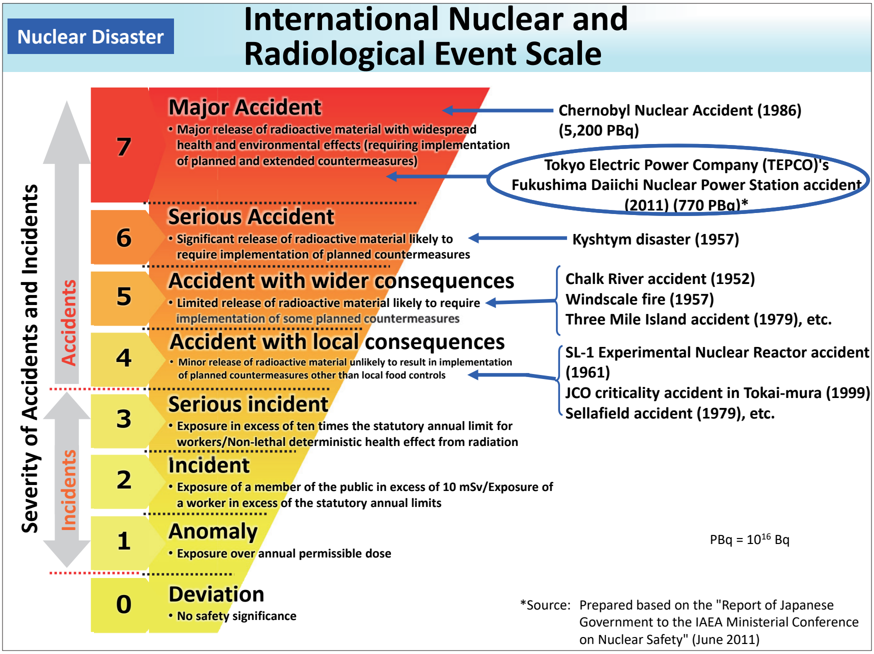


The International Nuclear and Radiological Event Scale (INES) was established by the INES (the International Atomic Energy Agency) and the OECD/NEA (Organization for Economic Co-operation and Development/Nuclear Energy Agency), and in 1992, all countries were recommended to formally adopt it.

Incidents and accidents at nuclear facilities are divided into seven categories according to their severity. Each country determines the severity of incidents or accidents using this scale and announces the results.

The accident at TEPCO's Fukushima Daiichi NPS was provisionally rated Level 7, indicating that it was the most serious accident because of the amount of radioactive materials released.

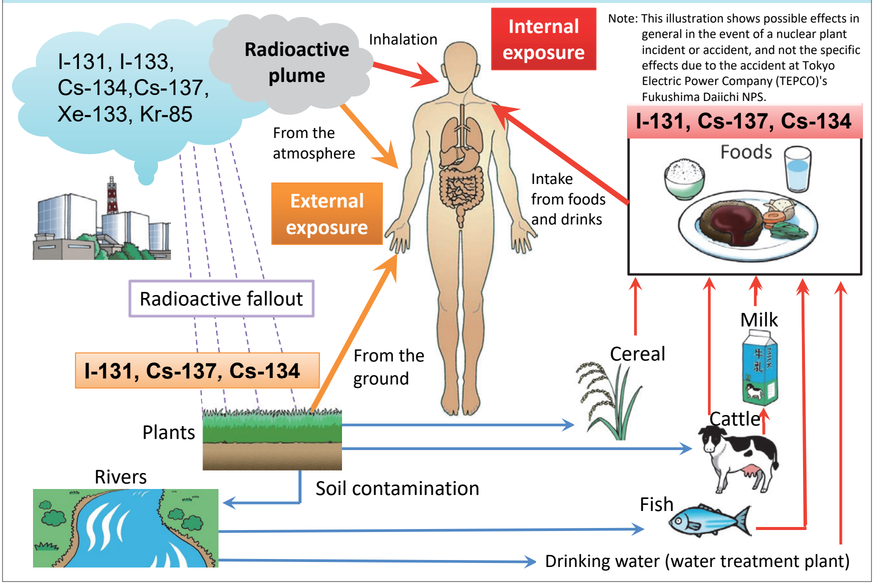
(Related to p.8 of Vol. 2, "International Nuclear Event Scale (INES)")

Included in this reference material on March 31, 2013

Updated on March 31, 2016

Nuclear Disaster

Effects of Reactor Accidents



If an emergency happens in a nuclear facility and radioactive gas leaks, it flows into the atmosphere in a state called "plume."

Plumes may contain radioactive noble gases and particulates such as radioactive iodine or Cesium-137.

Radioactive noble gases (krypton, xenon) are not deposited on the ground, and even if they enter the human body through inhalation, they do not remain in the body. However, people receive radiation emitted from radioactive materials contained in a plume passing overhead. This results in "external exposure." Radioactive iodine and cesium are deposited on the ground surface while a plume passes. Therefore, external exposure from deposited radioactive materials may occur even after the plume has passed.

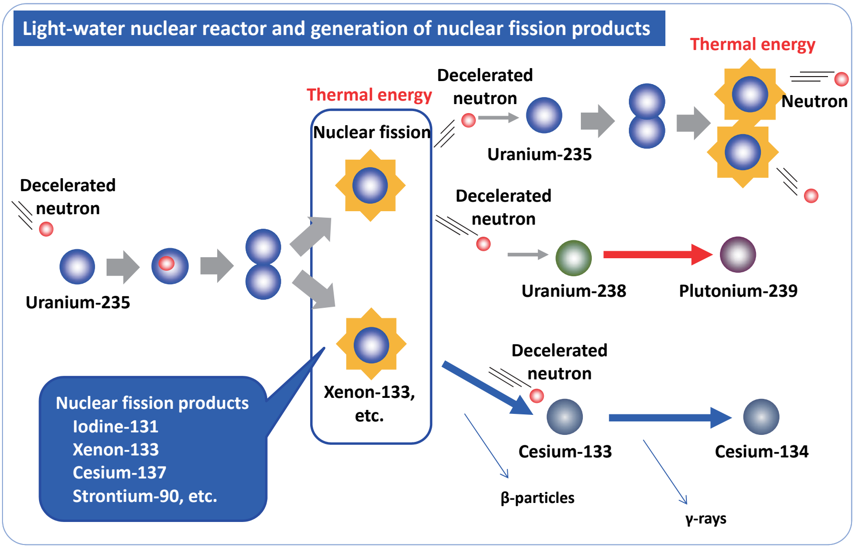
Internal exposure can also occur if one directly inhales radioactive materials while a plume passes or if one consumes drinking water or foods contaminated with deposited radioactive materials.

(Related to p.23 of Vol. 1, "Internal and External Exposure," and p.30 of Vol. 1, "Products in Nuclear Reactors")

Included in this reference material on March 31, 2013
Updated on March 31, 2015

Nuclear Disaster

Products in Nuclear Reactors



The light-water nuclear reactor is currently the most widely used type of reactor around the world (also used at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS). Bombarding enriched uranium fuel (Uranium-235: 3-5%; Uranium-238: 95-97%) with neutrons results in nuclear fission. Radioactive nuclear fission products such as Iodine-131, Cesium-137, and Strontium-90 are created in this process. When Uranium-238 is bombarded with neutrons, Plutonium-239 is created.

Cesium-134 is not created directly from the nuclear fission of Uranium-235. Through beta disintegration, Xenon-133 and the like, which are nuclear fission products, disintegrate into Cesium-133, and Cesium-133 then turns into Cesium-134 as decelerated neutrons are trapped.

As long as the reactor is working properly, these products remain in nuclear fuel rods and do not leak out of the reactor.

Nuclear facilities are equipped with a variety of mechanisms for preventing leakage of radioactive materials, but if they all stop functioning properly, radioactive leaks will occur.

Included in this reference material on March 31, 2013
Updated on March 31, 2016

Nuclear Disaster

Radioactive Materials Derived from Nuclear Accidents

	H-3 Tritium	Sr-90 Strontium-90	I-131 Iodine-131	Cs-134 Cesium-134	Cs-137 Cesium-137	Pu-239 Plutonium-239
Types of radiation	β	β	β, γ	β, γ	β, γ	α, γ
Biological half-life	10 days *1 *2	50 years *3	80 days *2	70-100 days *4	70-100 days *3	Liver: 20 years *4
Physical half-life	12.3 years	29 years	8 days	2.1 years	30 years	24,000 years
Effective half-life (calculated from biological half-life and physical half-life)	10 days	18 years	7 days	64-88 days	70-99 days	20 years
Organs and tissues where radioactive materials accumulate	Whole body	Bones	Thyroid	Whole body	Whole body	Liver and bones

Effective half-life: The time required for the amount of radioactive materials in the body to reduce to half through biological excretion (biological half-life) and the physical decay (physical half-life) of the radioactive materials; The values are cited from the "Emergency Exposure Medical Text" (Iryo-Kagaku Sha).
Effective half-lives are calculated based on values for organs and tissues where radioactive materials accumulate as indicated in the table of biological half-lives.
*1: Tritium water; *2: ICRP Publication 78; *3: JAEA Technical Manual (November 2011); *4: Assumed to be the same as Cesium-137; *5: ICRP Publication 48

Four types of radioactive materials, Iodine-131, Cesium-134, Cesium-137, and Strontium-90, are the major concerns in relation to health and environmental effects of radioactive materials released into the environment due to the accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS. While various other materials were also released, they are known to have shorter half-lives than these four types or have been released in negligible amounts.

Iodine-131 has a short half-life of about 8 days, but once it enters the body, 10-30% will accumulate in the thyroid. If this happens, the thyroid will continue to be locally exposed to β-particles and γ-rays for a while.

Two types of radioactive cesium, Cesium-134 and Cesium-137, are the major causes of contamination due to nuclear plant accidents. Cesium-137 has a long half-life of 30 years and continues to contaminate the environment for a long time. Since radioactive cesium has similar chemical properties to potassium, it will be distributed throughout the body, like potassium. The biological half-lives of cesium and iodine vary depending on the age of the person, and are known to become shorter, the younger the person is.

Strontium-90 has a long half-life, and once it enters the body, it accumulates in bones because of its chemical properties similar to calcium. Since it does not emit **γ**-rays, it is not as easy as in the case of Cesium-134 and Cesium-137 to detect where and how much it exists in the body. In a nuclear plant accident, Strontium-90 is also produced as a result of nuclear fission, though smaller in quantity than Cesium-134 and Cesium-137. Plutonium-239 and the like derived from the accident at TEPCO's Fukushima Daiichi NPS have also been detected, but detected amounts are almost equal to the results of the measurement conducted all over Japan before the accident.
(Related to p.30 of Vol. 1, "Products in Nuclear Reactors")

Included in this reference material on March 31, 2013
Updated on February 28, 2018

Nuclear Disaster

Comparison of Estimated Amounts of Released Radionuclides between Chernobyl and Fukushima Daiichi NPS Accidents

Nuclides	Half-life[a]	Boiling point[b] ℃	Melting point ℃	Release into the environment: PBq*		Fukushima Daiichi/ Chernobyl
				Chernobyl[d]	Fukushima Daiichi[e]	
Xenon (Xe)-133	5 days	-108	-112	6500	11000	1.69
Iodine (I)-131	**8 days**	**184**	**114**	**~1760**	**160**	**0.09**
Cesium (Cs)-134	**2 years**	**678**	**28**	**~47**	**18**	**0.38**
Cesium (Cs)-137	**30 years**	**678**	**28**	**~85**	**15**	**0.18**
Strontium (Sr)-90	29 years	1380	769	~10	0.14	0.01
Plutonium (Pu)-238	88 years	3235	640	1.5×10^{-2}	1.9×10^{-5}	0.0012
Plutonium (Pu)-239	24100 years	3235	640	1.3×10^{-2}	3.2×10^{-6}	0.00024
Plutonium (Pu)-240	6540 years	3235	640	1.8×10^{-2}	3.2×10^{-6}	0.00018

Ratio of radionuclides accumulated in the reactor core at the time of the accidents that were released into the environment

Nuclides	Chernobyl[f]	Fukushima Daiichi[g]
Xenon (Xe)-133	Nearly 100%	Approx. 60%
Iodine (I)-131	Approx. 50%	Approx. 2-8%
Cesium (Cs)-137	Approx. 30%	Approx. 1-3%

*PBq equals 1015Bq.

Sources: a: ICRP Publication 72 (1996); b and c (except for Np and Cm): Rikagaku Jiten 5th edition (1998); d: UNSCEAR 2008 Report, Scientific Annexes C, D and E; e: Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety (June 2011); f: UNSCEAR 2000 Report, ANNEX J; g: UNSCEAR 2013 Report, ANNEX A

This table shows a comparison between major radioactive materials released into the environment due to the Chernobyl accident and the Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS accident.

Among them, Cesium-134 and Cesium-137 are the major radionuclides that could pose health threats. The table shows the melting and boiling points of the respective nuclides.

Cesium has a boiling point of 678°C and is therefore in a gaseous state when the nuclear fuel is in a molten state (its melting point is 2,850°C). When cesium in a gaseous state is released into the atmosphere, it goes into a liquid state when the temperature within the containment vessel drops below its boiling point, and it further becomes particulate at temperatures below its melting point of 28°C. Thus, cesium is mostly in a particulate form in the atmosphere and will be diffused over wide areas by wind. This was roughly how radioactive cesium was spread to distant areas in the Fukushima Daiichi NPS accident.

Although it is difficult to directly compare the released amount between the Chernobyl accident and the Fukushima Daiichi NPS accident, the larger amount released at the time of the Chernobyl accident is considered to have been partly due to the fact that the core exploded and was directly exposed to the atmosphere. In contrast, a relatively small amount was released from TEPCO's Fukushima Daiichi NPS as extensive destruction of the containment vessel was barely avoided, making it possible to curb temperature declines and reduce leaks and releases of radioactive materials.

However, some noble gases such as Xenon-133 that are easily released into the atmosphere are considered to have been released also from the reactors at TEPCO's Fukushima Daiichi NPS at a high percentage (Fukushima Daiichi: approx. 60%; Chernobyl: up to 100%). The large power capacity (Fukushima Daiichi: total of approx. 2,000,000 kW; Chernobyl: 1,000,000 kW) and the large amount of noble gases remaining in the core at the time of the accident are considered to have caused the release of large amounts of noble gases from TEPCO's Fukushima Daiichi NPS.

Included in this reference material on March 31, 2017