Information on nuclear safety and emergency preparedness

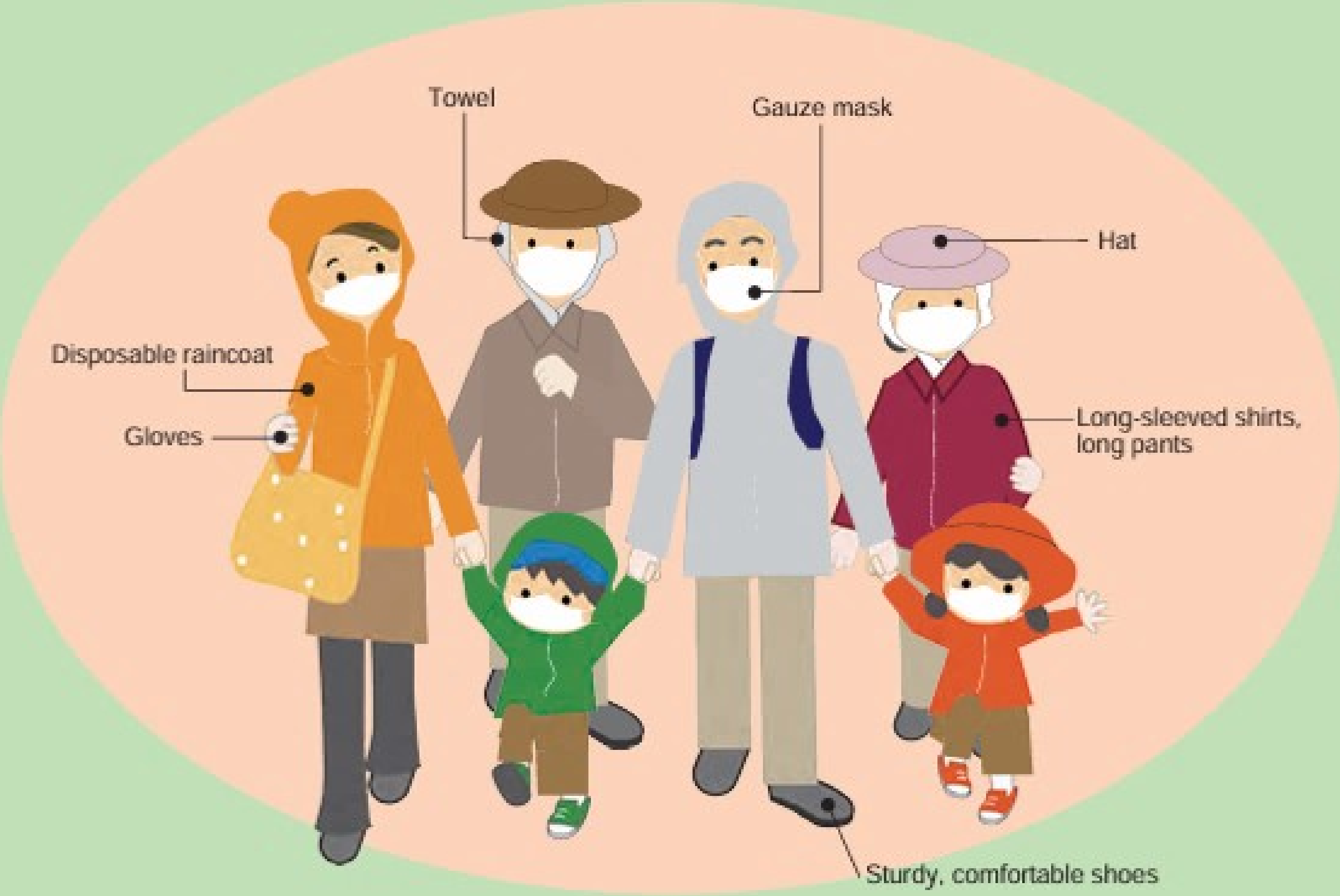
Tokai Village office

Important:

What to do if there is an evacuation instruction after a nuclear accident or disaster.

Take valuables with you but minimize the amount of luggage.
Wear a hat, long-sleeved outerwear, and long pants.

It is important to minimize exposure of your skin to the air.



Wear outerwear, such as a raincoat or rainwear, so that dust is prevented from getting into or under your clothes.

March 2023

Disaster Prevention and Nuclear Energy Safety Section
Villager Life Department

https://www.vill.tokai.ibaraki.jp/section/gensiryoku/
Tel.029-282-1711

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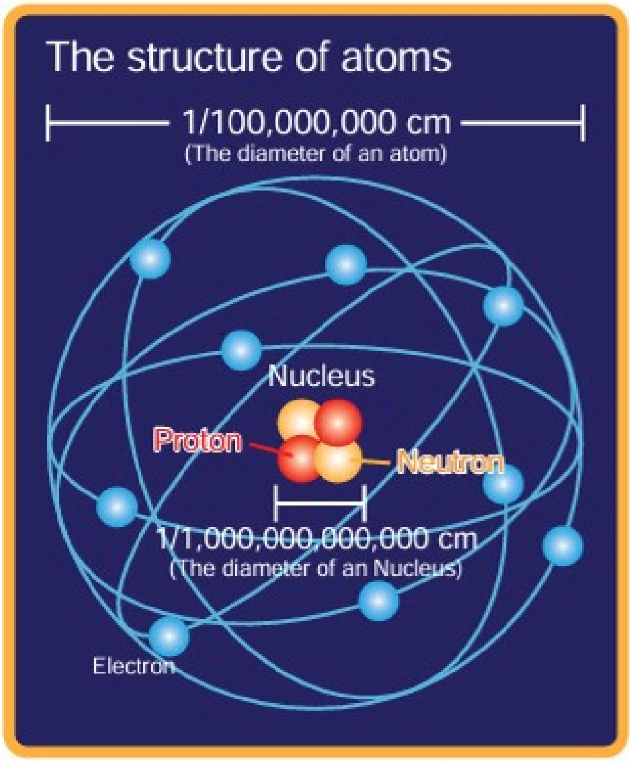
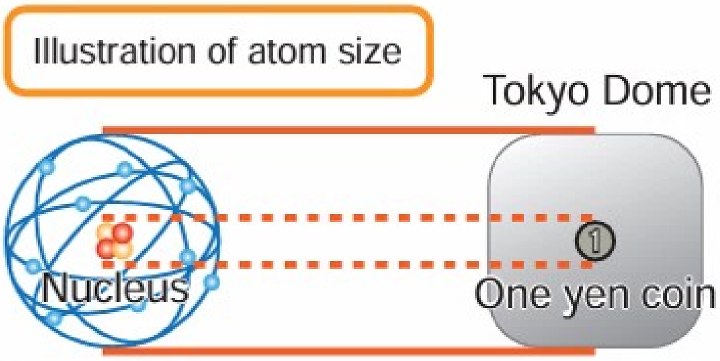
Atoms and nuclear fission

Atoms

Everything in this universe is made up of combinations of many different kinds of "atoms".
The diameter of an atom is very small, approximately 1/100,000,000 cm. Atoms are composed of a "nucleus" at the center, which has "electrons" orbiting around it; the nucleus itself is made up of "protons" and "neutrons".

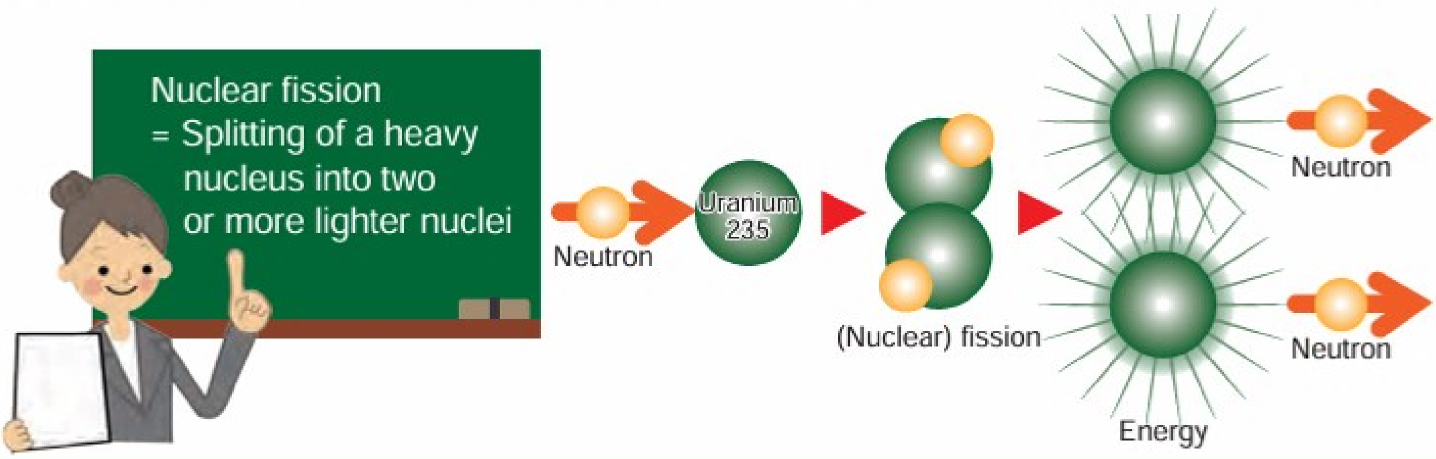




In every atom, electrons orbit the nucleus at a distance approximately 10,000 to 100,000 times greater than the size of the nucleus. If the size of the nucleus is scaled to the size of a one yen coin placed at the center of Tokyo Dome, its electrons would be in orbit at approximately the boundary of Tokyo Dome.

Nuclear fission

■Relation between nuclear fission and nuclear power
Atoms can change into different atoms through a process called "transmutation", and this can happen by, for example, nuclear fission, nuclear fusion, or radioactive decay. The energy released by nuclear transmutation is called "nuclear power".
In particular, "nuclear fission" releases a very large amount of energy. Heavy nuclei, such as uranium, split into two or more lighter nuclei when hit by a neutron (nuclear fission). When this happens, heat and radiation, such as neutrons and gamma rays, are released.
There are two types of uranium: uranium 235, which undergoes nuclear fission easily, and uranium 238, in which nuclear fission is more difficult. Uranium 238 transmutes into plutonium 239 when it absorbs a neutron; plutonium 239 easily undergoes nuclear fission.



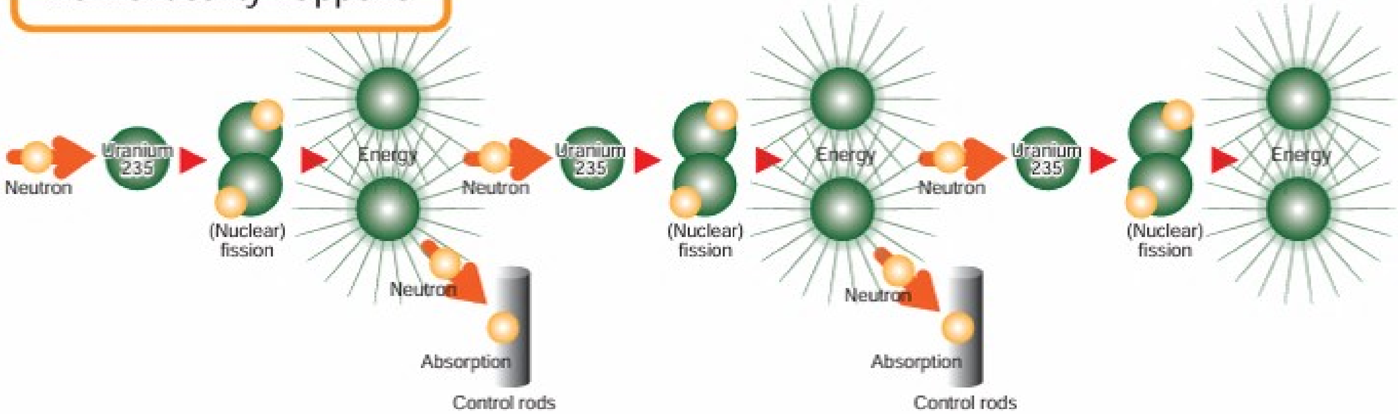
Criticality and radioactivity

Criticality

When a uranium 235 atom undergoes nuclear fission, two to three new neutrons are released and these then cause other nuclear fissions. Such a continuous chain of nuclear fission is called a "chain reaction of nuclear fission", and the state where this chain reaction continues at the same rate is called "criticality". Criticality should happen in a nuclear "reactor" facility, where there are "control rods" to control the criticality state. However, when criticality happens where it is not supposed to, such as outside a reactor, radioactive material and radiation leak out of the facility, which could result in serious accidents.

In the nuclear accident that happened at JCO Co., Ltd., a fuel processing facility in Tokai Village, on September 30, 1999, a criticality happened in a facility where it was not intended, and a nuclear chain reaction continued for about 20 hours. As there was no thick concrete wall to contain the radiation, some of it, including neutron rays, escaped to the atmosphere outside the facility.

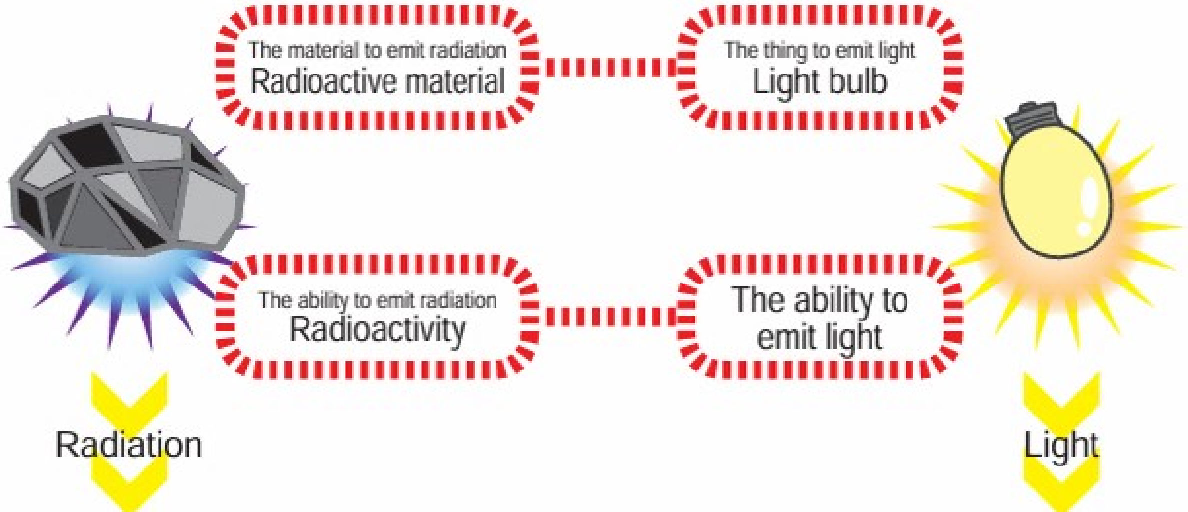
How criticality happens



Radioactivity and radiation

Uranium ore contains "radioactive material" such as uranium and radium. These materials emit rays that are similar to light rays, although they are invisible. This is called "radiation". The ability to emit radiation is "radioactivity", and materials with radioactivity are "radioactive materials". In an analogy, if we think of radioactive material as being a light bulb, its radioactivity is its power to emit light.

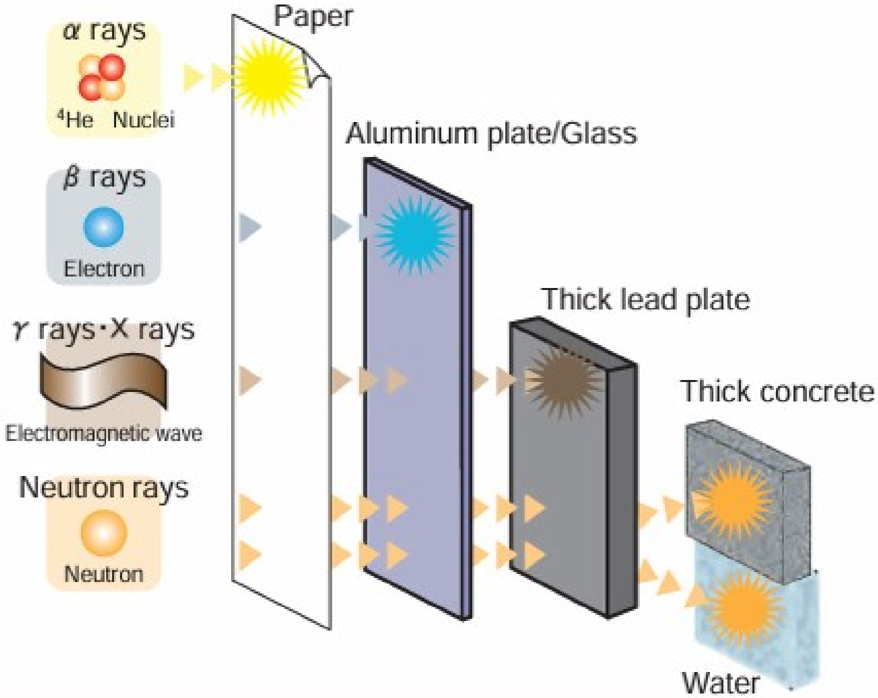
Difference between radiation, radioactivity, and radioactive materials



Radioactivity and radiation

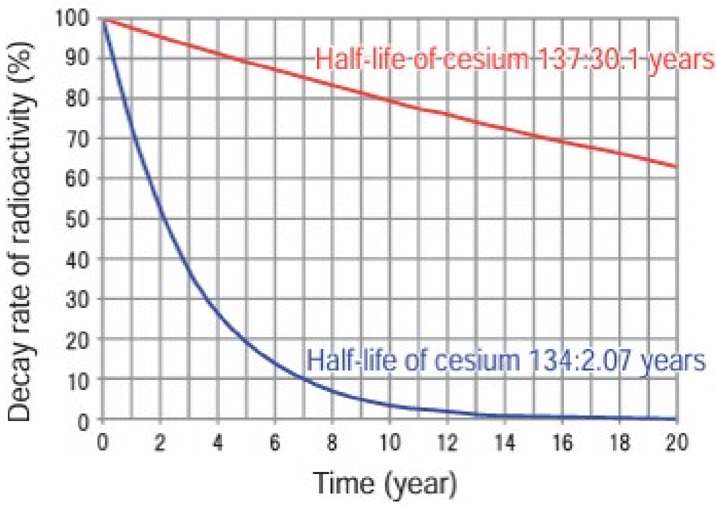
Types of radiation

Radiation types include α (alpha) rays, β (beta) rays, γ (gamma) rays, and neutron rays. X-rays that we use in health examinations are also radiation, and are a type of electromagnetic wave similar to γ rays. These types of radiation each have different penetrating power (ability to penetrate matter), for instance, α rays can be stopped with a sheet of paper, while neutron rays penetrate thick lead plates, but can be stopped by water or thick concrete.



Half-life

The radioactivity of radioactive materials becomes weaker over time. The time needed for the amount of radioactivity to decrease to the point where it is only half as strong as it was originally, is called its half-life. The half-life depends on the radioactive material; it can be as short as 1/1,000,000 of a second, or as long as 10 billion years. For example, the decay rate of cesium, which was released during the accident at the Fukushima Daiichi nuclear power station, is shown in the figure.



Units of radiation and radioactivity

Humans cannot directly feel radiation or radioactivity, but its strength and amount can be measured.

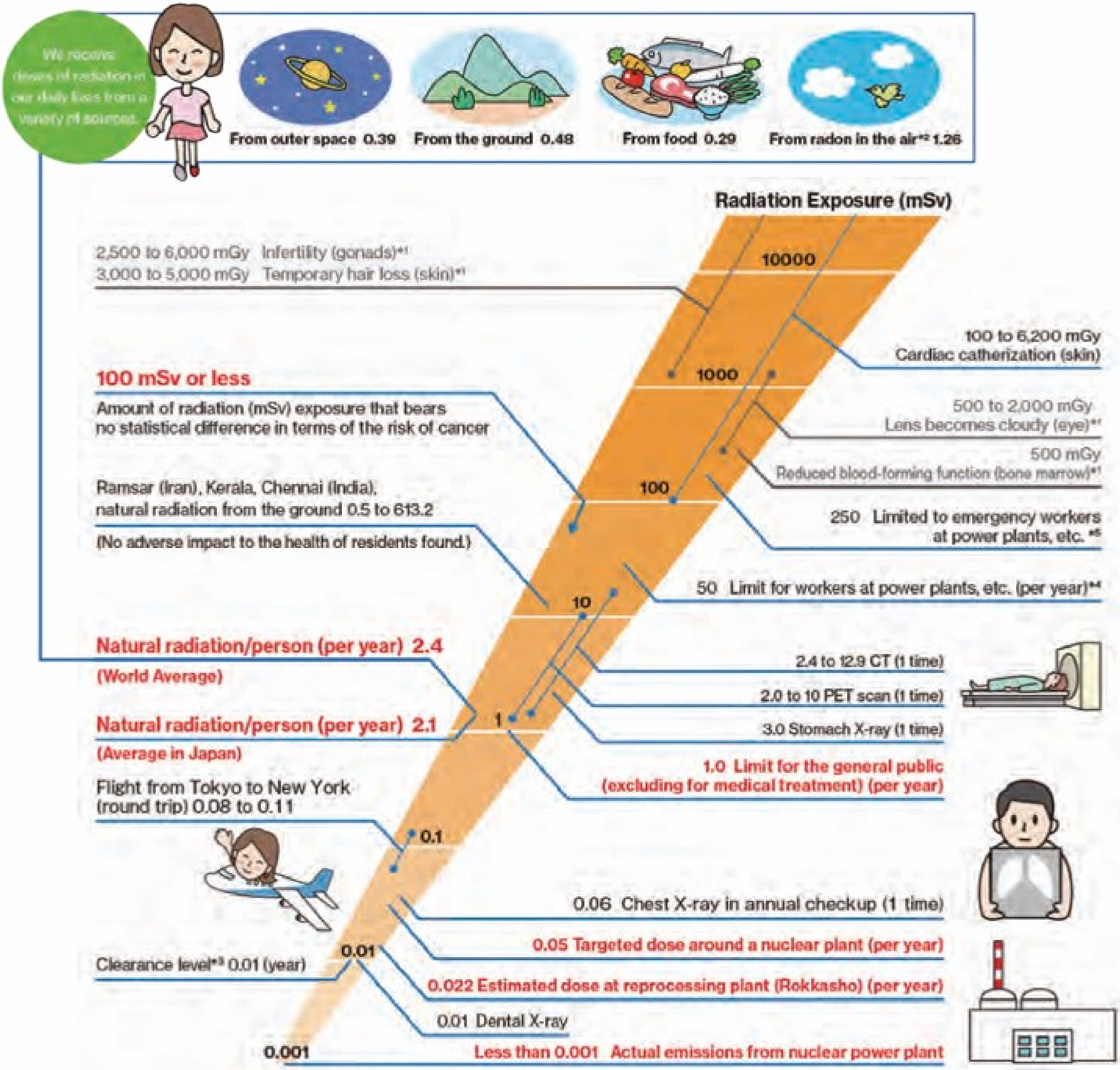
[Units of radiation dose and radioactivity]

	Unit	Symbol	Explanation
Unit of radiation dose	Gray	Gy	Unit of energy that is absorbed when radiation hits a material
	Sievert	Sv	Unit of effect when a human body is exposed to radiation
Unit of radioactivity	Becquerel	Bq	Unit of radioactivity of a radioactive material, which is the number of nuclei that cause radioactive decay (nuclei that emit radiation and are then destroyed) in one second

Radiation exposure in daily life

Radiation exposure in daily life

We are exposed to various types of radiation in daily life. An example is "background radiation", which comes from radioactive materials in nature, and cosmic rays from space. There is also "artificial radiation" from medical equipment used for the diagnosis and treatment of diseases. Receiving radiation is called "exposure", and the global average for exposure from background radiation is approximately 2.4 millisieverts (mSv) per year. This level of background radiation does not affect our bodies, while sudden exposure to a large amount of radiation can have seriously adverse effects on the human body.



* 1:When discussing radiation hazards, it is expressed as equivalent to an effective dose of 1 mSv, given that a dose of 1 mSv of gamma radiation is absorbed evenly by each part of the the entire body
* 2:Radioactive substances naturally present in the air
* 3:Insignificant compared to naturally-occurring radiation levels, and the level does not require handling as a radioactive substance that presents a safety risk.
* 4:Dose of radiation that must not be exceeded in 1 year is 50 mSV for workers at places such as power stations, or 100 mSv over 5 years.
* 5:The dose limit was raised to 250 mSv to emergency workers from April 2016 due to the revision of the Ionizing Radiation Hazard Prevention Regulations, etc.

Sources: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2008 Report, Nuclear Safety Research Association, Radiation in the Environment, New Edition, 2011, and ICRP, Publication 103, with others

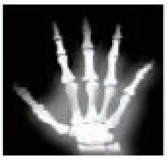
Use of radiation

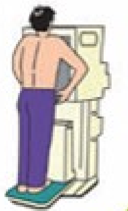
Radiation is effectively used in various fields around us in our society.

Use in medical care

Radiation is used for both diagnosis and treatment in the medical field. Radiographic examinations, X-rays, CT scans and nuclear medicine examinations (RI examinations) such as PET scans are widely used in diagnosis. In treatment, radiation is used to treat tumors effectively, which is one of the areas where further progress is expected.

- Boron Neutron Capture Therapy (BNCT) using neutron beams
- Particle therapy (proton therapy, heavy particle therapy)
- Sterilization of medical equipment and hygiene products





Use in agriculture

<u>Selective breeding</u>

Efficient breeding is possible by selecting breeds with useful characteristics among a variety of mutants created through irradiating plants with gamma rays. Many kinds of new breeds have been produced, such as large-grained, starchy rice for sake brewing and pears resistant to black spot disease.

<u>Pest control</u>

By releasing large numbers of pests sterilized by gamma irradiation, the probability that they will mate but not produce offspring is increased, and the number of pests is reduced and eventually eradicated over several generations. This method does not harm people or the environment whereas massive pesticide application could.

<u>Food irradiation</u>

Irradiating food and agricultural and livestock products with gamma rays or electron beams can prevent germination, have effects of sterilization and insecticide, and extend the shelf life of food products.

Use in industry

<u>Material processing</u>

Irradiation can modify materials to improve the functionality of strength, heat resistance, and wear resistance. For example, irradiating rubber with electron beams can increase strength and high-quality radial tires for cars can be precisely produced.

<u>Inspection and measurement</u>

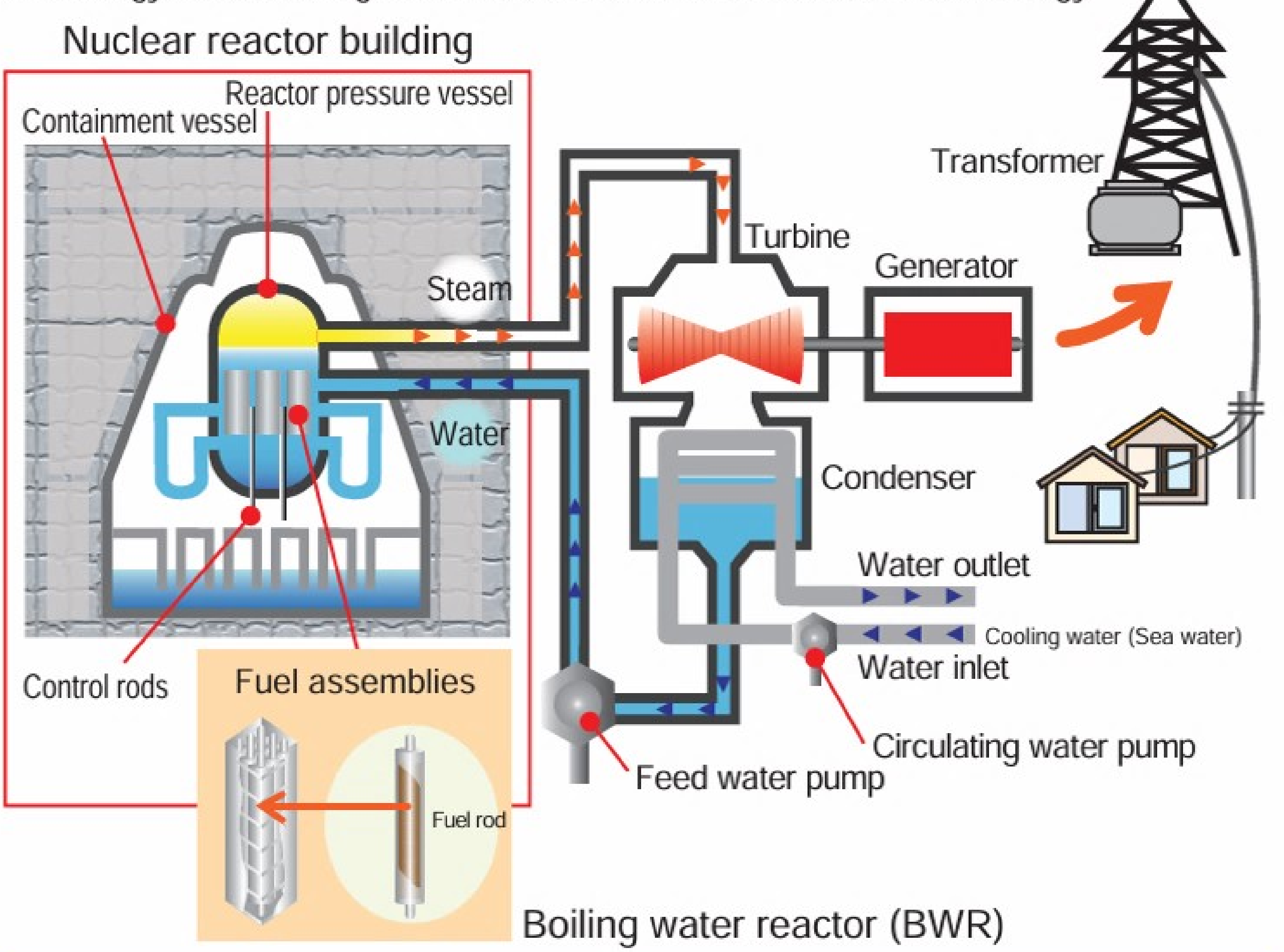
Radiation is used for precise measurements of thickness, density, and moisture content and nondestructive inspections of parts and products, such as a nondestructive inspection to examine the internal damage and deterioration of concrete structures, plant equipment diagnosis, engine wear inspection and aircraft weld inspection.

Source: "White Paper on Nuclear Energy 2021" (Excerpt), Atomic Energy Commission

Nuclear power generation

Mechanism of nuclear power generation

Nuclear power generation makes the electricity that we need in our lives, by converting the heat energy emitted during the nuclear fission of uranium into electrical energy.



Boiling water reactor (BWR)

Thermal power generation and nuclear power generation

Thermal power generation and nuclear power generation use the same principle, where water is boiled to make steam, and its force is then used to rotate turbines and make electricity. The largest difference is the fuel (thermal energy) used to boil the water. Thermal power generation uses energy from combustion of petroleum, natural gas, or coal, while nuclear power generation uses energy released by the nuclear fission of uranium.

Fuel for nuclear power generation

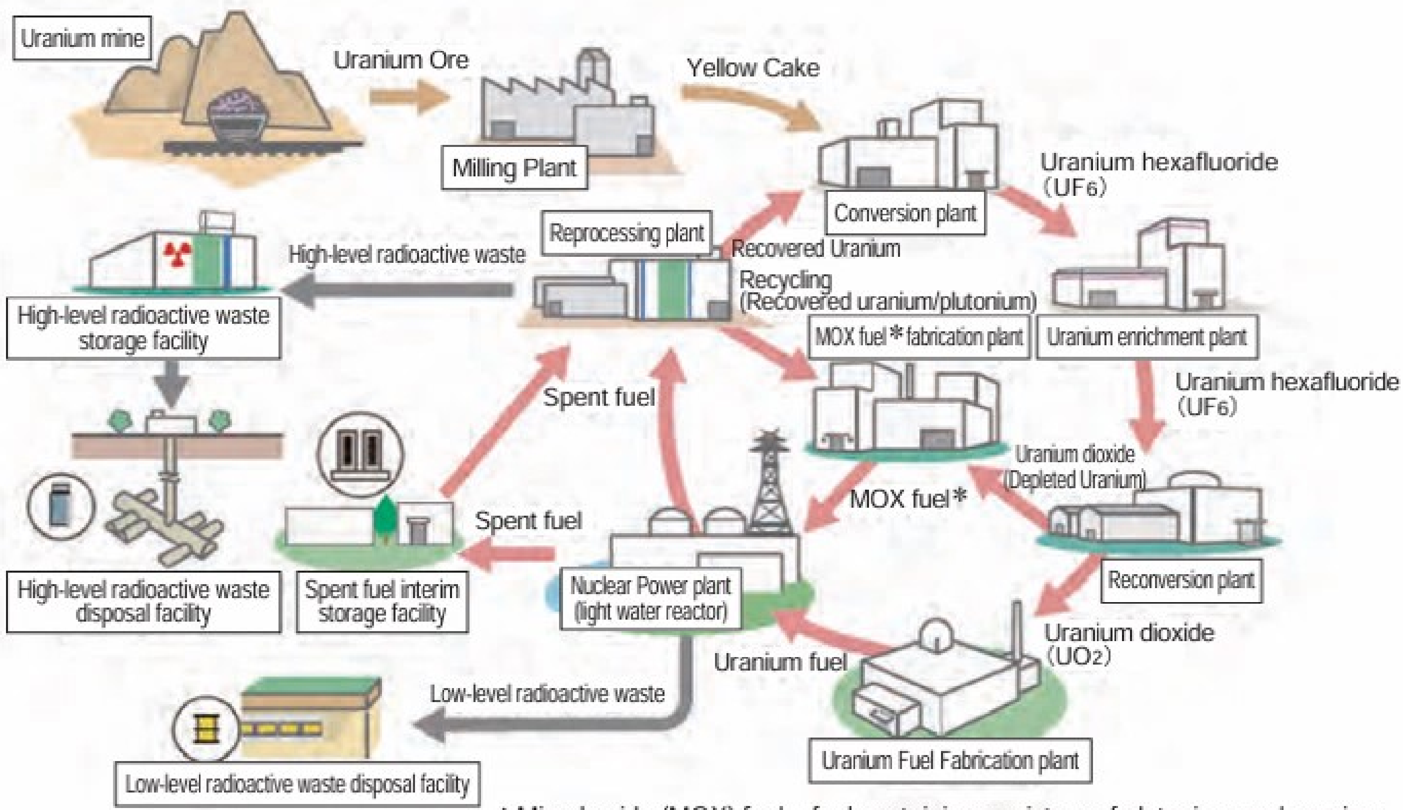
Fuel used in nuclear power generation is called "nuclear fuel" or "atomic fuel", and radioactive material, such as uranium, is used. Nuclear fuel contains uranium 235, which is a concentrated form of natural uranium that makes nuclear fission more likely to happen. Concentrated uranium is ground into powder, sintered into pellets in a process like making pottery, to enhance safety, and then placed into a sealed alloy tube to make a "fuel rod". A "nuclear fuel assembly", where many fuel rods are bundled together, is used in a reactor. Criticality from this nuclear fuel is maintained in a reactor, and the resulting thermal energy is used to make electricity. "Control rods" are used to manage the criticality state.

Processing after nuclear power generation

Nuclear fuel cycle

Fuel that has been used in a nuclear power plant, "spent fuel", can be reused by removing uranium and plutonium in a reprocessing plant, and then sending the extracted uranium and plutonium to a conversion plant and a mixed oxide (MOX) fuel fabrication plant, respectively. This flow is known as the nuclear fuel cycle.
Using MOX fuel, where plutonium and uranium are mixed in nuclear power generation, is called "pluthermal" in Japan.

Nuclear fuel cycle



＊Mixed oxide (MOX) fuel…fuel containing a mixture of plutonium and uranium

Sources: Graphical Flip-chart of Nuclear & Energy Related Topics (Partially modified)

Processing and disposal of radioactive waste

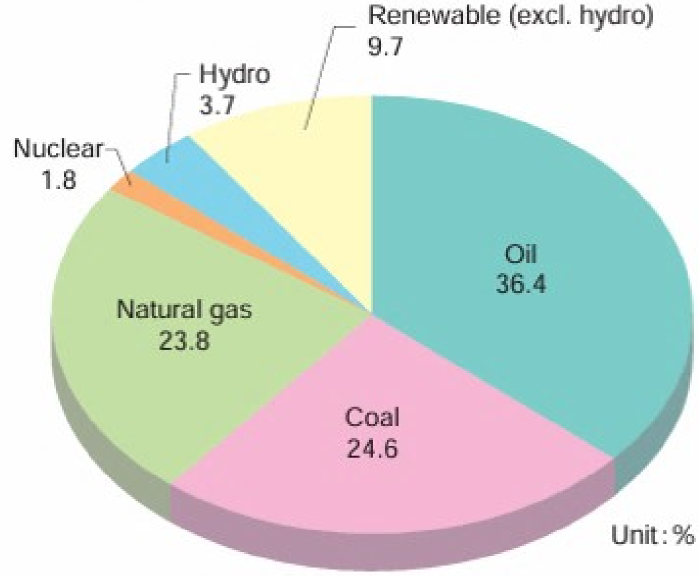
Operating nuclear power plants and reprocessing spent fuel generates effluent containing radioactive materials, as well as waste contaminated with radioactive materials. Such waste is called "radioactive waste", and must be properly processed and must then be disposed of carefully. The correct disposal method depends on the type of radioactive material and its concentration. Radioactive waste can be categorized as "low-level radioactive waste" or "high-level radioactive waste", containing low and high concentrations of radioactive materials, respectively.
Most radioactive waste is low-level radioactive waste, and includes materials such as paper towels used to clean up, work clothes, gloves, and wastewater from equipment. The volume of this waste is reduced by concentration, compression, and/or combustion, and is then hardened, for instance by using cement, sealed in metal drums, and then disposed of by burial.
Examples of high-level radioactive waste include the nuclear fission products that remained after extracting uranium and plutonium in a reprocessing plant. These require more stringent management, and careful measures are taken as part of their disposal into a stable geological layer more than 300 meters below the ground level.

Nuclear energy

Various energy sources

Among energy sources necessary for daily life and economic activities, the ratio that can be secured within a country is called energy self-sufficiency. Japan's energy self-sufficiency rate peaked at 58.1% in FY1960 and has declined significantly since then, due to the shift of fuel from domestically produced coal to oil. Today, almost all oil, natural gas, and coal are imported. Uranium, necessary for nuclear power generation, is also imported from abroad. Although the diversification of energy sources has progressed, the dependence on fossil energy in 2020 was significant at 84.8%. In particular, oil accounts for just under 40% of the total, most of which is imported from the Middle East.

Energy sources used in Japan (FY2020)

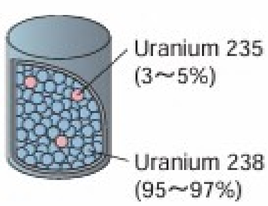
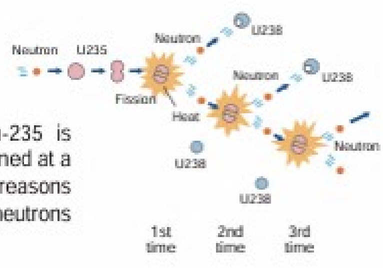
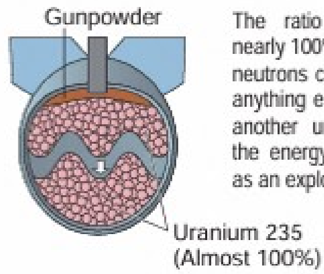
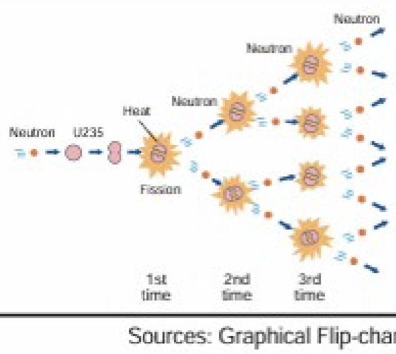


(Note 1) In "Comprehensive Energy Statistics", the calculation method for the figures has been changed since FY1990.
(Note 2) "Renewable (excl. hydro)" refers to solar, wind, biomass, geothermal, etc.

Source: Ibaraki Prefecture Nuclear Power and Energy Book for High School Students, 2022 Edition (excerpts)

Difference between nuclear power generation and atomic bombs

Nuclear power generation and atomic bombs both use energy from the nuclear fission of uranium. Atomic bombs must generate a vast amount of energy in an instant, thus highly enriched uranium, with close to 100% concentration of uranium 235, which easily undergoes nuclear fission, is used. In contrast, nuclear power generation aims to boil water continuously, thus low-enriched uranium, with 3-5% uranium 235 concentration, is used. Moreover, many control rods, consisting of material that absorbs neutrons, are placed like sleeves around the fuel rods in the reactor, to control the radiation emitted by the nuclear fission reaction.

	Ratio of Uranium-235 to Uranium-238 & Chain Nuclear Reaction	Method of Controlling Fission Rate
In a Nuclear Power Plant	 The ratio of Uranium-235 is low, so fission is sustained at a constant scale, for reasons such as absorption of neutrons by Uranium-238. 	Many control rods are installed and the reactions are self - limiting, so the rate of fission cannot increase rapidly.
In a Nuclear Bomb	 The ratio of Uranium-235 is nearly 100% and at this high level neutrons cannot be absorbed by anything else, so one atom after another undergoes fission and the energy is released instantly as an explosion. 	No control rods are installed and the reactions are not self - limiting, so the rapid increase in fission cannot be stopped.

Sources: Graphical Flip-chart of Nuclear & Energy Related Topics

Nuclear emergency

Nuclear emergency

Nuclear power plants take various multi-layered safety measures to ensure that, if there is an accident or breakdown, the immediate external release of large amounts of radioactive material is prevented. However, if the situation is serious and large amounts of radioactive materials are released outside a nuclear facility, that could result in contamination of the nearby environment and exposure of the residents. Such a situation is called a "nuclear emergency".
Taking measures to minimize damage and protect the safety and assets of residents in case of a nuclear emergency is called "nuclear preparedness".

Characteristics of a nuclear emergency

Nuclear emergencies have unique characteristics which are absent from fires, or natural disasters such as earthquakes, storms or floods.

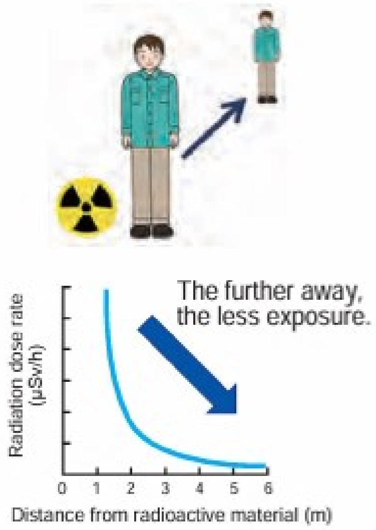
1. We cannot use our five senses to detect radiation, which is invisible, silent, and has no smell.
2. We cannot judge the extent of exposure by ourselves. Special measurement equipment is necessary.

Nuclear emergency preparedness

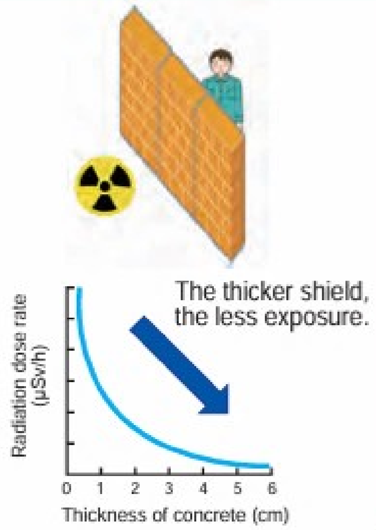
Disaster preparedness is to protect the lives, health, and assets of residents, workers and visitors from disasters, and to provide support for disaster victims and recovery from disasters, should a disaster occur. This is also true for nuclear emergency preparedness.
The most important point in nuclear emergency preparedness is to strengthen safety measures in nuclear facilities, and many measures are actually taken in the design, construction, and operation of nuclear facilities. However, it is important for us to know the basic facts on radiation and radioactivity, as well as the correct actions to take in order to minimize exposure in the case of a nuclear emergency.
There are three fundamental principles for radiation protection, as shown below.

Three principles to reduce external exposure

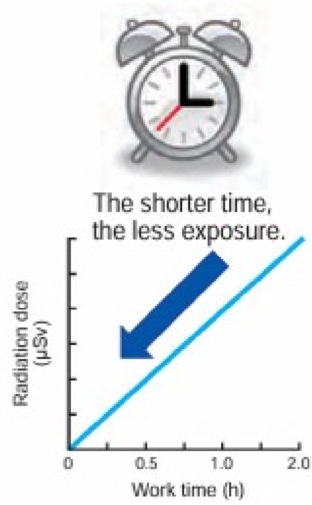
1 DISTANCE: Increase distance from the radiation source.



2 SHIELD: Block radiation by using a suitable shield.



3 TIME: Reduce exposure time.



In case of an emergency

Get accurate information first!

In case of a nuclear emergency, Ibaraki Prefecture and Tokai Village will promptly announce information, using disaster management radio communications, webpages, social networking sites (SNS), emergency alert emails, sound trucks, TV, and radio.

Use the information to help stay calm. Take note of the following points:

- ○Obtain accurate information, using disaster management radio communications, emergency alert emails, TV and/or the radio. Listen carefully to make sure you understand the information correctly.
- ○Do not act as you wish or against the public advice. Stay indoors until there are further instructions from the national or municipal government.
- ○Do not be misled by rumors or false information.
- ○Exchange information with your neighbors and check their safety.
- ○Refrain from asking for information by phone as much as possible, as phone calls may occupy phone lines unnecessarily and hinder emergency response activities.

Major information from Tokai Village

1. Situations of an accident or disaster
2. Countermeasures of national and municipal governments (Evacuation, radiation monitoring)

Remain calm and stay indoors.

Obtain accurate information, using disaster management radio communications, emergency alert emails, TV and/or the radio. Listen carefully to make sure you understand the information correctly.

Exchange information with your neighbors and check their safety.

Refrain from asking for information by phone as much as possible, as phone calls may occupy phone lines unnecessarily and hinder emergency response activities.

Do not be misled by rumors or false information.

In case of an indoor sheltering or evacuation instruction

In case of an instruction to shelter indoors

In case of an indoor sheltering instruction, promptly go to an indoor location, such as your home. In order to prevent exposure and contamination by radioactive materials, follow these instructions:

1. Close all doors and windows.
2. Shut down ventilation systems.
3. Shut down air conditioning if it takes in air from the outside.
4. People returning from outdoors should wash their hands and face, and change clothes, placing the clothing that was worn outside in a vinyl bag.
5. Collect information from TV, radio and the Internet.

In the case of an evacuation instruction

In the case of an evacuation instruction, confirm your evacuation center and assembly point for evacuation, and then act calmly. Try to be aware of the following information:

1. Which region is affected?
2. Is everyone in the region affected? Or only some people?
3. When and where should people meet, and where are people going?
4. How should people move? By private vehicle, bus, or by some other means?
5. Was there an instruction from national or municipal government regarding the preventive use of stable iodine pills?

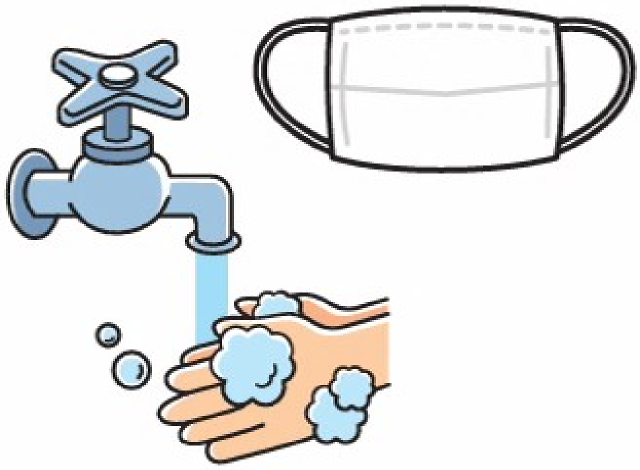
*Stable iodine pills are pharmaceutical products. Take the pills only when instructed by the national or municipal government and follow their dosage guidelines in the event of a nuclear emergency.

Check before evacuation.

1. Unplug electrical appliances and shut off the main gas valve before evacuation.
2. Lock windows and doors.
3. Talk with your neighbors and help each other.
4. Take only minimal belongings, but do not forget valuables and medicine.

During the new coronavirus pandemic

- During evacuation, take measures to prevent infection such as keeping distance from others, wearing masks and washing hands.
- When evacuating indoors at home, etc., give priority to avoiding exposure to radioactive materials. As a rule, do not ventilate rooms while an indoor evacuation order is in effect.



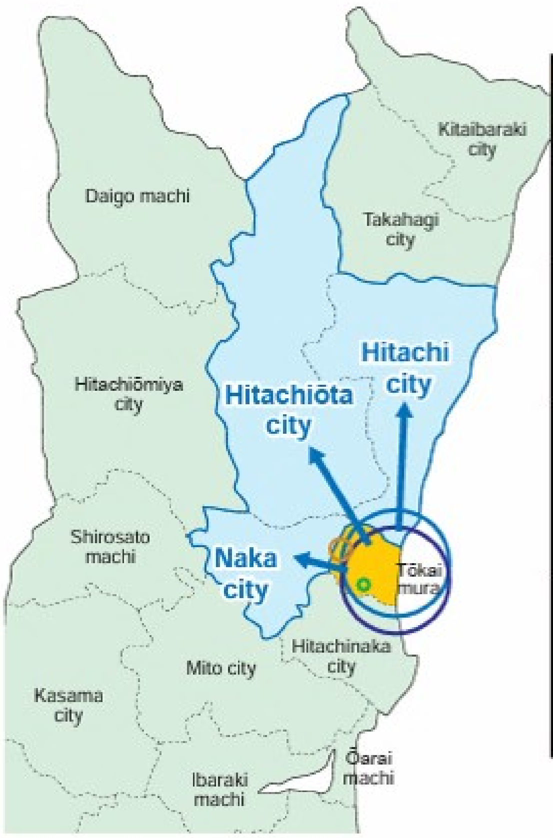
Evacuation destinations

Tokai Village Regional Evacuation Planning

Nuclear facility	Area	Evacuation destination
Tokai No.2 Power Station (Power reactor facility) PAZ: approx. 5km* UPZ: approx. 30km*	All areas of Tokai Village	Toride City, Moriya City, Tsukubamirai City

* PAZ (Precautionary Action Zone): Zones where precautionary protective measures such as immediate evacuation are to be prepared in the situation before radioactive substances are released, to avoid or minimize radiation exposure.
* UPZ (Urgent Protective Action Planning Zone): Zones where urgent protective measures such as indoor sheltering and evacuation are to be prepared in phases before and after radioactive substances are released, to reduce the risk of radiation exposure.

Tokai Village Indoor Sheltering and Evacuation Guidance Planning



Nuclear facility	Area	Evacuation destination
JRR-3 (Research reactor facility) UPZ: approx. 5km	All areas of Tokai Village	Hitachi City, Hitachiota City, Naka City
Reprocessing facility UPZ: approx. 5km	All areas of Tokai Village	Hitachi City, Hitachiota City, Naka City
Mitsubishi Nuclear Fuel (Fabrication facility) UPZ: approx. 1km	Funaishikawa-Ikku, Tojuku-Ikku, Funaba-ku	Within Tokai Village (Ishigami, Muramatsu, Nakamaru, Shirakata, Masaki Community Center), Hitachiota City
Nuclear Fuel Industries (Fabrication facility) UPZ: approx. 0.5km	Kawane-ku, Midorigaoka-ku, Oshinobe-ku, Suwama-ku	Within Tokai Village (Masaki, Funaishikawa, Muramatsu Community Center)