukushima disaster happened, and was even less stringent than the limits set in Japan itself. The Commission later revised its decision and reduced the permissible contamination limits for imports from Japan.

- But contradictions in the EU’s system governing permissible limits have not been eliminated. Products from countries other than Japan, which may be more highly contaminated than the same products from Japan, can still be marketed because they are not affected by the specific regulations which the EU has adopted for Japanese imports. By the same token, products from Japan no longer allowed for direct import into the EU may still be sold in Europe if they detour first through another country.

Current maximum permissible limits are dictated by commercial interests

- The excessively high radiation protection limits in the European Union and Japan are due to the fact that EURATOM and the International Commission on Radiological Protection (ICRP), which exert influence on the setting of maximum limits, are dominated by the nuclear industry and radiologists. The World Health Organization (WHO) made an agreement with the International Atomic Energy Agency (IAEA), now valid for more than 50 years, in which it relinquished jurisdiction to the IAEA for defining the health damage caused by radiation. The declared aim of the IAEA is the expansion and promotion of nuclear energy. Consequently, the assessment of health damage caused by the Chernobyl disaster was done by the IAEA, not WHO. Even in the case of Fukushima, WHO has not taken a leading role in assessing risks to health or preventing them.

Current maximum limits conflict with European law and international principles

- Environmental protection is anchored in the Treaty on the Functioning of the European Union (TFEU) and based explicitly on the precautionary principle (Article 191). This prescribes preventive action when human health is threatened. However, currently permissible limits are unnecessarily high due to economic interests and stand in conflict with the concept of protecting human health through preventive measures.

- Current limits contradict the principle of radiation minimization set out at an early stage by the International Commission on Radiological Protection; this principle has gained international acceptance and can be seen as central to legislation on radiation protection in Germany (§6 of the German Radiation Protection Ordinance). The minimization principle implies that all unnecessary exposure to radiation should be avoided.

There are no safe permissible limits

- People are exposed to a certain level of radiation in the normal course of life. We can’t elude cosmic and terrestrial radiation, the radiation inside our bodies from potassium-40, or the radon gas from the uranium decay series and its decay products. An adult in Germany is exposed on average to 2.1 millisieverts (mSv) per year from these sources. The use of radiation in medical diagnostics raises average exposure by another 1.8 mSv per year.

- Added to this is exposure to radiation from artificial, human activities such as the atmospheric nuclear bomb tests of the last century and the operation of nuclear power plants. Radionuclides such as the cesium-137 found in foods do not occur naturally. They are artificial products from nuclear reactors. Large quantities of them were released after the nuclear accidents at Chernobyl and Fukushima and have an additional effect on people.

- Setting official maximum levels of radionuclides to be tolerated in food is supposed to protect the population from danger. But, in contrast to chemical toxins, there is no threshold below which radioactivity is harmless. Thus there is also no dose of radiation, no matter how small, that is harmless, benign or unobjectionable. The authority (government or international organization) that recommends or sets standards, or maximum permissible value limits, basically decides on how many fatalities or cases of illness will be acceptable in a given situation.

- Consequently, there are no ‘safe’ limits, even if the German government stresses that maximum permissible levels accommodate “the basic principle of radiation protection to minimize exposure to radioactive contamination as far as possible.”[1] Even the lowest

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[1] German Bundestag, Printed Matter 17/5720, response of the German government to the minor interpellation put by Members of Bundestag Ulrike Höfken, Nicole Maisch, Bärbel Höhn, other members of

levels of radionuclides in food can lead to illness and death. The meaningless choice of words, “to minimize as far as possible,” accurately describes the attitude of authorities: the principle of radiation minimization is cancelled out through the practice of establishing permissible limits.

Stricter limits are needed to protect the population

Regulations for dealing with contaminated food must have as their first priority the health of the population. Given that the acceptance of any permissible radiation limits consciously tolerates illness and fatality, the protection of health must not be compromised by trade or commercial interests. A significant reduction in current limits is needed to reduce the risk of health problems.

- To derive limits that can be used as a standard to achieve this reduction, our calculations are based on a person being exposed to a maximum annual effective radiation dose of 0.3 millisieverts (mSv). This is the maximum exposure limit set out in Germany’s radiation protection legislation for normal operations in nuclear power plants; the figure applies to the exposure pathways of air and water. Therefore, the limits discussed here are designed to ensure that an effective annual dose of 0.3 mSv is not exceeded in dietary intake – under the assumption that the composition of radionuclides is the same as in fallout from Fukushima. Permitting higher effective annual doses from the consumption of food would result in a higher number of victims. This is avoidable. This means that current EU value limits must be reduced to 8 becquerels per kilogram of total cesium for baby food and 16 becquerels per kilogram of total cesium for all other foods.

  The maximum permissible limits for baby food and milk products presently stand at 370 becquerels total cesium (200 becquerels for imports from Japan), and 600 becquerels for other foods (500 becquerels for imports from Japan).[2]

- In terms of the precautionary principle, exposure to iodine-131 in food must be deemed completely unacceptable, given the isotope’s relatively short half-life of approximately 8 days. Within the period when iodine-131 decays, people should not be expected to eat food contaminated with this isotope. Many foods can be stored (or frozen) until the iodine-131 isotope has decayed and the foods have become suitable for consumption, unless they are contaminated by other radionuclides.

- Current limits in Japan do not guarantee enough health protection either. We urge the Japanese government to drastically lower permissible limits to ensure acceptable health protection.

- But fatalities must still be taken into account even when lower limits are enforced. If the setting of lower limits ensured that people in Germany were exposed to an effective annual dose of no more than 0.3 mSv from foodstuffs, there would still be at least 1,200 additional fatalities each year from radiation exposure. Indeed, even if people consumed

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the Bundestag and the parliamentary group of the Alliance 90/The Greens party – Printed Matter 17/5596 – Radioactively contaminated foods from Japan.

[2] This corresponds to limits of 4 or 8 becquerels when using cesium-137 as the indicator nuclide. The authors of the study in this report used indicator nuclide cesium-137 as a measurand for radiation exposure (please see a more detailed explanation in the study) because they believe that using ‘total cesium’ as a measurand exhibits weaknesses. For example, if ‘total cesium’ is used as the measurand, the degree of exposure from strontium increases – with consequences for health – because cesium-134 decays more rapidly over time. Apart from that, the division of food into ‘baby food’ and ‘food for children and adults’ is not accurate enough. Children and teenagers up to the age of 17 are much more sensitive to doses of radiation than adults are, and therefore need special protection. However, since ‘total cesium’ is used as a measurand in the EU’s limit system, the report, for practical reasons, calls for reducing ‘total cesium’ to allow comparability with current limits.

food containing only 5 percent of this dose, we could still expect at least 60 persons to die each year from radiation exposure. This would nevertheless represent a dramatic improvement in protecting the health of the population. The inevitability of people falling victim to radiation, regardless of the limits set, should be reason enough to question the continuing operation or new construction of nuclear facilities.

A uniform limit system that applies equally to normal and emergency situations

- Apart from the need to reduce limits to a level that ensures acceptable health protection, there must be an end to the chaos in the EU regarding official limits. There cannot be several systems side by side that govern different permissible limits in different countries. Furthermore, permissible values for the normal situation cannot be different from those in place for an emergency situation. Identical limits for all situations must ensure the best possible health protection for the population.

1. Summary

1. The absorption of radionuclides through food is the most important long term source of contamination after a nuclear catastrophe. Following the reactor catastrophe in Fukushima, the EU Commission put into effect new higher permissible limits for food imported from Japan; these value limits were predominantly higher than the limits allowed in Japan itself. The EU thus needlessly permitted the import of radioactively contaminated foodstuffs that would not have been authorized for consumption in Japan. After this became known, the value limits were “provisionally” brought into line with those in Japan. Furthermore, the EU limits are up to five hundred times higher than those that have been in effect for years in Ukraine and Belarus since the Chernobyl reactor meltdown.

2. When such value limits are set, a decision is made about the number of people that can be expected to fall victim to radiation exposure in the European and Japanese populations. According to Paragraph 47 of the German Radiation Protection Ordinance, a value limit of 0.3 millisieverts (mSv) of radiation exposure per individual per year is in effect regarding the “discharge of radioactive substances through air or water” in normally operating nuclear facilities. Exclusive consumption of solid food and beverages that are contaminated with radionuclides at the levels permitted by current EU value limits exceeds the limit of 0.3 mSv many times over, up to 276 times for children and 110 times for adults.

3. The EU limits, permitting a possible exposure of about 80 millisieverts per child per year, accept that about 400 to 4000 out of 100,000 children would later die each year from cancer due to this exposure. For adults, exposed to a permitted 33 millisieverts each year, additional cancers each year would lead to fatalities of 165 to 1650 out of 100,000.

4. By setting such value limits for foodstuffs, the Japanese government and the governments of the European states are demanding human sacrifice from their populations. That said, it is important to note here that according to the currently valid dose concept (effective dose), only cancer fatalities have been taken into account, not the number of illnesses – a higher figure. After the Chernobyl reactor catastrophe, not only were many people afflicted with cancer, but there was also a sharp increase in other somatic illnesses such as a weakening of the immune system, premature aging, cardiovascular disease even in younger patients, chronic diseases of the stomach, the thyroid gland and the pancreas (diabetes mellitus), as well as in neurological-psychiatric disorders and genetic or teratogenic disorders as a result of low-level doses of radiation. These are ignored by governments.

2. Health risks due to the consumption of radioactively contaminated foodstuffs

2.1. There are no safe value limits

In general, there is no limit below which radioactivity can cause no damage. This has been accepted scientific doctrine for decades. In its defined rules for the calculation of radiation doses, the German Radiation Protection Ordinance delineates dose-effect relationships down to the smallest dose of radiation, thus taking this fact for granted.[3] Even the smallest doses of radiation are not ‘harmless’, ‘benign’ or ‘unobjectionable’.

Radiation dose data expressed in sieverts (Sv) are a measure of the harmful potential of radiation exposure and serve to calculate radiation damage. In setting limits or maximum levels, officials are determining the number of ill and dead – of human sacrifices – that seem acceptable to them. In contrast to chemical toxins, the level of radiation exposure in the case of small doses of radiation (up to several tens of millisieverts) says nothing about the possible severity of the illnesses that develop as a result, but only something about the possible number of people who will become sick within an exposed group. The so-called effective dose only takes fatalities into account. The number of people suffering from illness is higher, since not everyone dies. Those who get cancer develop the illness in its full form. Yet, who is affected appears to be random. One speaks therefore of stochastic radiation damage, in contrast to deterministic damage, which occurs with higher doses of radiation where their level determines the expression of the acute radiation sickness. When it is said that there is “no acute danger,” this means simply that there is no acute danger of radiation sickness. An elevated risk for stochastic radiation damage may nonetheless exist (cancer, leukemia, and so forth). “No acute danger” therefore means anything but “all clear.”

The minimization principle means that as little radioactivity as possible should be absorbed. Adherence to the permissible value limits set by the EU does not guarantee health safety.

In the wake of Chernobyl, independent experts therefore recommended food with at most 30 to 50 becquerels total cesium activity per kilogram for adults and at most 10 to 20 becquerels per kilogram for children and nursing and pregnant women, based on the regulations of the German Radiation Protection Ordinance of 1976, which was then in force. A 50 percent share of cesium-134 and a 1 percent share of strontium-90 were assumed, based on the activity content of cesium-137 in foodstuffs, and plutonium was not taken into account. However, the actual amount of strontium in food was higher, as measurements taken by the Strahlenmessstelle [radiation measuring station] in Berlin revealed after Chernobyl. Therefore, and also because of uncertainty regarding the basis for evaluation, it was usually recommended that a maximum of only 5 becquerels of total cesium activity per kilogram should be in children’s dietary intake.[4]

The results of analyses from Japan published so far show that the distribution of radionuclides from fallout in foodstuffs appears to be different from that in Germany after Chernobyl; because of the higher percentage of short-lived cesium-134 it is more damaging. This too makes a new risk assessment necessary.

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[3] Ordinance for the implementation of EURATOM Directives on Radiation Protection (Radiation Protection Ordinance – StrlSchV) from 20 July 2001 (BGBl. I, p. 1714), reported on 22 April 2002 (BGBl. I, p. 1459), amended by Art. 3 of the law from 13 December 2007 (BGBl. I, p. 2930), last amended by Art. 2 of the law from 26 August 2008 (BGBl. I, p. 1793).

[4] *Strahlentelex* 11/1987, 18 June 1987.

2.2. Overview of important radionuclides

The absorption of radionuclides through foodstuffs is in the long term the most significant source of contamination after a nuclear disaster. Therefore, especially those radionuclides with longer half-lives must be observed, yet not all are sufficiently taken into consideration. Cesium-137 and cesium-134 are particularly easy to identify because of the percentage of gamma rays they emit during radioactive decay, and are therefore used as so-called lead nuclides or indicator nuclides, which signal radioactive contamination. For physiological reasons, it is also necessary to pay special attention to strontium-90, as well as to iodine-131, which has a relatively short half-life, but is nonetheless disseminated in high concentrations at the beginning. Lastly, with its especially long half-life, plutonium is particularly radiotoxic.

Radioactive iodine

Iodine is an essential trace element found in practically all living creatures. It is necessary for the maintenance of cell functions and for the production of thyroid hormones. Iodine-131, released in a reactor meltdown, takes the place of natural iodine in organisms and is stored in high concentrations in the thyroid. A steep increase in thyroid function disorders and an especially aggressive form of thyroid cancer, in both children and adults, were therefore the first particularly noticeable effects of radioactive contamination after the Chernobyl catastrophe.[5]

Radiocesium

Since the beginning of atmospheric testing of nuclear weapons, radioactive cesium-137 has been detected in all living creatures. In 1959 and 1964, concentration peaks in mammals were found at levels up to eight times higher than cesium-137 values in 1962. It was shown that nearly 100 percent of the radioactivity absorbed by the body came from food, and the quantitative proportion of cesium to chemically similar potassium was on average double the corresponding quantitative proportion in food. Despite having a biological half-life of only about 100 days in the human body, radiocesium does accumulate to a certain extent. Muscle cells in particular prefer cesium to potassium. In metabliolic equilibrium, muscles exhibit the highest cesium radioactivity, followed by the liver, heart, spleen, reproductive organs, lungs and brain.[6]

Strontium

Strontium-90 is a pure beta emitter and therefore has a radiotoxic effect in the body only after absorption (through food). Strontium-90 is chemically similar to calcium and thus replaces it, becoming incorporated into bone tissue. From there, it contaminates the organ responsible for producing blood, the red bone marrow. Due to its long biological half-life (many months to several years), strontium – in contrast to radiocesium – gradually accumulates more, building up a considerable potential for danger, even if food contains only scant verifiable traces. Its high radiotoxicity is reflected in high official dose factors, set about 10 times higher than those for radiocesium, although their decay energy is the same. The high-energy particle radiation of strontium-90 during decay contaminates the red bone marrow in particular. The results can be disorders of blood production and immune system as well as leukemia.[3,7]

Plutonium

Plutonium is one of the most dangerous substances produced by human beings – both in respect to its radioactive toxicity and its use in the manufacture of nuclear weapons. The radioactive toxicity of plutonium outweighs by far its chemical toxicity, which is comparable to that of other heavy metals. If inhaled, there is a high probability that reactor plutonium will cause lung cancer.

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[5] E. Lengfelder, E. Demidschik, J. Demidschik, K. Becker, H. Rabes and L. Birukowa, “10 Jahre nach der Tschernobyl-Katastrophe: Schilddrüsenkrebs und andere Folgen für die Gesundheit in der GUS” [10 Years After the Chernobyl Disaster: Thyroid Cancer and Other Consequences on Health in the C.I.S.], *Münchener Medizinische Wochenschrift* 138 (15), 1996, pp. 259-264.

[6] Jacqueline Burkhardt, Erich Wirth, Bundesgesundheitsamt, Institut für Strahlenhygiene [German Federal Health Office, Institute for Radiation Hygiene], *ISH-Heft* 95, September 1986; see also *Strahlentelex* 39, 18 August 1988, pp. 2, 5.

[7] Roland Scholz, “Bedrohung des Lebens durch radioaktive Strahlung” [The Threat to Life From Radiation], *IPPNW Studienreihe*, Vol. 4, 1997.

Up to 50 or 60 percent of the mass of reactor plutonium consists of plutonium-239, a good 20 percent of plutonium-240 and about 15 percent of plutonium-241. Plutonium-238 is present only in a magnitude of about 2 percent. However, because of the different half-lives of individual plutonium isotopes, mass ratios do not correspond to activity ratios. In that regard, plutonium-241 leads with about 98 percent, followed by plutonium-238 with about 1.6 percent, plutonium-239 with 0.25 percent and plutonium-240 with 0.32 percent. Alpha disintegrations are especially relevant from a radiological point of view. In its poorly soluble form (for example as plutonium oxide), plutonium-238 is much more quickly redistributed from the lungs into the bones and liver and reaches higher concentrations there than plutonium-239. Nonetheless, the International Committee on Radiological Protection (ICRP) treats all plutonium isotopes the same in its model calculations.[8]

More soluble compounds like plutonium nitrate make their way increasingly into the food chain, since plants absorb them from soil more easily than poorly soluble plutonium compounds. On the other hand, poorly soluble compounds ingested with food are for the most part quickly excreted. Since plutonium is relatively firmly bound in soil, absorption by plants occurs only to a relatively minor extent. Plutonium is therefore absorbed into the body mainly through the inhalation of tiny airborne particles.

Table 1: Half-lives, types of decay and decay products of some selected radionuclides occurring in a nuclear facility[9]

Radionuclide	Half-life	Decay type	Decay products
H-3 (Tritium)	13.32 years	β-	He-3 (stable)
I-131	8.02 days	β-	Xe-131 (stable)
I-134	52.5 minutes	β-	Xe-134 (stable)
Cs-137	30.17 years	β-	Ba-137 (stable)
Cs-134	2.06 years	β-	Ba-134 (stable)
Xe-133	5.25 days	β-	Cs-133 (stable)
Kr-85	10.76 years	β-	Rb-85 (stable)
Sr-90	28.78 years	β-	Y-90 → Zr-90 (stable)
Sr-89	50.53 days	β-	Y-89 (stable)
Te-129m	33,6 days	β-	I-129 → Xe-129 (stable)
Fe-55	2.73 years	ε, γ	Mn-55 (stable)
Pu-238	87.7 years	α	U-234 → Th-230 → etc.
Pu-239	24,110 years	α	U-235 → Th-231→ etc.
Pu-241	14.35 years	β-	Am-241 → etc.
Am-241	432.3 years	α	Np-237 → etc.

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[8] "Verfassungsklage gegen Plutonium-Nutzung" [Complaint of Unconstitutionality Against the Use of Plutonium], *Strahlentelex* 35/1988 (after R. Steinberg, S. de Witt, "Antrag an das Bundesverfassungsgericht in Sachen Dr. H.-J. Vogel et al. 179 Mitglieder des Deutschen Bundestages" [Application to the German Constitutional Court in the Matter of H.-J. Vogel and 179 Members of the German Bundestag], 21 April 1988, Frankfurt a.M./Freiburg, PR. No. 2424.87.T.; H. Kuni, "Die Gefahr von Strahlenschäden durch Plutonium" [The Threat of Radiation Damage From Plutonium], 15 December 1987, Marburg; B. Splieth, "Strahlenbelastung durch Plutonium: Alte und neue Abschätzungsverfahren" [Exposure to Radiation From Plutonium: Old and New Assessment Procedures], *Symposium über die Wirkung niedriger Strahlendosen auf den Menschen* [Symposium on the Effects of Low-level Doses of Radiation on Humans], Univ. Marburg, 27 February 1988).

[9] *Strahlentelex* 590-591, 4 August 2011, p. 4.

2.3. ‘Natural’ radiation and artificial radionuclides

We are unavoidably exposed to a certain amount of radiation. We can hardly escape cosmic and terrestrial radiation, radiation within the body from potassium-40, and radon gas from the uranium decay series and its decay products. Nonetheless, this natural background radiation is not an absolute quantity. For example, we can reduce our exposure to cosmic radiation by flying less frequently. Uranium and its decay products become more dangerous because of human activities such as mining and processing, allowing them to be more easily absorbed with food, air and water. Furthermore, the meaning of the term ‘background radiation’ is not clearly defined. It is standard practice in the United States to attribute radioactive substances released from a nuclear plant to ‘background radiation’ if it still has not subsided after a year.[10]

In Germany, adults are exposed on average to about 2.1 millisieverts of radiation from natural sources each year. The use of radiation in medical diagnosis means that an average dose of about 1.8 millisieverts yearly can be added to this. These are the values which have been given more or less constantly for years in reports on environmental radiation and radioactive exposure published by the Bundesamt für Strahlenschutz [German federal office for radiation protection].

Potassium, for example, is retained in the human body in constant, restricted concentration limits. Only every ten-thousandth potassium atom is the radioactive isotope potassium-40, which decays at a half-life of 1.28 billion years. While potassium is an element vital to natural life, radionuclides such as cesium-137 and cesium-134, in contrast, do not occur in nature. They are generated artificially in nuclear reactors, and after being released during nuclear accidents, they also impact on human beings. Furthermore, fallout from the atmospheric nuclear testing that took place up to the mid-1960s contained about equal amounts of strontium-90 and cesium-137. Before the Chernobyl reactor catastrophe, about 1000 becquerels of cesium-137 per square meter of land surface were present throughout Europe. The fallout from Chernobyl raised these contamination levels, for example in northern Germany and around Berlin, to about 4000 to 5000 and in southern Germany, for example around Munich, to 40,000 or more becquerels of radiocesium per square meter of land.[11]

Plutonium is yet another artificially produced chemical element that rarely occurs in nature. Only in uranium ore do we find traces of plutonium dating back to the early geological history of the planet, present at a ratio of one plutonium atom to one trillion uranium atoms. In the entire crust of the earth, there are only 2 to 3 grams of ancient plutonium. Today, plutonium is produced by the ton, above all for military purposes.

The atmospheric nuclear bomb tests that took place until the mid-1960s distributed an estimated 6 tons of man-made plutonium-239 over the earth’s surface.[12]

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[10] Rosalie Bertell, *Keine akute Gefahr?* [No Immediate Danger: Prognosis for a Radioactive Earth], Goldmann, 1987, p. 39.

[11] Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin [Berlin Senate Office for Urban Development and Environmental Protection] (ed.), “Radioaktivität im Boden (Cäsium-134 und Cäsium-137)” [Radioactivity in Soil (Cesium-134 and Cesium-137)], *Umweltatlas Berlin*, March 1992; E. Lengfelder, “Strahlenwirkung – Strahlenrisiko, Daten, Bewertung und Folgerungen aus ärztlicher Sicht” [Effect of Radiation – Radiation Risks, Data, Assessment, and Consequences From a Physician’s Point of View], maps, *ecomed* 1990.

[12] “Verfassungsklage gegen Plutonium-Nutzung” [Complaint of Unconstitutionality Against the Use of Plutonium], *Strahlentelex* 35/1988 (after R. Steinberg, S. de Witt, “Antrag an das Bundesverfassungsgericht in Sachen Dr. H.-J. Vogel et al. 179 Mitglieder des Deutschen Bundestages” [Application to the German Constitutional Court in the Matter of H.-J. Vogel and 179 Members of the German Bundestag], 21 April 1988, Frankfurt a.M./Freiburg, PR. No. 2424.87.T.; H. Kuni, “Die Gefahr von Strahlenschäden durch Plutonium” [The Threat of Radiation Damage From Plutonium], 15 December 1987, Marburg; B. Splieth, “Strahlenbelastung durch Plutonium: Alte und neue Abschätzungsverfahren” [Exposure to Radiation From Plutonium: Old and New Assessment Procedures], *Symposium über die Wirkung niedriger Strahlendosen auf den Menschen* [Symposium on the Effects of Low-level Doses of Radiation on Humans], Univ. Marburg, 27 February 1988).

3. Current limits that apply to radioactively contaminated food

3.1 The political background to current radioactivity value limits

One legal, long-term consequence of the Chernobyl nuclear disaster was the adoption of the Precautionary Radiation Protection Act in Germany, which came into force early in 1987. Subsequently, all measures to be taken in case of disaster were centralized. Most importantly, the evaluation of data and the determination of new dose limits were put solely into the hands of Germany's Minister for the Environment, Nature Conservation and Nuclear Safety. "This will have the effect of basically ruling out contradictions in recommendations from federal and state authorities," the explanatory memorandum to the bill of 29 September 1986 said.[13]

The European Community also wanted to be prepared for the next nuclear disaster. The EU Commission on 23 January 1987 submitted to the Council of the European Community a recommendation drawn up by an "ad hoc group of independent highly-qualified experts."[14] A proposed 'exposure control system' was based on the principle that the costs for society and the risks associated with the introduction of certain countermeasures should not be higher than the costs and risks associated with the prevention of radiation exposure.[11]

This replaced the principle of radiation minimization in the Radiation Protection Ordinance valid at that time with the 'alara' (as low as reasonably achievable) principle propagated by the International Commission on Radiological Protection (ICRP).[15] In this context, 'reasonably' is determined by economic considerations. In 1973 and 1977, the ICRP clarified its position and explained that a cost-benefit analysis would help to assess what was "practical or reasonably possible to achieve." In 1982, two representatives of the American nuclear industry published an article in the journal Health Physics explaining procedures for calculating and figures used in the quantitative assessment of follow-up costs for society resulting from radioactive pollution in the United States.[16] The article set the cost of radiation protection measures in relation to "benefits" defined in dollars and cents. The equivalent of a cancer patient or cancer fatality was calculated at USD 35,000 in 1975 and, with adjustment for inflation, at USD 100,000 in 1988. This approach meant that the cost of radiation protection measures and the societal cost of long-term health consequences resulting from the failure to provide radiation protection measures, were to be kept as low as possible altogether.

Since then, radiation protection in the European Union as well has been subordinate to economic considerations.[17] Accordingly, the first prolongation, to the autumn of 1987, of permissible value limits set by the European Community after the Chernobyl disaster, was justified by the argument that "the regulation did not lead to significant problems in trade."[12]

The International Commission on Radiological Protection (ICRP), whose recommendations generally form the basis for recommendations by national radiation protection authorities and for legislation, is characterized by conflicts of interest.[18] Its members

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[13] Quoted here after Ernst Rößler, "'Vorsorge' für den nächsten GAU" ['Precautions' Against the Next Maximum Credible Accident], *Strahlentelex* 11/1987.

[14] Report of the European Communities on 23 January 1987.

[15] ICRP Recommendation No. 9 from 17 September 1965. Relevant conformations were legally adopted in Germany's Radiation Protection Ordinance in 2001. The radiation minimization principle was overridden by introducing so-called decontrol regulations affecting the release of radioactive substances to the environment.

[16] Paul G. Voillequé, Robert A. Pavlick, "Societal Cost of Radiation Exposure," *Health Physics,* Vol. 43, No. 3, 1982, pp. 405-409; quoted here from "Tod und Leid mit 500 Millionen Dollar verrechnet" [Death and Suffering Offset for 500 Million Dollars], *Strahlentelex* 53/1989.

[17] In the meantime, the new version of Germany's Radiation Protection Ordinance in 2001 overrode the minimization principle by introducing so-called decontrol regulations for the release of radioactive substances to the environment.

[18] Compare Karl Z. Morgan, physicist and director of health physics at the Oak Ridge National Laboratory in Tennessee (USA) and member of the ICRP from 1950 to 1971. Karl Z. Morgan, "Veränderungen wünschenswert – Über die Art und Weise, wie internationale Strahlenschutzempfehlungen verfasst werden," [Changes Are Desirable – How International Recommendations for Radiation Protection Are Drawn Up]

recruit themselves, and are under the auspices of the International Society of Radiology (ISR), which supervises the management of the ICRP. The minutes of ICRP negotiations unambiguously reveal that recommendations for radiation protection have always been formulated so that they do not obstruct operations in relevant work areas. They are routinely many years behind existing scientific findings.[19]

Another potential standard setter, the World Health Organization (WHO), had in May 1958 already abdicated its power to define limits, ceding this to the International Atomic Energy Agency (IAEA).[20] In 1957, WHO convened a conference on the genetic effects of radiation, attended by experts from around the world.[21] The conference recommended a deeper investigation into the long-term risks associated with increasing radiation exposure. In 1958, in connection with this conference, WHO was asked to convene a conference on *Mental Health Aspects of the Peaceful Uses of Atomic Energy*, with the intention of looking at the inevitability of radiation exposure in the nuclear age and the problems arising from excessive public concern with health effects.[22] It was proposed that the public should not be fully acquainted with health consequences. On 28 May 1959, the IAEA and WHO signed an agreement in which both parties recognized that "the International Atomic Energy Agency has the primary responsibility for encouraging, assisting and coordinating research and development and practical application of atomic energy for peaceful uses throughout the world without prejudice to the right of the World Health Organization to concern itself with promoting, developing, assisting and co-ordinating international health work, including research, in all its aspects" (Article 1 of the Agreement).

Since then, the IAEA sees itself as the custodian of published information on the effects of radiation on health, while WHO is allowed to contribute to medical care for the sick and the promotion of public health. Article 1, Paragraph 3 of the convention imposes even more restrictions on WHO: "Whenever one of the two organizations intends to initiate a program or an activity which is of substantial interest to the other party, the initiator should consult with the other side to the effect that the matter is regulated in mutual agreement." This is apparently interpreted by the IAEA to the effect that its physicists are the ones who decide on research projects on radiation and health and that information which could have negative impact on the IAEA's objective of expanding the use of nuclear energy is suppressed.

The effects of this agreement became especially clear after the Chernobyl disaster when it was the IAEA and not WHO that evaluated health risks. The IAEA, which implements the philosophy of the International Commission on Radiological Protection (ICRP), denied that noticeable health consequences for the exposed population stood in any connection with radiation; it recognized only thyroid cancer in children as radiation-induced.

"Radiation protection is not a democratic event." This view was conveyed at a symposium organized by the Wirtschaftsverband Kernbrennstoff-Kreislauf und Kerntechnik e.V. (WKK) [nuclear engineering industry association] in Berlin in September 2009. The managing director of the association pointed out that the concept of 'optimal' radiation protection for the population was not to be understood as minimizing exposure to radiation but rather had to take economic considerations into account at all times. This message, as well as the desire voiced by the industry lobby for "continuity and stability", addressed to "relevant circles in the area of regulatory legislation for radiation protection," was underlined by Dr. Bernd Lorenz, representing

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German Society for Radiation Protection, *Berichte des Otto Hug Strahleninstitutes* [reports from the Otto Hug radiation institute], Bonn, No. 6/1993, pp. 3-12.

[19] Wolfgang Köhnlein, "Der nationale und internationale Strahlenschutz: die ICRP – ihre Aktivitäten und Empfehlungen, Teil I und II" [National and International Radiation Protection: The ICRP – Its Activities and Recommendations, Parts I and II], *Medizin - Umwelt – Gesellschaft,* 12 2/99, pp. 157-162 and 3/99, pp. 244-252.

[20] "Schutz der Strahlen gegen Schutz vor Strahlung: Interessenkonflikt zwischen IAEA und WHO" [Protection of Radiation Instead of Protection Against Radiation: Conflicts of Interest Between IAEA and WHO], *Strahlentelex* 316-317/2000.

[21] WHO, *Effects of Radiation on Human Heredity*, 1957.

[22] WHO, *Mental Health Aspects of the Peaceful Uses of Atomic Energy,* Technical Report Series No. 151, Report of a Study Group, 1958.

the Gesellschaft für Nuklear-Service (GNS) [association for nuclear services] in Essen. Until German reunification, he worked for the former East German government's Staatliches Amt für Atomsicherheit und Strahlenschutz [state office for nuclear safety and radiation protection] and since then has been a lobbyist for nuclear power plant operators. He is also an observer member of the ICRP and member of the ENISS Initiative (European Nuclear Installations Safety Standards group), founded by FORATOM, the trade association of the European nuclear energy industry. He said that his attitude was shaped at the time when ICRP Publication 26 was issued, when in East Germany the radiation protection principle of minimization was replaced by an 'optimization,' and the worth of a human being was calculated at 30,000 East German marks per person-sievert of reduced radiation exposure. Lorenz said that the ICRP had now issued its new recommendations (ICRP Publication 103 in 2007) under the slogan of "continuity and stability." Laws based on the old ICRP recommendation 60 of 1990 therefore didn't need to be revised, and even value limits could stay where they are, he said. Optimizations in radiation protection below dose guideline values or dose limits would be "dire" because in the end they would lower the boundary between acceptable and unacceptable radiation damage from higher limits to lower guidance values. Lorenz was troubled by the ICRP recommendation advocating environmental protection that was independent of radiation protection for humans; he thought the idea of setting radiation limits for animals and plants should be left alone. It would be much more important to have a process of optimization using the 'alara' principle, especially because levels 'as low as reasonably achievable' could be kept very ambiguous, depending on the interests involved.[23]

3.2 Current value limits in Germany, Europe and Japan

After the Chernobyl nuclear disaster, limits regarding food in Germany were set only for radioactive cesium (cesium-134 and cesium-137), with values not to exceed 370 becquerels per liter or kilogram for milk, milk products and baby food, and not to exceed 600 becquerels per kilogram for other foods.[24]

370 becquerels per liter or kilogram	for milk, milk products and baby food
600 becquerels per liter or kilogram	for all other foods

As early as 1987, as a 'precaution' in case of another super-meltdown, the European Union defined higher value limits to be put into effect automatically in a disaster situation without further discussion or public attention.[25] These limits were later justified by the argument that perhaps only 10 percent of the food consumed would be contaminated to such an extent.

On 25 March 2011, without the German ministry for consumer protection even pointing this out to the public, the EU Commission, in a Commission Implementing Regulation, put into effect these higher limits, restricting them to imports of food and animal feed from Japan.[26] Strontium and plutonium were not mentioned in this regulation, and only the limits for iodine-131, cesium-134 and cesium-137 were to be monitored. The ruling did not apply to imports from other countries.

In this way, the EU needlessly allowed the import of radioactively contaminated foods from Japan that were no longer approved for human consumption in Japan itself. After this became public and protests were voiced, the European Commission and EU Member States on 8 April 2011 agreed to set new limits for the radionuclide contamination of food and feed products from Japan which were the same as the permissible limits in Japan, according to a press release that day from Germany's Ministry of Food, Agriculture and Consumer Protection.

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[23] T. Dersee, "Strahlenschutz ist keine demokratische Veranstaltung" [Radiation Protection is Not a Democratic Event], *Symposium des Wirtschaftsverbandes Kernbrennstoff-Kreislauf (WKK)* [Symposium held by the nuclear engineering industry association], Berlin, 16 September 2009, in: *Strahlentelex* 546-547/2009, pp. 7-8.

[24] Council Regulation (EC) No 733/2008.

[25] Council Regulation (EURATOM) No 3954/87 and Commission Regulation (EURATOM) No 779/90.

[26] Commission Implementing Regulation (EU) No 297/2011.

This amendment to the Fukushima regulation was officially published on 12 April 2011 (see Table 2).[27]

The Japanese limits thereby ‘provisionally’ replace the old values set in EURATOM Regulation No. 779 of 1990. ‘Provisionally’ means that limits can be raised again to the limits set out in the old EURATOM Regulation should Japan decide to increase its own limits. The values for concentrated or dried products are also “calculated on the basis of the direct consumption of a reconstituted product,” the EU regulation says, meaning that limits can be set higher for products that will be consumed after they have been diluted from a concentrated or dried form.

Regarding food originating in Germany, Europe and other countries except Japan, the original limits on radioactive cesium still apply at 370 becquerels per liter or kilogram for milk and milk products and 600 becquerels per kilogram for other foods. Today, even 25 years after Chernobyl, these limits are still exceeded in some regions, especially in wild mushrooms, game (wild boar, deer, red deer), sheep and freshwater predator fish (perch, pike, pike-perch).

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[27] Commission Implementing Regulation (EU) No 351/2011 of 11 April 2011 amending Regulation (EU) No 297/2011 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station; Official Journal of the European Union L97/20-23 of 12 April 2011.

Table 2: Current limits applying to imports of food from Japan [27] in becquerels per kilogram (Bq/kg)

	Food for babies and toddlers	Milk and milk products	Other foods except liquid foods	Liquid foods
Sum of strontium isotopes, especially strontium-90†	75	125	750	125
Sum of iodine isotopes, especially iodine-131	100 (1) (previously 150) (2)	300 (1) (previously 500) (2)	2000	300 (1) (previously 500) (2)
Sum of alpha-emitting isotopes of plutonium and transplutonium elements, especially plutonium-239, americium-241	1	1 (1) (previously 20) (2)	10 (1) (previously 80) (2)	1 (1) (previously 20) (2)
Sum of all other radionuclides with half-lives higher than 10 days, especially cesium-134, cesium-137, except carbon-14 (C-14) and tritium (H-3)	200 (1) (previously 400) (2)	200 (1) (previously 1,000) (2)	500 (1) (previously 1,250) (2)	200 (1) (previously 1,000) (2)

(1) "In order to ensure consistency with action levels currently applied in Japan, these values replace on a provisional basis the values laid down in Council Regulation (EURATOM) 3954/87."[27]

(2) Limits set in EURATOM Regulation No 779 of 1990.[25] These were replaced by Japanese limits as specified in Commission Implementing Regulation (EU) No 351/2011 of 11 April 2011.[27]

Highest limits for feed in Bq/kg

Sum of cesium-134 and cesium-137	500 "In order to ensure consistency with action levels currently applied in Japan, this value replaces on a provisional basis the value laid down in Commission Regulation (EURATOM) No 770/90."[27]
Sum of iodine isotopes, especially iodine-131	2000 "This value is laid down on a provisional basis and taken to be the same as for foodstuffs, pending an assessment of transfer factors of iodine from feedingstuffs to food products."[27]

† Note: The regulations in Japan do not contain maximum limits for strontium.

3.3 Current value limits in Ukraine and Belarus (see Appendix I, Tables 1-4)

After the Chernobyl disaster, populations not only in the direct region around Chernobyl, but all across Europe were forced to seek clarity on the handling of radioactively contaminated food. Individual states took very different routes of action.

In Western Europe, the destruction of agricultural products and the obstruction of the food trade within countries and even between European countries triggered all-consuming reflection. If another disaster occurred, the losses involved were supposed to be significantly reduced or indeed completely avoided. The official argument was that this would be the only way to ensure the security of food supply. Protection of the population from contaminated food was last on the list after concern for the losses suffered by agriculture and commerce. The ruling on maximum permissible limits for cesium isotopes, strontium-90, alpha emitters and iodine-131, indicated in parentheses in the table above, is still lying in the drawer today, waiting for the next disaster, and can be tacitly put into force immediately, without parliamentary debate, in the event of another disaster. The response to the Fukushima disaster shows that those responsible had been thinking more about an accident happening in Europe than overseas.

In Ukraine and Belarus, authorities set other priorities in the aftermath of Chernobyl. Their concern was directed at keeping any additional radiation exposure through contaminated food as low as possible because the population was already exposed to very high contamination that could not be prevented (direct exposure from contaminated soils and the inhalation of contaminated dust).

For Ukraine, we can see how this developed over time. A few days after the Chernobyl event, a maximum limit of 3,700 becquerels per liter (Bq/l, radionuclides not specified) was set for drinking water; a month later this value dropped to 370 Bq/l (total beta activity), and at the end of 1987 the maximum limit for cesium-137 was at 20 Bq/l. Ten years later it was at 2 Bq/l. The maximum limit for potatoes – a basic food staple in this region – dropped from 3,700 Bq/kg (total beta activity in 1986) to today's value of 70 Bq/kg for cesium-137. For bread, the limit dropped from 370 Bq/kg (total beta activity) to 20 Bq/kg for cesium-137. For baby food, today's maximum limits stand at 40 Bq/kg for cesium-137 and 5 Bq/kg for strontium-90.

In Belarus, maximum limits for drinking water have been 10 Bq/l for cesium-137 and 0.37 Bq/l for strontium-90 since 26 April 1999. For milk, these values are 100 and 3.7 Bq/l respectively. The maximum limits for cesium-137 in potatoes, bread and baby food are close to Ukrainian values; the limit for strontium-90 in baby food is particularly low at only 1.85 Bq/kg.

After the Chernobyl disaster, Ukraine and Belarus set much lower limits on food contamination than those limits set by the EU that are still valid today for responding to a nuclear power plant disaster. Of particular importance are the significantly lower limits for drinking water, milk, vegetables, potatoes, and bread and baked goods, as well as baby food. For radioactive cesium they amount to an average of only one-tenth to one-sixtieth, and for strontium-90 to only one-fifteenth to one-two hundredth of the EU limits. For drinking water, these figures are only one-sixtieth to one-five hundredth (see Appendix 1, Tables 4 to 7). These are basic foodstuffs that people need every day. Strict maximum limits in Ukraine and Belarus have apparently not led to shortages in food supply. Food is inspected in the official food trade business. However, the monitoring of food at open markets has been limited. It is also worrying that not only villagers but also townspeople, driven by poverty, gather mushrooms and berries in woodlands, and grow potatoes and cabbages at their dachas – relatively unconcerned about how highly contaminated the soil might be.

Decision-makers in Belarus were convinced that it was economically more effective and cheaper to keep the collective radiation level down by setting lower maximum limits, thereby keeping health problems to a possible minimum. This is in stark contrast to attitudes in western countries, where higher maximum limits are less restrictive for the food business, but where it is also accepted that more cancers and other diseases in the population will generate higher costs in health care and more human suffering.

An absurd consequence of the difference in limits set in Ukraine and Belarus on one hand, and Germany on the other hand (where limits for cesium isotopes stand at 370 Bq/kg or Bq/l for milk and milk products and 600 Bq/kg for other foods), is that many foods that can’t be sold in Ukraine and Belarus can be exported for sale in Germany.

No assumption can be made that different eating habits in Japan would change the priorities on how maximum value limits are set. Maximum limits were set across-the-board for different kinds of food so that there is no influence on dose calculations. The way in which dealing with contaminated food has been regulated in Ukraine and Belarus is definitely more oriented towards preserving the health of the population than is the EURATOM regulation of 1987.

4. Health hazards due to present-day maximum limits for food

4.1 Germany's Radiation Protection Ordinance

The specifications in Germany's currently valid Radiation Protection Ordinance[28] are used for classification and comparison in all following calculations. Radiation protection ordinances are based on the Atomic Energy Act and adopted by the German government with the consent of the Bundesrat, but without the participation of the Bundestag. They turn the recommendations of the International Commission on Radiological Protection (ICRP) and the European Union into law and make the rules for calculating doses legally binding.[29] The Radiation Protection Ordinance was last revised in 2001. It is used here as a reference point because it represents current law. It therefore makes sense to derive from it the radiation protection values applicable to a normal situation (without a disastrous nuclear event). However, this conservative approach should not be misunderstood as an acceptance of the way of thinking and the figures in the current ordinance.

4.2 European Union

The maximum limits in Table 2 above apply to foods imported from Japan to the Member States of the European Union. For food from Germany and Europe, as well as from other countries, only the limits mentioned above in section 3.2 for radioactive cesium, at 370 becquerels per kilogram for milk and milk products, and 600 becquerels per kilogram for all other foods, still apply.

4.2.1 Thyroid exposure to radioactivity in food contaminated up to the permissible EU limit

A diet containing radionuclides up to the permissible EU limits set for iodine (as listed in Table 2), consumed at the average rates defined in Annex VII, Table 1 of Germany's 2001 Radiation Protection Ordinance, results in the following permissible annual doses for thyroid exposure:

for a baby (up to one year in age)	760 millisieverts thyroid dose limit per year[30],
for a toddler from 1 to 2 years of age	1,390 millisieverts thyroid dose limit per year[31],
for a child from 2 to 7 years of age	1,340 millisieverts thyroid dose limit per year[32],
for a child from 7 to 12 years of age	750 millisieverts thyroid dose limit per year[33],
for a teenager from 12 to 17 years of age	560 millisieverts thyroid dose limit per year[34],
for an adult (older than 17 years)	360 millisieverts thyroid dose limit per year[35].

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[28] Ordinance for the implementation of EURATOM Directives on Radiation Protection (Radiation Protection Ordinance – StrlSchV) from 20 July 2001 (BGBl. I, p. 1714), reported on 22 April 2002 (BGBl. I, p. 1459), amended by Art. 3 of the law from 13 December 2007 (BGBl. I, p. 2930), last amended by Art. 2 of the law from 26 August 2008 (BGBl. I, p. 1793).

[29] Serving size in kg × concentration of radioactivity in Bq/kg × dose coefficient, according to the ICRP recommendation and the specification of the German environment ministry on 23 July 2001, in Sv/Bq = dose in Sv; 1 Sv = 1,000 millisieverts. For instance, E-6 is a bureaucratic notation used in the German Radiation Protection Ordinance for the precise mathematical description of 10^{-6} = 0.000,001.

[30] (145 kg/year × 100 Bq/kg + 45 kg × 300 Bq/kg + 80.5 kg × 2000 Bq/kg + 55 kg × 300 Bq/kg) × 3.7E-6 Sv/Bq = 0.76 Sv = 760 mSv/year

[31] (160 kg/year × 300 Bq/kg + 154 kg/year × 2000 Bq/kg + 100 kg/year × 300 Bq/kg) × 3.6E-6 Sv/Bq = 1.39 Sv/year = 1,390 mSv/year

[32] (160 kg/year × 300 Bq/kg + 280 kg/year × 2000 Bq/kg + 100 kg/year × 300 Bq/kg) × 2.1E-6 Sv/Bq = 1.34 Sv/year = 1,340 mSv/year

[33] (170 kg/year × 300 Bq/kg + 328.5 kg/year × 2000 Bq/kg + 150 kg/year × 300 Bq/kg)× 1.0E-6 Sv/Bq = 0.75 Sv/year = 750 mSv/year

[34] (170 kg/year × 300 Bq/kg + 356 kg/year × 2000 Bq/kg + 200 kg/year × 300 Bq/kg)× 6.8E-7 Sv/Bq = 0.56 Sv/year = 560 mSv/year

[35] (130 kg/year × 300 Bq/kg + 350.5 kg/year × 2000 Bq/kg + 350 kg/year × 300 Bq/kg)× 4.3E-7 Sv/Bq = 0.36 Sv/year = 360 mSv/year

According to Section 47 of the German Radiation Protection Ordinance of 2001, the maximum permissible limit for the organ absorbed dose to the thyroid during normal operations at nuclear facilities is 0.9 millisieverts (mSv) per year. In case of an accident, Section 49 of the German ordinance allows an organ absorbed dose of up to 150 mSv, corresponding to a so-called effective dose of 7.5 mSv.[36] Currently permissible contamination levels for radioactive iodine in food exceed these values many times over in all cases.

Iodine-131 has a half-life of 8.06 days. After the burning out of the Fukushima nuclear facilities and the cessation of radioactive emissions into the environment, it takes 7 half-life periods, or just under 2 months until the amount of iodine-131 has been reduced to less than one percent of the original quantity. This means that an original value of 2,000 becquerels of iodine-131 has gone down to about 16 becquerels after nearly 2 months, and that not until about 11 half-life periods (88 days or nearly 3 months) have passed, has the original radioactivity of the iodine-131 gone down to less than one becquerel. At the time this report was being written, the nuclear reactions at Fukushima had not yet come to rest, so it can be assumed that fresh iodine-131 is still being generated.

4.2.2 Effective radiation doses from foodstuffs contaminated up to the permissible EU limit

Of particular interest in the long term 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 28.8 years, and plutonium-239 with a half-life of 24,110 years.

Published findings from the testing of foodstuffs from Japan indicate that cesium-137 and cesium-134 are present in roughly equal proportions. On this basis, and applying current permissible EU limits and the average consumption rates defined in Annex VII, Table 1 of Germany's 2001 Radiation Protection Ordinance, the following effective annual doses are permissible:

for a baby (up to 1 year in age)	63 millisieverts effective dose per year[37],
for a toddler from 1 to 2 years of age	83 millisieverts effective dose per year[38],
for a child from 2 to 7 years of age	78 millisieverts effective dose per year[39],
for a child from 7 to 12 years of age	60 millisieverts effective dose per year[40],
for a teenager from 12 to 17 years of age	58 millisieverts effective dose per year[41],

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[36] According to Appendix VI Part C 2 of the German Radiation Protection Ordinance, the thyroid gland receives a weighting of only 5 percent. The explanation given for this very low weighting is that cancer of the thyroid is easily operable.

[37] 145 kg baby food/year × [100 Bq/kg × (2.1E-8 Sv/Bq Cs-137 + 2.6E-8 Sv/Bq Cs-134) + 75 Bq/kg × 2.3E-7 Sv/Bq Sr-90 + 1 Bq/kg × 4.2E-6 Sv/Bq Pu-239 + 100 Bq/kg × 1.8E-7 Sv/Bq I-131] + 100 kg milk and other beverages/year × [100 Bq/kg × (2.1E-8 Sv/Bq Cs-137 + 2.6E-8 Sv/Bq Cs-134) + 125 Bq/kg × 2.3E-7 Sv/Bq Sr-90 + 1 Bq/kg × 4.2E-6 Sv/Bq Pu-239 + 300 Bq/kg × 1.8E-7 Sv/Bq I-131] + 80.5 kg other foodstuffs/year × [250 Bq/kg × (2.1E-8 Sv/Bq Cs-137 + 2.6E-8 Sv/Bq Cs-134) + 750 Bq/kg × 2.3E-7 Sv/Bq Sr-90 + 10 Bq/kg × 4.2E-6 Sv/Bq Pu-239 + 2000 Bq/kg × 1.8E-7 Sv/Bq I-131] = 62.8 mSv/year.

[38] 260 kg milk and beverages/year × [100 Bq/kg × (1.2E-8 Sv/Bq Cs-137 + 1.6E-8 Sv/Bq Cs-134) + 125 Bq/kg × 7.3E-8 Sv/Bq Sr-90 + 1 Bq/kg × 4.2E-7 Sv/Bq Pu-239 + 300 Bq/kg × 1.8E-7 Sv/Bq I-131] + 154 kg other foodstuffs/year × [250 Bq/kg × (1.2E-8 Sv/Bq Cs-137 + 1.6E-8 Sv/Bq Cs-134) + 750 Bq/kg × 7.3E-8 Sv/Bq Sr-90 + 10 Bq/kg × 4.2E-7 Sv/Bq Pu-239 + 2000 Bq/kg × 1.8E-7 Sv/Bq I-131] = 82.8 mSv/year.

[39] 260 kg milk and beverages/year × [100 Bq/kg × (9.6E-9 Sv/Bq Cs-137 + 1.3E-8 Sv/Bq Cs-134) + 125 Bq/kg × 4.7E-8 Sv/Bq Sr-90 + 1 Bq/kg × 3.3E-7 Sv/Bq Pu-239 + 300 Bq/kg × 1.0E-7 Sv/Bq I-131] + 280 kg other foodstuffs/year × [250 Bq/kg × (9.6E-9 Sv/Bq Cs-137 + 1.3E-8 Sv/Bq Cs-134) + 750 Bq/kg × 4.7E-8 Sv/Bq Sr-90 + 10 Bq/kg × 3.3E-7 Sv/Bq Pu-239 + 2000 Bq/kg × 1.0E-7 Sv/Bq I-131] = 78.4 mSv/year.

[40] 320 kg milk and beverages/year × [100 Bq/kg × (1.0E-8 Sv/Bq Cs-137 + 1.4E-8 Sv/Bq Cs-134) + 125 Bq/kg × 6.0E-8 Sv/Bq Sr-90 + 1 Bq/kg × 2.7E-7 Sv/Bq Pu-239 + 300 Bq/kg × 5.2E-8 Sv/Bq I-131] + 328.5 kg other foodstuffs/year × [250 Bq/kg × (1.0E-8 Sv/Bq Cs-137 + 1.4E-8 Sv/Bq Cs-134) + 750 Bq/kg × 6.0E-8 Sv/Bq Sr-90 + 10 Bq/kg × 2.7E-7 Sv/Bq Pu-239 + 2000 Bq/kg × 5.2E-8 Sv/Bq I-131] = 60.1 mSv/year.

[41] 370 kg milk and beverages/year × [100 Bq/kg × (1.3E-8 Sv/Bq Cs-137 + 1.9E-8 Sv/Bq Cs-134) + 125 Bq/kg × 8.0E-8 Sv/Bq Sr-90 + 1 Bq/kg × 2.4E-7 Sv/Bq Pu-239 + 300 Bq/kg × 3.4E-8 Sv/Bq I-131] + 356

for an adult (older than 17 years)	33 millisieverts effective dose per year[42].

According to Section 47 of Germany's current Radiation Protection Ordinance, the maximum limit of exposure for individuals from "discharges of radioactive substances through air or water" during the normal operation of nuclear facilities is 0.3 millisieverts (mSv) per year. This limit of 0.3 mSv is exceeded many times over if a person can consume only solid foods and beverages contaminated with radionuclides up to the permissible EU level. The amount consumed by an adult would stay below the level specified in the German ordinance only if he/she consumed no more than 0.9 percent of foodstuffs contaminated at levels permissible in the EU. A toddler's diet could not have more than 0.36 percent of foodstuffs contaminated at permissible EU levels.

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kg other foodstuffs/year × [250 Bq/kg × (1.3E-8 Sv/Bq Cs-137 + 1.9E-8 Sv/Bq Cs-134) + 750 Bq/kg × 8.0E-8 Sv/Bq Sr-90 + 10 Bq/kg × 2.4E-7 Sv/Bq Pu-239 + 2000 Bq/kg × 3.4E-8 Sv/Bq I-131] = 58.0 mSv/year.

[42] 480 kg milk and beverages/year × [100 Bq/kg × (1.3E-8 Sv/Bq Cs-137 + 1.9E-8 Sv/Bq Cs-134) + 125 Bq/kg × 2.8E-8 Sv/Bq Sr-90 + 1 Bq/kg × 2.5E-7 Sv/Bq Pu-239 + 300 Bq/kg × 2.2E-8 Sv/Bq I-131] + 350.5 kg other foodstuffs/year × [250 Bq/kg × (1.3E-8 Sv/Bq Cs-137 + 1.9E-8 Sv/Bq Cs-134) + 750 Bq/kg × 2.8E-8 Sv/Bq Sr-90 + 10 Bq/kg × 2.5E-7 Sv/Bq Pu-239 + 2000 Bq/kg × 2.2E-8 Sv/Bq I-131] = 33.0 mSv/year.

4.2.3 Radiation damage from foodstuffs contaminated up to the permissible EU limit

If 100,000 children are each exposed to about 80 millisieverts (mSv) per year (as calculated above), the risk calculation figures of the International Commission on Radiological Protection (ICRP) indicate that about 400 of these children will later additionally die each year of cancer.[43] But independent analyses of data from Hiroshima and Nagasaki[44], taking into account the fact that the effects of nuclear bomb blasts in Hiroshima and Nagasaki can't be equated with the exposure to fallout after reactor meltdowns, show that this figure could be up to 10 times higher, so that about 4,000 out of 100,000 children exposed to 80 mSv per year would die. For adults consuming food exposing them to 33 mSv per year, this figure would range from 165 to 1,650 out of 100,000 who would later additionally die each year of cancer.

These figures only reflect the range of the debate. The ICRP set the lowest estimate. Rudi H. Nussbaum's and Wolfgang Köhnlein's deliberations, first published by Nussbaum in 1987, stimulated numerous other independent analyses of the data from Hiroshima and Nagasaki.[42] The range today extends up to 7.6 times higher than the ICRP estimate and applies to the atomic flash of the bombings.[45] When comparing this to exposure to fallout from reactor meltdowns, it is also necessary to take into account the one-time exposure to external radiation from the blast and the subsequent long-lasting internal exposure from radionuclides. It should be noted that alpha emitters are to be weighted higher than radiation from the atomic blast and beta radiation, which suggests a deviation from the ICRP calculations by about one order of magnitude (factor of 10).

It should also be noted that the concept of the so-called effective dose takes only fatalities from cancer into account, but not the number of illnesses, which is higher. After the Chernobyl reactor disaster, people were afflicted not only with cancer but with an increasing weakening of the immune system, premature aging, cardiovascular diseases at an early age, chronic diseases of the stomach, thyroid and pancreas (diabetes mellitus), and neurological and psychiatric disorders that were the somatic effects of low-dose radiation. Particularly disturbing are the genetic effects that will be expressed more fully in coming generations. All of these detriments to health have not been taken into account in estimates calculated according to the rules set by the Radiation Protection Ordinance.

4.3 Japan

The Japanese government released the first information on foodstuff contamination on 19 and 20 March 2011.[46]

Spinach in the Ibaraki Prefecture, Hitachi City, more than 100 kilometers south of the Fukushima reactor meltdowns, had 54,000 becquerels of iodine-131 and 1,931 becquerels of radioactive cesium per kilogram.

Spinach in the Ibaraki Prefecture, Kitaibaraki City, some 75 kilometers south of Fukushima, had 24,000 becquerels of iodine-131 and 690 becquerels of radioactive cesium per kilogram.

Edible spring chrysanthemums (a Japanese leafy vegetable) from Asahi in Chiba Prefecture near Tokyo, had 4,300 becquerels of iodine-131 per kilogram.

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[43] ICRP estimation of risk: 5 percent per sievert.

[44] R. H. Nussbaum, E. Belsey, W. Köhnlein, "Recent Mortality Statistics for Distally Exposed A-Bomb Survivors: The Lifetime Cancer Risk for Exposure under 50 cGy (rad)," *Medicina Nuclearis* 1990, 2, pp. 151-162; see *Strahlentelex* 90-91, 4 October 1990, and; R. H. Nussbaum, W. Köhnlein, "Inconsistencies and Open Questions Regarding Low-Dose Health Effects of Ionizing Radiation," *Environmental Health Perspectives* Vol. 102, No. 8, August 1994, pp. 656-667.

[45] W. Köhnlein, "Die Aktivitäten und Empfehlungen der Internationalen Strahlenschutzkommission (ICRP)" [The Activities and Recommendations of the International Commission on Radiological Protection (ICRP)], *Berichte des Otto Hug Strahleninstitutes* [reports from the Otto Hug radiation institute], No. 21-22, 2000, pp. 5-25 (Table 2).

[46] *Strahlentelex* 582-583, 7 April 2011, p. 10.

4.3.1 Thyroid exposure to radiation

One example will be used to show that even small amounts of food contaminated with radioactive iodine (iodine-131) to the extent that has actually occurred in Japan can result in extensive exposure of the thyroid to radiation.

The organ absorbed dose of radiation to the thyroid after eating only 100 grams (0.1 kilogram) of spinach with 54,000 becquerels of iodine-131 per kilogram, as measured in Japan, is:[27]

for a baby (up to one year in age)	20 millisieverts thyroid dose[47]
for a toddler from 1 to 2 years of age	19.4 millisieverts thyroid dose[48]
for a child from 2 to 7 years of age	11.3 millisieverts thyroid dose[49]
for a child from 7 to 12 years of age	5.4 millisieverts thyroid dose[50]
for a teenager from 12 to 17 years of age	3.7 millisieverts thyroid dose[51]
for an adult (older than 17 years)	2.3 millisieverts thyroid dose[52]

According to Section 47 of the German Radiation Protection Ordinance of 2001, the permissible maximum organ absorbed dose to the thyroid during normal operations at nuclear facilities is 0.9 millisieverts (mSv) per year. This limit is exceeded severalfold in Japan when only 100 grams of spinach are consumed. In case of an accident, Section 49 of the German ordinance allows an organ absorbed dose to the thyroid of up to 150 millisieverts (mSv), which corresponds to a so-called effective dose of 7.5 mSv.[53]

Iodine-131 has a half-life of 8.06 days. After the burning out of the Fukushima nuclear facilities and the cessation of radioactive emissions into the environment, it takes 7 half-life periods, or nearly 2 months until the amount of iodine-131 has been reduced to less than one percent of the original quantity. This means that an original value of 54,000 becquerels has gone down to about 422 becquerels after nearly 2 months, and that not until about 16 half-life periods (129 days or 4.3 months) have passed, has the radioactivity of the iodine-131 gone down to less than one becquerel.

4.3.2 Effective radiation doses from consuming foodstuffs in and from Japan

At present measuring results of Japanes foods are too few in number to permit conclusions concerning large groups of people. As an aid to assessment, this section will calculate the effective doeses for various age groups, assuming that food intake for one year is contaminated with only 100 bq/kg of the indicator nuclide cesium-137. For other levels of contamination this is easily convertible and may also be used to assess dose load by food consumption over longer years.

In the long term, the radionuclides with longer half-lives are of particular interest:

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 28.8 years; and
plutonium-239 with a half-life of 24,110 years.

After two years of burning time in a nuclear power plant, the inventory of radionuclides with longer half-lives in reactor fuel rods is usually present in a ratio of

100 : 25 : 75 : 0.5 (cesium-137 : cesium-134 : strontium-90 : plutonium-239).

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[47] 0.1 kg × 54,000 Bq/kg × 3.7E-6 Sv/Bq = 20 millisieverts
[48] 0.1 kg × 54,000 Bq/kg × 3.6E-6 Sv/Bq = 19.4 millisieverts
[49] 0.1 kg × 54,000 Bq/kg × 2.1E-6 Sv/Bq = 11.3 millisieverts
[50] 0.1 kg × 54,000 Bq/kg × 1.0E-6 Sv/Bq = 5.4 millisieverts
[51] 0.1 kg × 54,000 Bq/kg × 6.8E-7 Sv/Bq = 3.7 millisieverts
[52] 0.1 kg × 54,000 Bq/kg × 4.3E-7 Sv/Bq = 2.3 millisieverts
[53] According to Appendix VI Part C 2 of the German Radiation Protection Ordinance, the thyroid gland receives a weighting of only 5 percent. The explanation given for this very low weighting is that cancer of the thyroid is easily operable.

In the fallout from Chernobyl, however, there were typically two parts of cesium-137 for one part of cesium-134. Measurements from Japan published so far show that cesium-137 and cesium-134 occur in about equal share in the fallout. Levels for strontium-90 and plutonium-239 are in question because adequate test results will not be available very quickly. The mixed oxide (MOX) fuel rods in Fukushima Dai-ichi contained more plutonium, but this was probably not blown out completely. In past nuclear accidents, strontium has tended to fall out in the vicinity of a plant and is therefore usually found in lower concentrations at a distance.[54] The following calculation therefore assumes that the ratio of radionuclides in Japan is

100 : 100 : 50 : 0.5 (cesium-137 : cesium-134 : strontium-90 : plutonium-239).

If food is consumed at the average rates defined in Annex VII, Table 1 of Germany's 2001 Radiation Protection Ordinance, with dietary intake consistently containing 100 becquerels of cesium-137 (Cs-137) and cesium-134 (Cs-134), 50 becquerels of strontium-90 (Sr-90) and 0.5 becquerels of plutonium-239 (Pu-239) per kilogram of contaminated foodstuffs, these age groups are exposed to the following effective annual doses:

for a baby (up to 1 year in age)	6 millisieverts effective dose per year[55]
for a toddler from 1 to 2 years of age	2.8 millisieverts effective dose per year[56]
for a child from 2 to 7 years of age	2.6 millisieverts effective dose per year[57]
for a child from 7 to 12 years of age	3.6 millisieverts effective dose per year[58]
for a teenager from 12 to 17 years of age	5.3 millisieverts effective dose per year[59]
for an adult (old than 17 years)	3.9 millisieverts effective dose per year[60]

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[54] *Strahlentelex* 8, 7 May 1987, pp. 1, 3; *Strahlentelex* 19, 15 October 1987.

[55] 325.5 kg/year × [100 Bq/kg × (2.1E-8 Sv/Bq Cs-137 + 2.6E-8 Sv/Bq Cs-134) + 50 Bq/kg × 2.3E-7 Sv/Bq Sr-90 + 0.5 Bq/kg × 4.2E-6 Sv/Bq Pu-239] = 6 mSv/year.

[56] 414 kg/year × [100 Bq/kg × (1.2E-8 Sv/Bq Cs-137 + 1.6E-8 Sv/Bq Cs-134) + 50 Bq/kg × 7.3E-8 Sv/Bq Sr-90 + 0.5 Bq/kg × 4.2E-7 Sv/Bq Pu-239] = 2.8 mSv/year.

[57] 540 kg/year × [100 Bq/kg × (9.6E-9 Sv/Bq Cs-137 + 1.3E-8 Sv/Bq Cs-134) + 50 Bq/kg × 4.7E-8 Sv/Bq Sr-90 + 0.5 Bq/kg × 3.3E-7 Sv/Bq Pu-239] = 2.6 mSv/year.

[58] 648.5 kg/year × [100 Bq/kg × (1.0E-8 Sv/Bq Cs-137 + 1.4E-8 Sv/Bq Cs-134) + 50 Bq/kg × 6.0E-8 Sv/Bq Sr-90 + 0.5 Bq/kg × 2.7E-7 Sv/Bq Pu-239] = 3.6 mSv/year.

[59] 726 kg/year × [100 Bq/kg × (1.3E-8 Sv/Bq Cs-137 + 1.9E-8 Sv/Bq Cs-134) + 50 Bq/kg × 8.0E-8 Sv/Bq Sr-90 + 0.5 Bq/kg × 2.4E-7 Sv/Bq Pu-239] = 5.3 mSv/year.

[60] 830.5 kg/year × [100 Bq/kg × (1.3E-8 Sv/Bq Cs-137 + 1.9E-8 Sv/Bq Cs-134) + 50 Bq/kg × 2.8E-8 Sv/Bq Sr-90 + 0.5 Bq/kg × 2.5E-7 Sv/Bq Pu-239] = 3.9 mSv/year.

5. Maximum limits derived from Germany's Radiation Protection Ordinance

Current permissible limits in the European Union and Japan do not in any way offer protection from damage to health. On the contrary, they expose humans to a politically calculated risk of suffering or death from radiation damage. Because government policies are not designed to openly clarify the risks involved in setting permissible limits, consumers are led to believe they are safe. This circumvents a debate on what kind of protection people want and how much protection is feasible.

Even the standards set in the German Radiation Protection Ordinance for the normal operation of nuclear facilities can't provide comprehensive safety, although they do significantly reduce the risk of damage in comparison to the European Union's regulations in case of disaster. Since the German ordinance is law, the following discussion is based on deriving maximum permissible limits for radionuclides in food that result if we engage with the way of thinking found in Section 47 of the ordinance.

According to Section 47 of the current German Radiation Protection Ordinance, the maximum limit of exposure for individuals from "discharges of radioactive substances through air or water" during the normal operation of nuclear facilities is 0.3 millisieverts (mSv) per year. This standard was worked out after years of deliberation and research and finally laid down by law in 1976. It represented a compromise between the nuclear industry and the needs of the population, and was based on recommendations from the International Commission on Radiological Protection (ICRP Publication No. 9 of 1966).[61] Accordingly, the population was not to be exposed to more than 0.05 sieverts per generation (30 years) that were caused by human activity. The Commission took the view that this value would provide a reasonable margin for nuclear programs in the conceivable future. This was adopted in 1969 by Germany's Atomic Commission at that time. Very specifically, 0.02 sieverts per 30 years were to be allotted to nuclear facilities. This was to ensure that nuclear technology alone did not claim the entire dose deemed permissible at that time for genetic reasons. This maximum exposure limit of 0.02 sieverts was also divided so that half could be accounted for by radioactive discharges through air and the other half by discharges through water. If these exposure limits are annualized, one arrives at the so-called '0.3 mSv concept' as the condition imposed on operators of nuclear facilities. Regarding both air and water exposure pathways, Annex VII of Germany's current Radiation Protection Ordinance allows assumptions for determining radiation exposure pathways and explains that exposure pathways should not be taken into account, or additional exposure pathways should be considered, if this is justified by the local peculiarities of the site or by the plant or facility. With this, practically any exposure pathway can be constructed.

We have therefore chosen 0.3 mSv per year as the benchmark for comparison because it represents exposure pathways with the lowest radiation exposure deemed permissible and therefore the lowest ratio of damage. Using higher values as a benchmark would suggest tolerating a higher than acceptable ratio of damage. This would presuppose a public debate and a democratically legitimate agreement on the extent of damage to be accepted; neither of these has ever occurred.

The conservatism of the assessment here arises from the fact that the 0.3 mSv concept has been left unchanged for several decades, even though during this period of time the evaluation of the threat posed by ionizing radiation has significantly increased. We are confident that more realistic assumptions would lead to the lowering of permissible limits for radionuclides in food.

The value of 0.3 mSv per year is already exceeded when there is exclusive dietary intake of solid food and beverages containing 100 becquerels of the indicator nuclide cesium-137 per kilogram (and with accordant shares of cesium-134, strontium-90 and plutonium-239). If there

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[61] W. Köhnlein, "Die Aktivitäten und Empfehlungen der Internationalen Strahlenschutzkommission (ICRP)" [The Activities and Recommendations of the International Commission on Radiological Protection (ICRP)], *Berichte des Otto Hug Strahleninstitutes* [reports from the Otto Hug radiation institute], No. 21-22, Berlin, Bremen, 2000, pp. 5-25.

is an intention to keep exposure limited to 0.3 mSv per year, then it follows from the logic of the German Radiation Protection Ordinance that food may not contain more than the amounts listed below for each age group.

for babies up to 1 year in age	5.0 becquerels cesium-137 per kilogram of food
for toddlers from 1 to 2 years of age	10.7 becquerels cesium-137 per kilogram of food
for children from 2 to 7 years of age	11.5 becquerels cesium-137 per kilogram of food
for children from 7 to 12 years of age	8.3 becquerels cesium-137 per kilogram of food
for teenagers from 12 to 17 years of age	5.7 becquerels cesium-137 per kilogram of food
for adults	7.7 becquerels cesium-137 per kilogram of food

Because of uncertainties in the bases of valuation, we recommend that the highest permissible value for children and adolescents is 4 becquerels of the indicator nuclide cesium-137 in a kilogram of food, and 8 becquerels for adults, to guarantee that there is compliance with the exposure limit of 0.3 mSv. Accordant with the isotope ratio calculated above in Section 4.3.2, we conclude that the highest permissible values for the indicator nuclide cesium-137, as well as cesium-134, strontium-90 and plutonium-239, should be:

for children altogether	4 becquerels cesium-137 per kilogram of food 4 becquerels cesium-134 per kilogram of food 2 becquerels strontium-90 per kilogram of food 0.02 becquerels plutonium-239 per kilogram of food
for adults altogether	8 becquerels cesium-137 per kilogram of food 8 becquerels cesium-134 per kilogram of food 4 becquerels strontium-90 per kilogram of food 0.04 becquerels plutonium-239 per kilogram of food

If the risk figures used by the International Commission on Radiological Protection (ICRP) are applied to 100,000 people, each exposed to 0.3 mSv per year, then still one or two people will later additionally die of cancer each year.[41] According to independent analyses of data from Hiroshima and Nagasaki,[42] and taking into account the fact that the effects of nuclear bomb blasts in Hiroshima and Nagasaki can't be equated with exposure to fallout after reactor meltdowns, this figure could however be up to 10 times higher, amounting to about 15 fatalities out of 100,000 people exposed to 0.3 mSv per year (see Section 4.2.3).[43] In Germany, with a population of about 80 million, some 1,200 to 12,000 people would later additionally die each year of cancer under these conditions.

If exposure is higher than 0.3 mSv per year, cancer mortality increases correspondingly.

Note

In this study, the activity of the indicator nuclide cesium-137 is used as a benchmark for radiation exposure and for recommendations on maximum permissible limits in food. This is in contrast to European Union practice, which sets permissible limits using only data for total cesium radioactivity (cesium-137 plus cesium-134) (see Table 1). It should be pointed out here that if limits for total cesium activity are applied for several years using only total activity as the benchmark, the proportion of cesium-134 (with a half-life of 2.06 years) gradually decreases, and at the same rate, the accepted proportion of cesium-137 (with a half-life of 30.2 years) increases up to double its original figure. What is not detected in measurements of cesium is that the shares of strontium-90 (half-life of 28.8 years) and plutonium-239 (half-life of 24,110 years) also double. This means, for example, that radiation exposure for a child, if measured using only the steady total activity of cesium, would actually continually increase from 0.3 to 0.5 mSv per year in the course of 13 years. This stands in contrast to the principle of exposure minimization in radiation protection.

6. Conclusions

6.1

In Europe and in Japan and other regions, regulations concerning contaminated foodstuffs should focus primarily on protecting the health of the population. Commercial and economic interests must not be allowed to interfere with protecting human health, particularly in light of the fact that the acceptance of any radiation limit consciously takes fatality and illness into account.

6.2

The events in Fukushima do not make it necessary to adopt limits in Europe that were once designed for an emergency situation. The limits for Europe should be lowered substantially to the limits designated in Germany's Radiation Protection Ordinance for the normal situation, for example. This means that infants, children and adolescents should not consume more than 4 becquerels of the indicator nuclide cesium-137 per kilogram of foodstuffs. For adults, this value would be 8 becquerels.

6.3

There should be public debate in Japan and Europe on the extent to which fatality and illness is taken into account through the acceptance of specified maximum permissible value limits for radionuclides. Since there are no safe limits, every decision taken is about life and death. It is important to explain to the public that there are no safe limits for radioactivity, and that any radiation whatsoever is too much.

6.4

There is no medical or ethical justification for establishing radiation value limits that differentiate between normal conditions and disaster situations. The only purpose this serves is to legally measure out health damage to the population in disaster situations for which they are not responsible. In this way, the operators accountable for the disaster are released across-the-board from their culpability.

6.5

The population must be advised to entirely abstain from consuming milk, salads, leafy vegetables and edible wild herbs if it is acutely exposed to high levels of radioactive iodine.

This recommendation may be effective for a long time. On 17 April 2011 and repeatedly afterwards, the Japanese operator Tokyo Electric Power Company (Tepco) said that radioactive emissions from the Fukushima Dai-ichi reactors would continue for the whole year. It would be another nine months until the meltdowns in the reactors and the fuel rod storage ponds would reach a “dry” state – if nothing unforeseen happened. There is a particularly high risk that even more radioactive particles will fall out across the country during the Japanese rainy season, especially when winds turn inland from the Pacific Ocean.

6.6

Tepco's and the Japanese government's communication policy so far has unfortunately strengthened the suspicion that the population is not being informed promptly and openly about hazards. Japanese citizen initiatives and NGOs should call on government and industry to change these information practices, and it is to be encouraged that they take radiation measurements themselves in order to provide the population with proper information. That official sources give poor information to the public is not a problem specific to Japan, but associated with the use of nuclear energy around the world.

6.7

Scientists are challenged to objectively inform the public about the complicated issue of health damage from ionizing radiation, and help the population understand how to behave in a reasonable way. It would be a tragedy if giving disinformation to the public, as happened after the Chernobyl disaster (by using false slogans like "radiophobia" and "there is no risk with radiation doses below 100 mSv"), would be repeated in Japan by top representatives of science.

6.8

As far as the European region is concerned, we want to bring special attention to a passage in the Treaty of Lisbon which is far from being upheld in the area of nuclear energy:

"Union policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Union. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay."[62]

> "Who does not know the truth is just a fool.
> But who knows it, and calls it a lie, is a criminal."
>
> *Bertolt Brecht: Life of Galileo, Scene 13.*
> *Brecht wrote the play in 1938/39 while in exile in Denmark;*
> *newspapers were reporting that*
> *German physicists had recently split the uranium atom.*

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[62] Treaty of Lisbon 2007/2009, Title XX Environment, Article 191 (2)

Appendix 1

Table 1: Provisionally permissible limits for radionuclides in foodstuffs and drinking water in Ukraine

	Limits in Bq/l or Bq/kg on								
Foodstuffs	6 May 1986	30 May 1986	15 Dec 1987	6 Oct 1988	22 Jan 1991	25 June 1997		3 May 2006	
	*	(Total beta activity)	Cesium-137	Cesium-137	Cesium-137	Cesium-137	Strontium-90	Cesium-137	Strontium-90
Drinking water	**3700**	**370**	**20**	**20**	**20**	**2**	**4**	**2**	**2**
Milk	**3700**	**370**	**370**	**370**	**370**	**100**	**20**	**100**	**20**
Condensed milk	-	18500	1110	1110	1110	300	60	300	60
Powdered milk	-	3700	1850	1850	1850	500	100	500	100
Curd cheese	3700	370	370	370	370	-	-	100	20
Sour cream	18500	3700	370	370	370	-	-	100	20
Cheese	74000	7400	370	370	370	-	-	200	100
Butter	74000	7400	1110	1110	370	-	-	200	40
Vegetable oil	-	7400	370	-	185	-	-	100	30
Margarine	-	7400	370	-	185	-	-	100	30
Animal fats	-	-	370	-	185	-	-	100	30
Meat/meat products	-	3700	1850	1850	740	200	20	200	20
Beef	-	-	2960	2960	740	-	-	200	20
Pork / Lamb	-	-	1850	1850	740	-	-	200	20
Poultry	-	3700	1850	1850	740	-	-	200	20
Eggs	-	1850	1850	1850	740	6	2	100	30
Fish	37000	3700	1850	-	740	150	35	150	35
Vegetables	-	3700	740	740	600	40	20	40	20
Linseed	37000	3700	740	740	600	40	20	40	20
Root crops	-	-	740	740	600	40	20	40	20
Potatoes	**-**	**3700**	**740**	**740**	**600**	**60**	**20**	**60**	**20**
Fresh fruit / Berries	-	3700	740	740	600	70	10	70	10
Wild berries / Mushrooms	-	-	-	-	-	500	50	500	50
Dried berries/ Mushrooms	-	-	-	-	-	2500	250	2500	250
Dried fruits / Berries	-	3700	11100	1110	2900	-	-	280	40
Juice	-	3700	740	-	-	-	-	70	10
Marmalade	-	-	740	-	-	-	-	140	20
Grains	-	370	370	370	370	-	-	50	20
Bread and baked goods	**-**	**370**	**370**	**370**	**370**	**20**	**5**	**20**	**5**
Herbs	-	-	-	-	-	600	200	200	100
Baby food	**-**	**-**	**-**	**-**	**-**	**40**	**5**	**40**	**5**

* Note from the authors: becquerels are given without a nuclide allocation.

Appendix 1

Table 2: Permissible limits for cesium-137 and strontium-90 in foodstuffs and drinking water in the Republic of Belarus (RDU-99 regulation)

	Limits in Bq/l or Bq/kg	
	from 26 April 1999/2001/2006	
Foodstuffs	Cesium-137	Strontium-90
Drinking water	10	0.37
Milk and milk products	100	3.7
Condensed milk	200	-
Curd cheese and related products	50	-
Cheese	50	-
Butter	100	-
Meat and meat products		-
Beef, Mutton	500	-
Pork, Poultry	180	-
Potatoes	80	3.7
Bread and baked goods	40	3.7
Flour, Barley, Sugar	60	-
Vegetable oil	40	-
Animal fat and margarine	100	-
Vegetables and root crops	100	-
Fruit	40	-
Garden berries	70	-
Preserved vegetables, fruits and berries	74	-
Wild berries and marmalades	185	-
Fresh mushrooms	370	-
Dried mushrooms	2500	-
Baby food	37	1.85
Other foodstuffs	370	-

Appendix 1

Table 3: Permissible limits for contamination in foodstuffs according to EURATOM 1987

	Limits in Bq/l or Bq/kg			
Foodstuffs	Strontium isotopes, especially strontium-90	Iodine isotopes, especially iodine-131	Alpha emitters, especially plutonium-239 and americium-241	Cesium-134, cesium-137, and all other radionuclides with a half-life of more than 10 days
Baby food	75	150	1	400
Milk products	125	500	20	1000
Other foodstuffs	750	2000	80	1250
Liquid foodstuffs	125	500	20	1000

Appendix 1

Table 4: Comparison of limits for radionuclides in foodstuffs in Bq/l or Bq/kg

	Ukraine 2006		**Belarus 2006**		**EURATOM 1987**			
	Cesium-137	Strontium-90	Cesium-137	Strontium-90	Cesium-134, cesium-137	Strontium-90	Alpha emitters, plutonium-239, americium-241	Iodine-131
Drinking water	**2**	**2**	**10**	**0.37**	**1000**	**125**	**20**	**500**
Milk	**100**	**20**	**100**	**3.7**	**1000**	**125**	**20**	**500**
Condensed milk	300	60	200	-	1000	125	20	500
Dried milk	500	100	100	-	-	-	-	-
Cottage cheese	100	20	50	-	1000	125	20	500
Sour cream	100	20	100	-	1000	125	20	500
Cheese	200	100	50	-	1000	125	20	500
Butter	200	40	100	-	1000	125	20	500
Vegetable oil	100	30	40	-	1250	750	80	2000
Margarine	100	30	100	-	1250	750	80	2000
Animal fats	100	30	100	-	1250	750	80	2000
Meat/meat products	200	20	-	-	-	-	-	-
Beef	200	20	500	-	1250	750	80	2000
Pork / Lamb	200	20	180	-	1250	750	80	2000
Poultry	200	20	180	-	1250	750	80	2000
Eggs	100	30	-	-	1250	750	80	2000
Fish	150	35	-	-	1250	750	80	2000
Vegetables	**40**	**20**	**100**	**-**	**1250**	**750**	**80**	**2000**
Linseed	40	20	-	-	1250	750	80	2000
Root crops	40	20	100	-	1250	750	80	2000
Potatoes	**60**	**20**	**80**	**3.7**	**1250**	**750**	**80**	**2000**
Fresh fruit, berries	70	10	40.7	-	1250	750	80	2000
Wild berries, Mushrooms	500	50	370	-	1250	750	80	2000
Dried wild berries/ Mushrooms	2500	250	2500	-	1250	750	80	2000
Dried fruits/berries	280	40	370	-	1250	750	80	2000
Marmalade	140	20	370	-	1250	750	80	2000
Grains	50	20	370	-	1250	750	80	2000
Bread and baked goods	**20**	**5**	**40**	**3.7**	**1250**	**750**	**80**	**2000**
Herbs	200	100	370	-	1250	750	80	2000
Juice	70	10	-	-	1000	125	20	500
Baby food	**40**	**5**	**37**	**1.85**	**400**	**75**	**1**	**150**

Appendix 2: Terms and units of measure

Terms

An **atom** consists of a positively charged nucleus and a shell of negatively charged electrons. The nucleus consists of positively charged protons and neutrally charged neutrons. Each chemical element is characterized by a certain number of positive charges in its nucleus. The charge of the nucleus thus differentiates the chemical elements from one another.

It is possible for an element to have multiple **isotopes**. The isotopes of an element are differentiated by the number of their neutrons. For example, uranium has 92 protons in its nucleus, which however can contain 143 or 146 neutrons. This corresponds to the uranium isotopes, uranium-235 and uranium-238.

A **nuclide** is an atomic species characterized by the number of its protons and neutrons and its charge. Currently about 275 stable and 1400 unstable nuclides are known. Few unstable nuclides occur in the natural environment. All other unstable nuclides are artificially produced. Today, they are generated mostly through the operation of nuclear power plants.

Radioactivity is a property of unstable atoms to transmute on their own, without any external stimulus, and in the process to release a characteristic radioactive emission. We can speak of natural radioactivity whenever radioactive nuclides occur in nature and when, through the radioactive transformation of naturally occurring unstable atoms, stable atoms arise. If however, the radioactive nuclides have been produced by artificial nuclear transformation, we speak of artificial radioactivity. During the radioactive transformation – also called radioactive decay – a radioactive atom of another element usually arises. For example, with the emission of an electron, radioactive strontium-90 decays to the radioactive nuclide yttrium-90, which, with the emission of a further electron, transforms into stable zircon-90.

Half-life expresses the time needed for an existing number of radioactive atoms to decay and is a measure for the probability of decay. A half-life can be a fraction of a second or several thousand years. A gram of iodine-129, for example, decays by half only after about 15.7 million years. Only then has it lost half of its radiation effect. Iodine-131, an isotope highly present after the Chernobyl disaster and now again after the Fukushima disaster, has a half-life of about eight days. After approximately eight days, only about half of a gram of iodine-131 remains, and after another eight days, a quarter of a gram still remains, and so forth.

Apart from the physical half-life (T_{phys}) measurement, there is also a **biological half-life** (T_{biol}), which expresses the time needed for the initial amount of a normal, non-radioactive substance to be reduced by half through metabolism or transport out of an organ. If the substance is also radioactive, then the **effective half-life** (T_{eff}), a combination of the physical and biological half-life, is significant for quantifying radiation exposure. Biological half-life varies according to the individual and also depends on the health of the person. For example, the biological half-life of substances ingested by people with kidney disorders can be higher as a result of changes in urinary discharge. The following formula expresses the effective half-life: $T_{eff} = T_{biol} \cdot T_{phys} / (T_{biol} + T_{phys})$. Determining biological and effective half-lives is subject to great uncertainty, however, since these can be ascertained only in controlled human experiments, which ethical considerations do not permit.

Ionizing radiation: The radiation emitted during the radioactive decay of atoms is classified as alpha, beta, or gamma radiation. This high-energy radiation can excite other atoms and molecules or dislodge electrons from the electron shell of other atoms, thereby generating electrically charged atoms (ions). This is referred to as ionizing radiation. The damaging effect of alpha, beta and gamma radiation depends largely on their capacity to ionize atoms.

Alpha rays are positively charged particles emitted from a nucleus. They consist of two neutrons and two protons (as in helium nuclei). Because of their great mass and their charge, they often collide with other atoms and molecules and emit all of their energy over a short distance. They penetrate biological tissue to a depth of about one-twentieth of a millimeter, crossing several cells.

Beta rays are electrically charged particles with a very low mass, usually electrons released during the decay of certain atomic nuclei. They penetrate biological tissue for distances ranging from several millimeters up to a few centimeters. Strontium-90 emits only beta rays.

Gamma rays are a form of electromagnetic radiation. After emitting alpha or beta rays, a nucleus often remains in an excited, high-energy state. Within a fraction of a second, this excess energy is emitted in the form of electromagnetic waves. Gamma rays can penetrate biological tissue and are similar to X-rays. Iodine-131, cesium-134 and cesium-137 emit gamma rays as well as beta rays. Their characteristic gamma energy levels make it relatively easy to identify these isotopes.

Neutron radiation consists of electrically uncharged nucleic particles that are emitted mainly during nuclear reactions. They are difficult to block, even with lead, but large amounts of water or paraffin are good shields. Neutron radiation is significant for people working in the nuclear industry, for the transportation of spent nuclear fuel and other nuclear waste, and when nuclear accidents occur.

Units of measure

The physical measure for the radioactivity of a substance is the frequency of radioactive decay per unit of time. The unit of measure for the **activity** of a substance used to be expressed by the measure Curie (Ci), but is now given in becquerels (Bq). The activity quantified by one **becquerel (Bq)** is the decay of one nucleus per second, regardless of whether this is alpha or beta radiation. One Curie corresponds to 37 billion becquerels. (This unusual number for a Curie is a result of the fact that one gram of radium decays at a rate of about 37 billion atoms per second. Radium earlier served as the standard against which other substances were compared.)

Many nuclear disintegrations per second (a high becquerel number) thus mean that a lot of ionizing radiation will be emitted. Few nuclear disintegrations per second (a low becquerel number) mean that little ionizing radiation will be emitted.

These units of measure are also used to express how much radioactive material a nuclear plant discharges. However, expressing values in becquerels is somewhat misleading and plays down the danger involved. Low values do not automatically mean less danger. The dangerousness of a radioactive isotope is determined not only by its momentary radioactivity, but also by its longevity. A comparison of the very different half-lives of the radioactive substances iodine-129 and iodine-131 makes this clear. As the following example illustrates, the same levels of activity are exhibited by completely different quantities of radioactive substances:

37 billion becquerels (1 Curie) of radiation come from six-millionths of a gram of iodine-131,
37 billion becquerels (1 Curie) of radiation come from 5.6 kilograms of iodine-129.

There is no explicit unit of measure for the effect of radioactivity that would define terms such as ‘radiation exposure’ or ‘radiation damage’ with precision. Effects are highly variable, depending on what the radiation is affecting (humans, animals, plants, dead matter, or even skin, lungs, gonads, genes, and so forth). Many of these effects have not been researched. Nonetheless, to attempt an estimation of them and the threat they pose, scientists have more or less agreed on the following terms and units for dosage:

The **absorbed dose** expresses how much energy remains present in the material affected by radiation and is described with the unit rad (radiation absorbed dose) or **Gray** (1 Gray = 100 rad). One Gray means that in 1 kilogram of a given substance, 1 watt-second or 1 Joule of energy remains present. This amount of energy is very small. Although a dose of 10 Grays represents enough radiation to kill a human being, converted to heat it could warm the body only by a few thousandths of a degree centigrade.

Yet it was soon recognized that expressing the energy absorbed by a material from radiation does not sufficiently describe its effect, certainly not where the biological effect is concerned. This also depends on the type of radiation. As explained above, there are four basic types of radiation. These are judged to have different potencies. Expressed somewhat more scientifically: they are evaluated with factors for their different biological potency (**Radiation Weighting Factors w_R**):

Radiation Type	**w_R-Factor**
Alpha	20
Beta	1
Gamma	1
Neutron	5 to 20, depending on the speed or energy of the neutrons

That means that alpha rays are estimated to be twenty times more potent than, for example, beta rays.

Thus the **equivalent dose** was introduced, measured in **sieverts (Sv)**, with

1 Gray alpha rays = 20 sieverts
1 Gray beta rays = 1 sievert
1 Gray gamma rays = 1 sievert
1 Gray neutron radiation = 5 to 20 sieverts

In this way, **organ absorbed doses** caused by external radiation are calculated. They are the product of the average absorbed dose of radiation in the organ or tissue and the radiation weighting factor.

The International Committee on Radiological Protection (ICRP) has drawn up lists of **dose coefficients** for the various radionuclides, so that radiation exposure inside the body can be converted into equivalent doses in becquerels for the radioactivity absorbed by inhaling or ingesting food. These lists are subdivided according to the type of absorption (breathing and swallowing) and also according to the age group of the people. These coefficients (in Sv/Bq), multiplied by the activity (in Bq), yield the equivalent dose (in Sv). Governments have declared the ICRP lists as binding for the calculation of radiation exposure.

Yet these are only estimates which are meant to facilitate comparisons between radiation effects. The radiation weighting factors and the dose coefficients are disputed. They depend not only on the type of radiation and the age of the person, but also on the level of the relevant amount of radiation, its distribution over time, the state of health of the person, organ or organ system impacted by the radiation, as well as whether or not the radiation occurs in conjunction with other adverse effects (mutually reinforcing, synergetic effects). The estimates are also invalid for other animals and plants.

The **effective dose** or in turn the **effective equivalent dose**, also expressed in sieverts, characterizes the sum of all organ absorbed doses multiplied by the accompanying **tissue weighting factor**. ‘Effective’ means here that these tissue weighting factors do not take into account possible illnesses, but only fatalities caused by radiation, as well as genetic damage only into the first subsequent generation. For example, German authorities weighted the thyroid gland at a mere 5 percent, arguing that today not everyone dies from thyroid cancer since it is easily operable. On the other hand, in terms of radiation exposure, the gonads are the most heavily weighted of all organs and organ systems at 20 percent.

All reservations aside, these figures expressed in sieverts are calculation values that are meant to represent the exposure of the human being to radiation. These are quite abstract assumptions that allow no individual prognosis for affected persons. Furthermore, data in sieverts represent no objective physical values. They are interim results of little use, from which the health consequences of radiation are supposed to be statistically estimated, in other words, the number of resulting additional cases of leukemia, radiation cancers, deformities, stillbirths, and so forth in a population exposed to radiation.

These impact assessments are subject to constant manipulation. The International Committee on Radiological Protection (ICRP) was founded by the lobby organizations of radiologists and the nuclear industry. Yet the governments responsible for setting standards follow their recommendations. The ICRP repeatedly emphasizes that radiation exposure of humans should be permitted so that all can enjoy "the economic and social advantages" of the nuclear industry. In the past, the ICRP has underlined that it hardly expects severe genetic disorders caused by radiation and fatal cases of cancer to result from recommended radiation values, and that at any rate, these can hardly be discerned in the "natural range of variation" of disorders and fatalities not caused by radiation. Mild mutations in progeny and a generally worse state of health would however be the most frequent consequences, although these could only be detected in epidemiological surveys. At no time have governments taken the trouble to document these more subtle effects on the state of health of their populations.

Rosalie Bertell, the Canadian scientist and recipient of the Alternative Nobel Prize, stated in her book, *No Immediate Danger: Prognosis for a Radioactive Earth* (1985; 1987 in German): "Workers, military service personnel and the general public have been given the impression that exposure to radiation involves a slight risk of dying of cancer and that one's chances of escaping this are better than the chances of escaping an automobile accident. The probabilities of early occurrence of heart disease, diabetes mellitus, arthritis, asthma or severe allergies – all resulting in a prolonged state of ill health – are never mentioned. Most people are unaware of the fact that ionising radiation can cause spontaneous abortions, stillbirths, infant deaths, asthmas, severe allergies, depressed immune systems (with greater risk of bacterial and viral infections), leukaemia, solid tumours, birth defects, or mental and physical retardation in children. Most of the above-mentioned tragedies affect the individual or family unit directly and society only indirectly."

The same holds true today and is also manifested in dose calculations which completely fail to take into account accelerated aging and senility after radiation exposure. Decisions about risks and benefits, based on the trade-off between health damage versus "economic and social advantages," have much more to do with the risks and benefits for society in the shape of government than on the price that the individual or the family has to pay.

The authors

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Dr.rer.nat **Sebastian Pflugbeil** is president of the German Society for Radiation Protection and member of the Otto-Hug-Strahleninstitut [radiation institute] in Bonn; he is also on the board of the European Committee on Radiation Risk (ECRR). He is involved in various education projects regarding the disasters at Chernobyl and Fukushima, and in particular in projects for the rehabilitation of children in affected areas. In 1990, he founded the Children of Chernobyl association in Berlin and for many years was on the board of the German Association for Chernobyl Aid in Munich. He co-founded the Neues Forum in 1989 [a citizens' movement in the late era of former East Germany], and in 1990 he served as minister for several months in the government under Hans Modrow, aiming to bring about change in East Germany's energy policy. Between 1991 and 1995 he represented the Neues Forum in the Berlin City Parliament.