Radiation Safety Course
(School of Science, the University of Tokyo)

Biological Effects of Radiation to Human Body

FY2025

UTokyo

東京大学 理学部 放射線管理室

RADIATION MANAGEMENT OFFICE, SCHOOL OF SCIENCE, THE UNIVERSITY OF TOKYO

Japanese

Slides & Documents

Documents for the Radiation Course

- Radiation Safety Manual (English version)
- Radiation Safety Manual (Japanese version)
- Regulation on Prevention of Radiation Hazards (Japanese only)

Slides for the Radiation Course

- RadiationCourse-Regulations
- RadiationCourse-Biology
- RadiationCourse-TopicAndSafety

UTokyo Radiation Re-education Materials

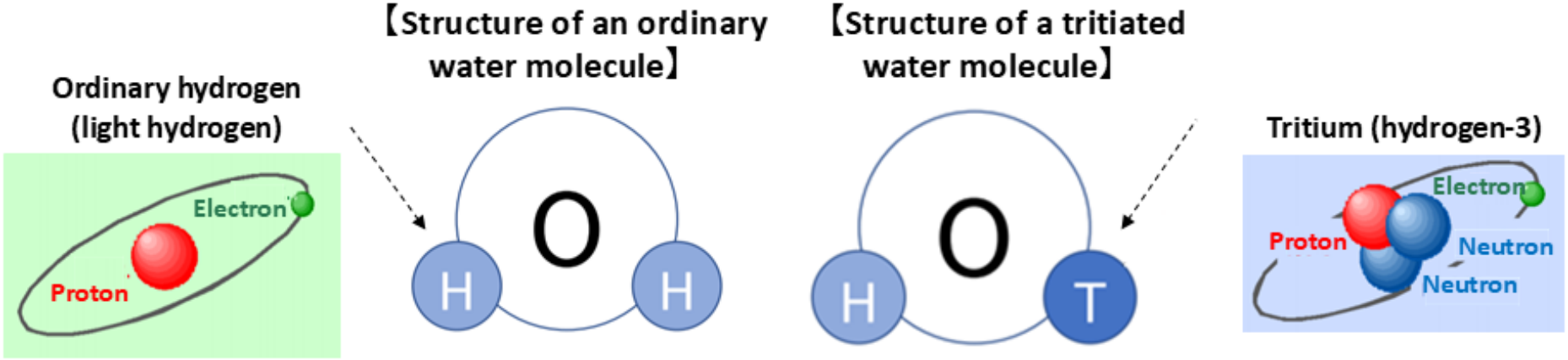
- Radiation Re-education Materials No.43 (2025)
edited by the Division for Environment, Health and Safety (EHS), UTokyo.
- Radiation Re-education Materials No.42 (2024)
edited by the Division for Environment, Health and Safety (EHS), UTokyo.
- Radiation Re-education Materials No.41 (2023)
edited by the Division for Environment, Health and Safety (EHS), UTokyo.

2025

RADIATION RE-EDUCATION MATERIALS
THE UNIV. OF TOKYO DOC No. 43 (2025)

Characteristics of Tritium

Tritium is a radioisotope of hydrogen, called "hydrogen-3," and exists around us mostly being contained in water molecules. β-particles emitted from tritium only have low energy (18.6 keV at the largest) and can be shielded with a sheet of paper.



Water molecule solely consisting of ordinary hydrogen

Water molecule consisting of ordinary hydrogen and tritium

Physical half-life：12.3 year
E_{mean} ： 5.7 keV
E_{max} : 18.6 keV

Source: Prepared based on the "Important Stories on Decommissioning 2018" by the Agency for Natural Resources and Energy, METI, the "Tritiated Water Task Force Report" by the Tritiated Water Task Force (2016), and the "Scientific Characteristics of Tritium (draft)" by the Subcommittee on Handling of the ALPS Treated Water

経済産業省

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

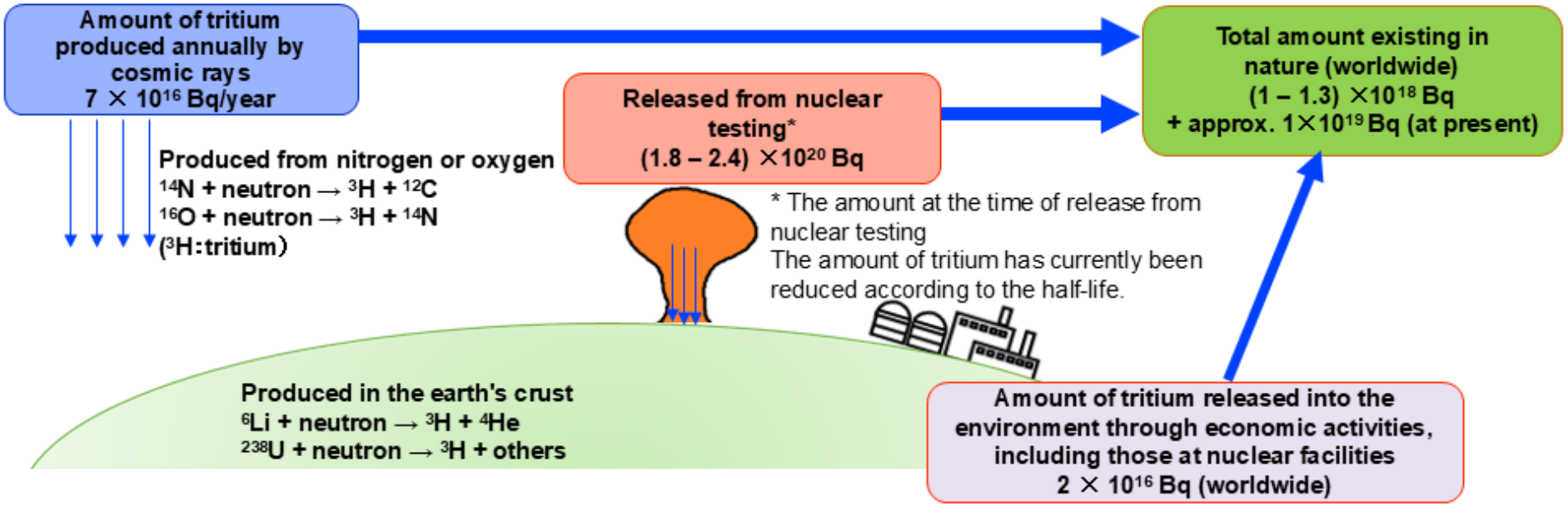
Radioactive Materials Derived from Nuclear Accidents

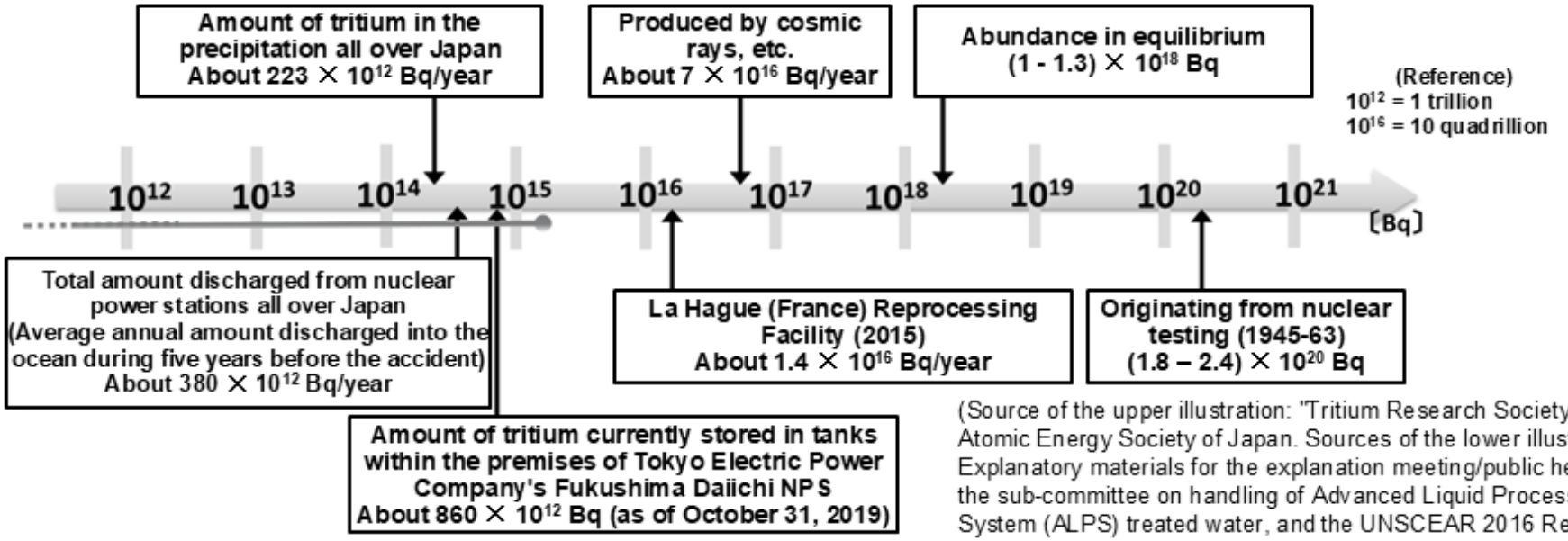
	H-3 Tritium	Sr-90 Strontium-90	I-131 Iodine-131	Cs-134 Cesium-134	Cs-137 Cesium-137	Pu-239 Plutonium-239
Types of radiation	β	β	β, γ	β, γ	β, γ	α, γ
Biological half-life	10 days *1 *2	50 years *3	80 days *2	70-100 days *4	70-100 days *3	Liver: 20 years *5
Physical half-life	12.3 years	29 years	8 days	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: Related to p.27 of Vol. 1, "Internal Exposure and Radioactive Materials"
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

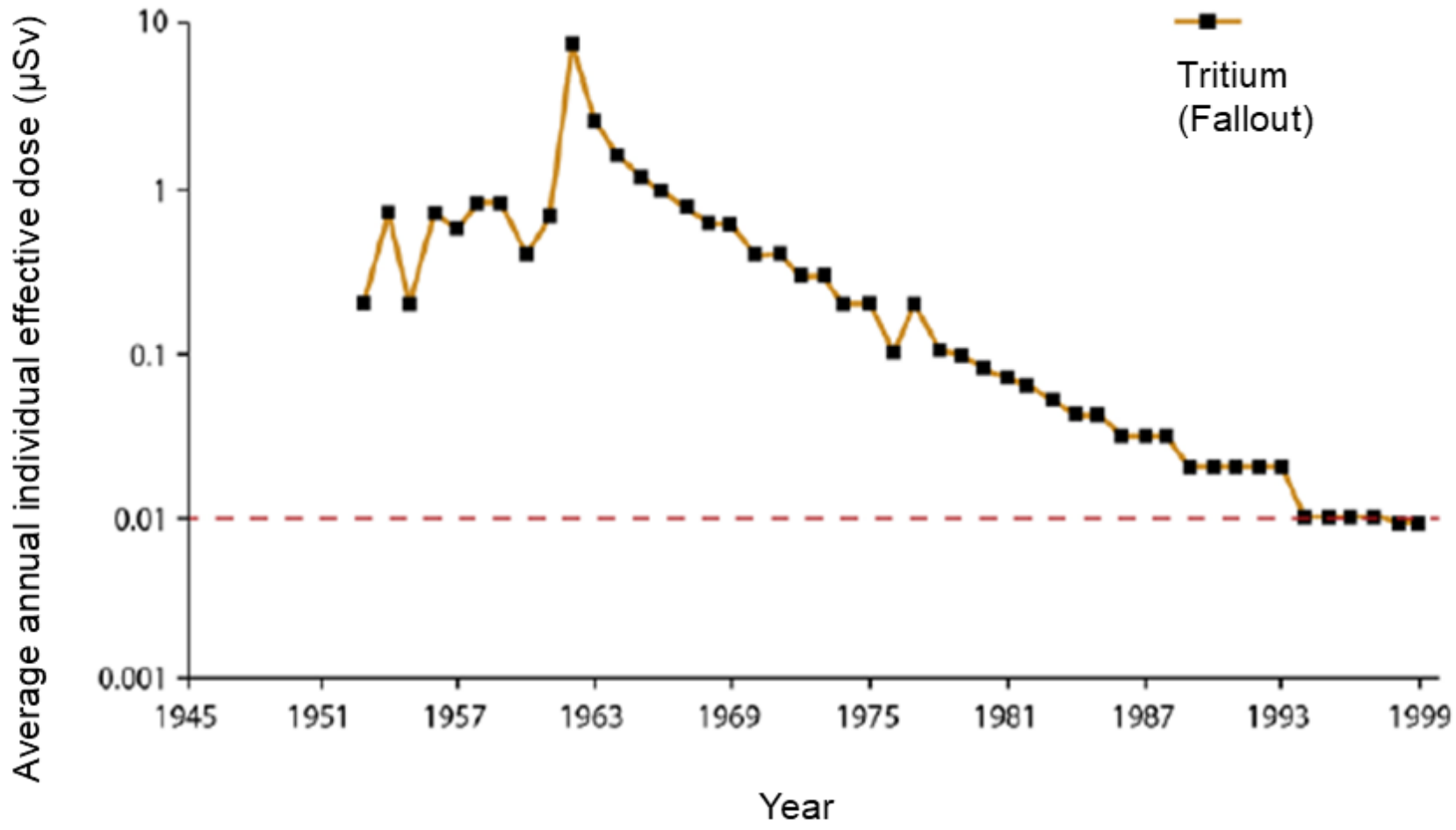
Amount of Tritium Existing in the Environment





(Source of the upper illustration: "Tritium Research Society" 2014 by Atomic Energy Society of Japan. Sources of the lower illustration: Explanatory materials for the explanation meeting/public hearing by the sub-committee on handling of Advanced Liquid Processing System (ALPS) treated water, and the UNSCEAR 2016 Report)

Changes in Tritium in Radioactive Fallout over Time

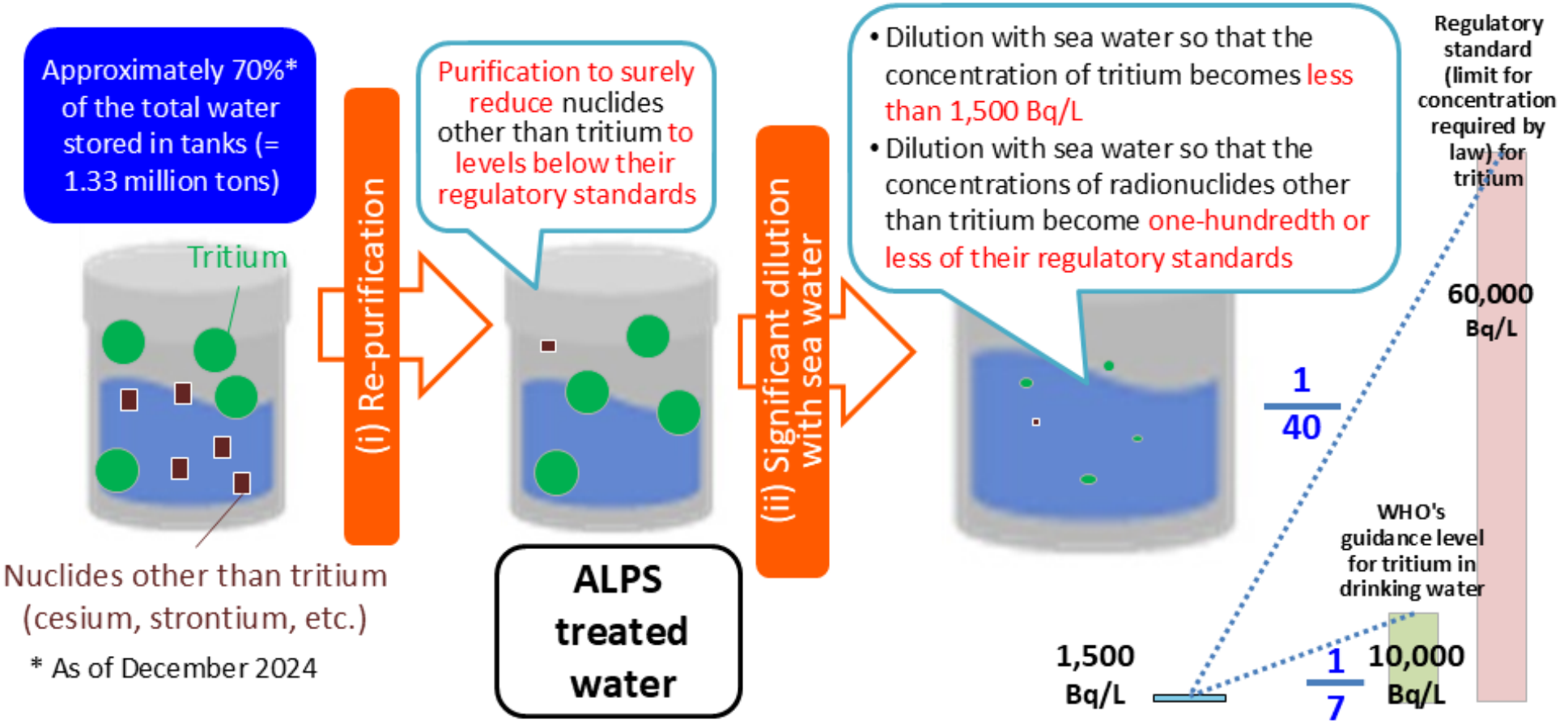


Source: UNSCEAR 2016 Report, Annex C-Biological effects of selected internal emitters-Tritium

出典:「放射線による健康影響等に関する統一的な基礎資料 令和6年度版」

Treatment Method for Water Stored in Tanks

- Reduce concentrations of the radioactive materials contained in treated water far below the regulatory standards through 1) re-purification of radionuclides other than tritium; and 2) dilution by more than 100 times with sea water.
- Discharge water into the sea from TEPCO's Fukushima Daiichi NPS, and conduct monitoring before and after the discharge (evaluation and review by third parties, such as an international organization).

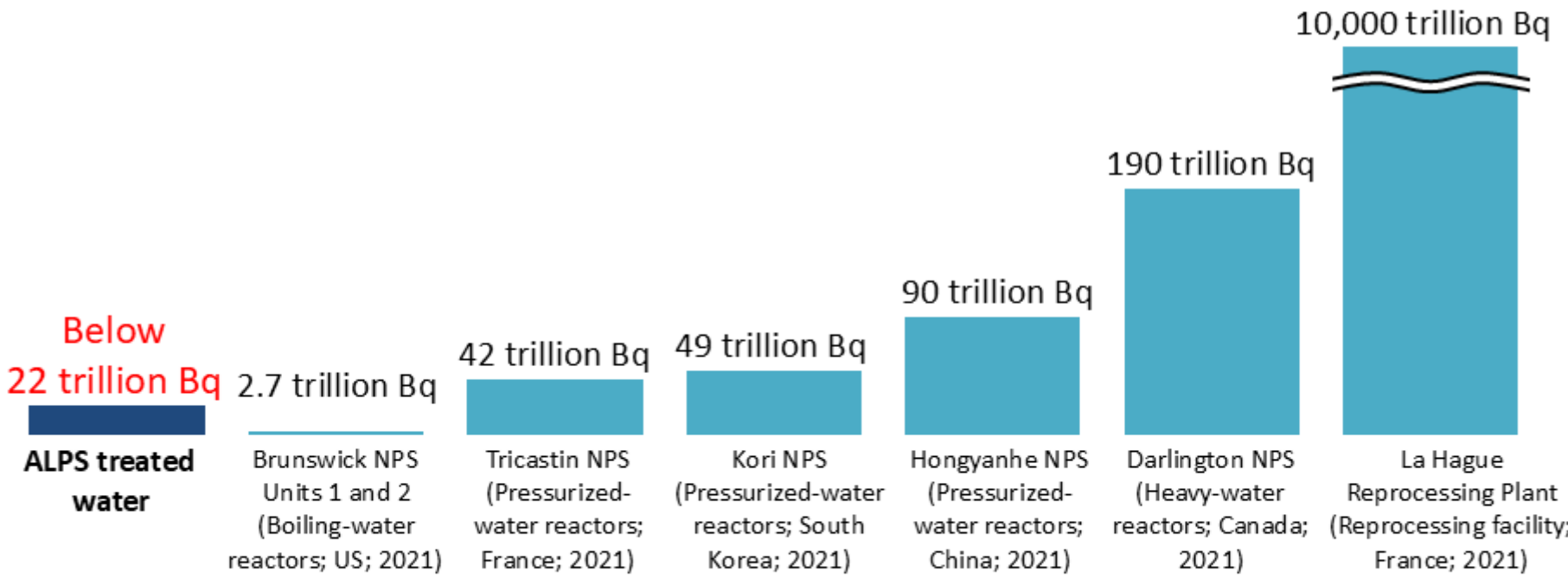


(Source) "ALPS Treated Water" (website of the Ministry of Economy, Trade and Industry) (https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/atw.html)

経済産業省

Annual Discharge Amounts of Tritium - International Comparison -

- The total amount of tritium at the time of discharge of ALPS treated water is below 22 trillion Bq per year (operational target value prior to the accident).
- Tritium is discharged as liquid waste into the sea or rivers or as gaseous waste into the air also at other nuclear power stations and reprocessing facilities inside and outside Japan in compliance with the laws and regulations of respective countries.

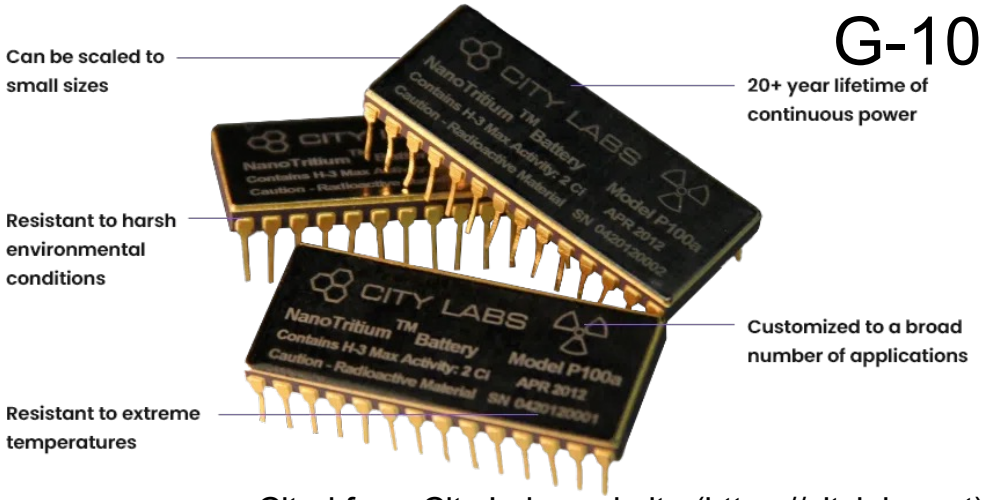


Annual discharge amounts of tritium (liquid) from ALPS treated water and at nuclear facilities around the world

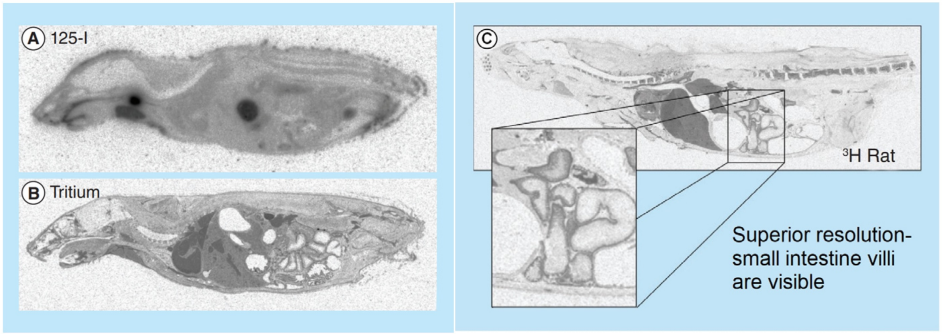
(Source) Prepared based on "ALPS Treated Water" on the website of the Ministry of Economy, Trade and Industry (https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/atw.html)

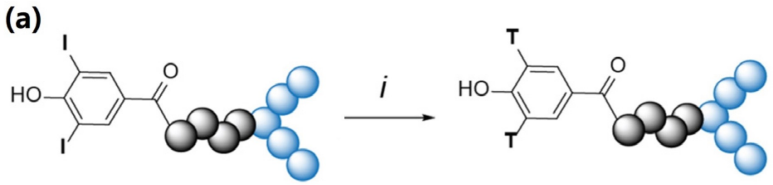
経済産業省

Cited from Wikipedia

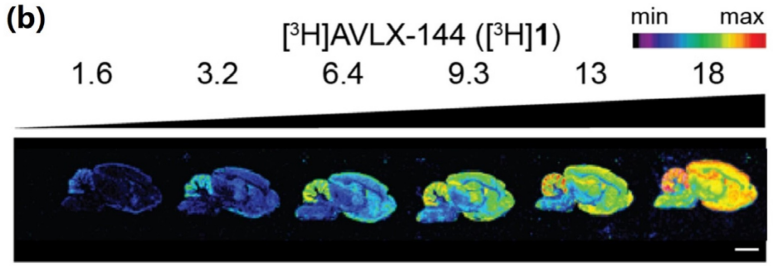


Cited from City Labs website (https://citylabs.net)

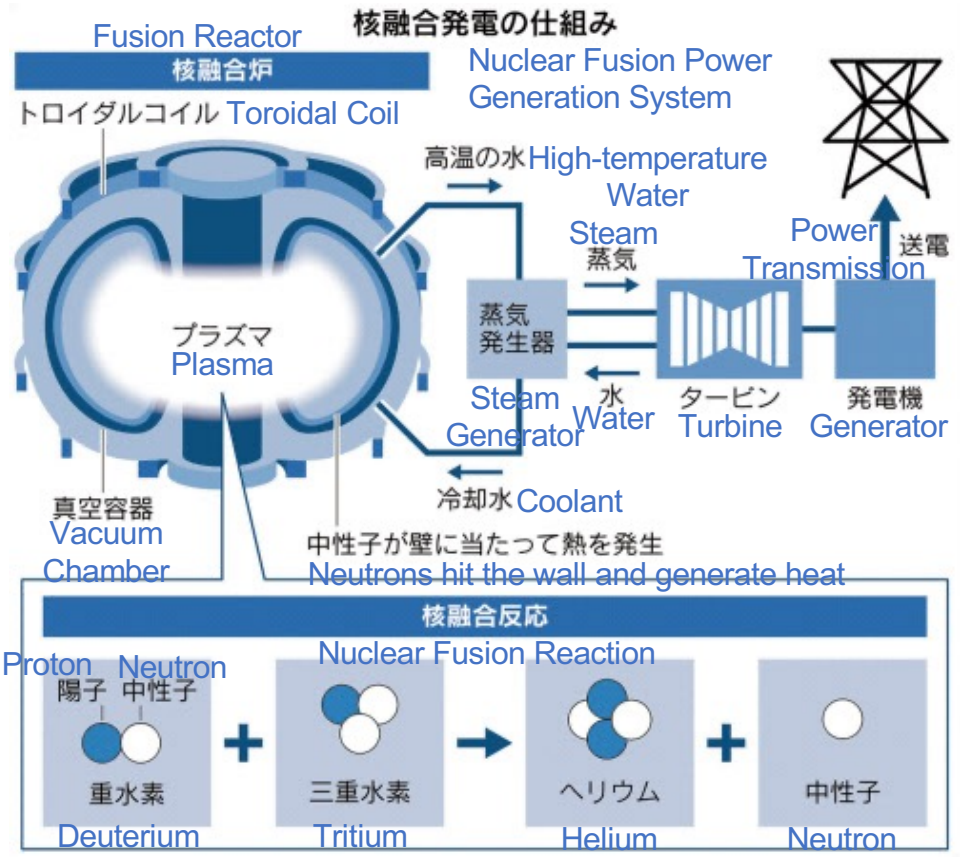




[³H]AVLX-144 ([³H]**1**)

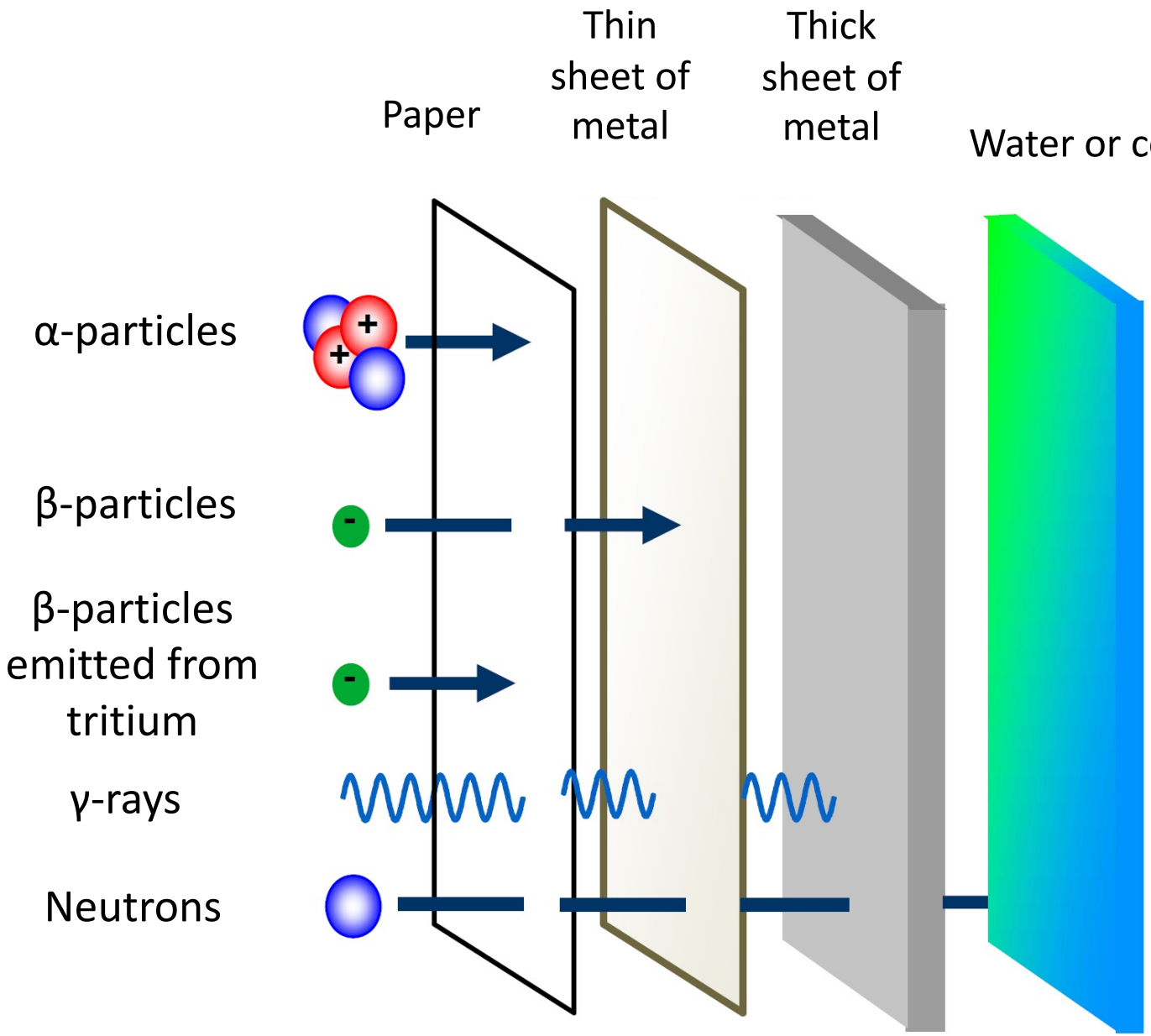


Teng *et al*., Molecules 2024



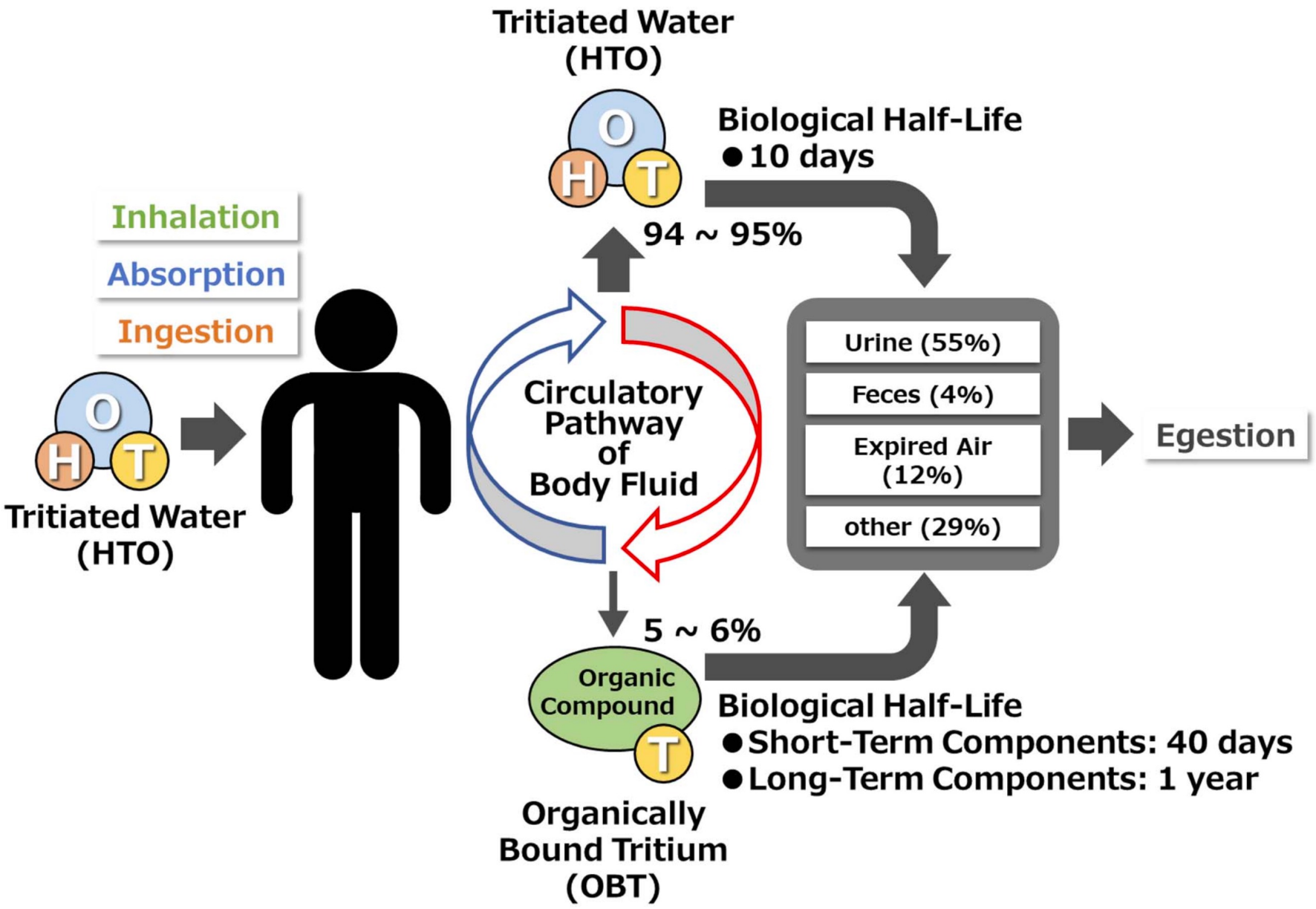
Cited from Nikkei website (https://www.nikkei.com)

Penetrating Power of Radiation



Cited from Reconstruction Agency website (https://www.reconstruction.go.jp)

Metabolism of Tritiated Water in the Human Body



H. Matsumoto *et al., J Radiat Res.*, 2021

Dose Measurement and Calculation

Conversion Factors to Effective Doses

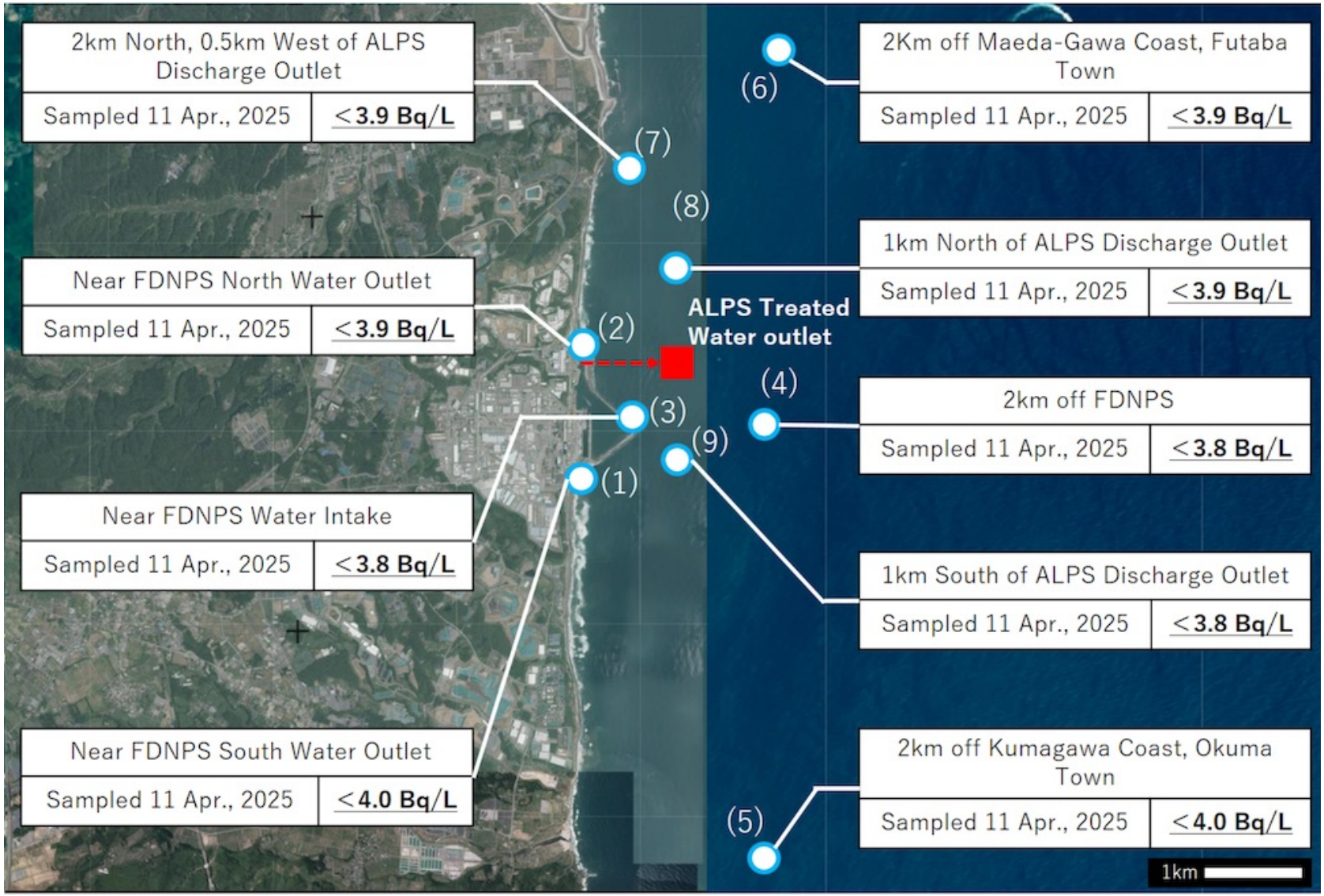
Committed effective dose coefficients (μSv/Bq) (ingestion)

	Strontium-90	Iodine-131	Cesium-134	Cesium-137	Plutonium-239	Tritium*
Three months old	0.23	0.18	0.026	0.021	4.2	0.000064
One year old	0.073	0.18	0.016	0.012	0.42	0.000048
Five years old	0.047	0.10	0.013	0.0096	0.33	0.000031
Ten years old	0.06	0.052	0.014	0.01	0.27	0.000023
Fifteen years old	0.08	0.034	0.019	0.013	0.24	0.000018
Adult	0.028	0.022	0.019	0.013	0.25	0.000018

μSv/Bq: microsieverts/becquerel

*Tissue free water tritium

Source: Prepared based on the ICRP Publication 119, Compendium of Dose Coefficients based on ICRP Publication 60, 2012, International Commission on Radiological Protection (ICRP)



Cited from Fukushima Revitalization Information Portal Site
https://www.pref.fukushima.lg.jp/site/portal/

If an adult drank 2 liters of seawater from this area every day, the amount of radiation exposure from tritiated water in a year would be…

4.0 Bq/L x 2 L/day x 365 days x 0.000018 μSv/Bq ＝ 0.05256 μSv/y ≒ 0.000053 mSv/y

Breakdown of Natural Exposure Doses (Japanese)

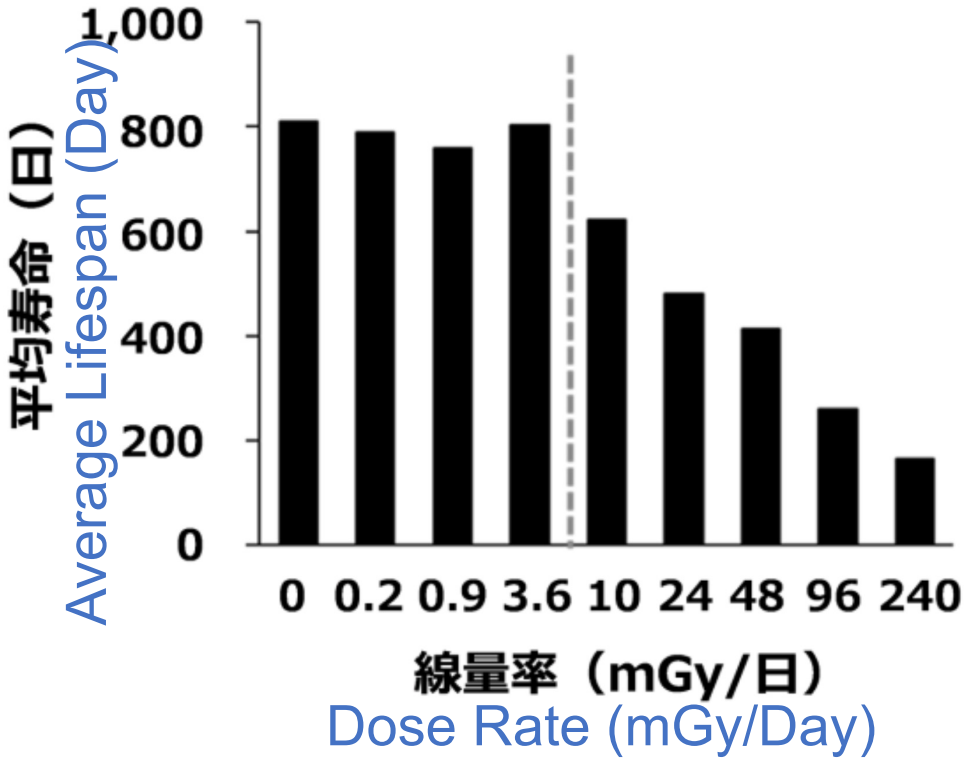
Type of exposure	Breakdown of radiation sources	Effective dose (mSv/year)
External exposure	Cosmic rays	0.3
	Terrestrial radiation	0.33
Internal exposure (inhalation)	Radon-222 (indoors and outdoors)	0.37
	Radon-220 (thoron) (indoors and outdoors)	0.09
	Smoking (Lead-210, Polonium-210, etc.)	0.006*
	Others (uranium, etc.)	0.006
Internal exposure (ingestion)	Mainly Lead-210 and Polonium-210	0.80
	Tritium	0.0000049
	Carbon-14	0.014
	Potassium-40	0.18
Exposure under special environments	Exposure due to hot springs or other subsurface environments	0.005
	Exposure due to the use of aircraft	0.008
Total		**2.1**

(*) Per capita effective doses; The average exposure dose for smokers is 0.040 mSv/y.

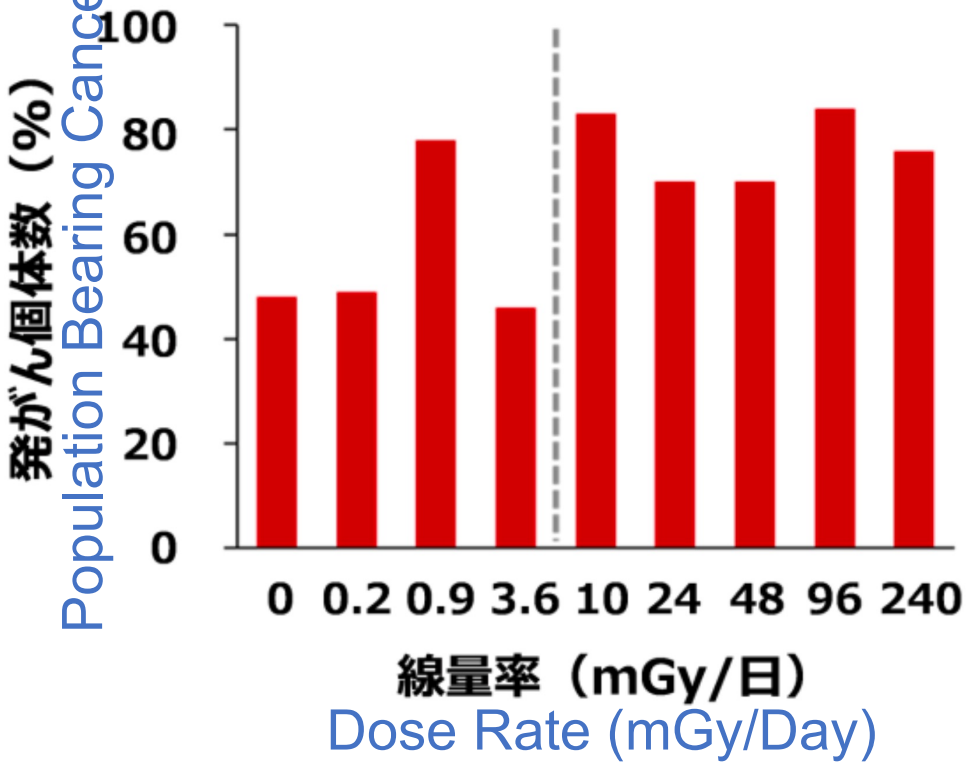
Source: Prepared based on "Environmental Radiation in Daily Life (Calculation of National Doses), ver. 3" (2020), Nuclear Safety Research Association

Effects of HTO Ingestion in Mice

Average Lifespan



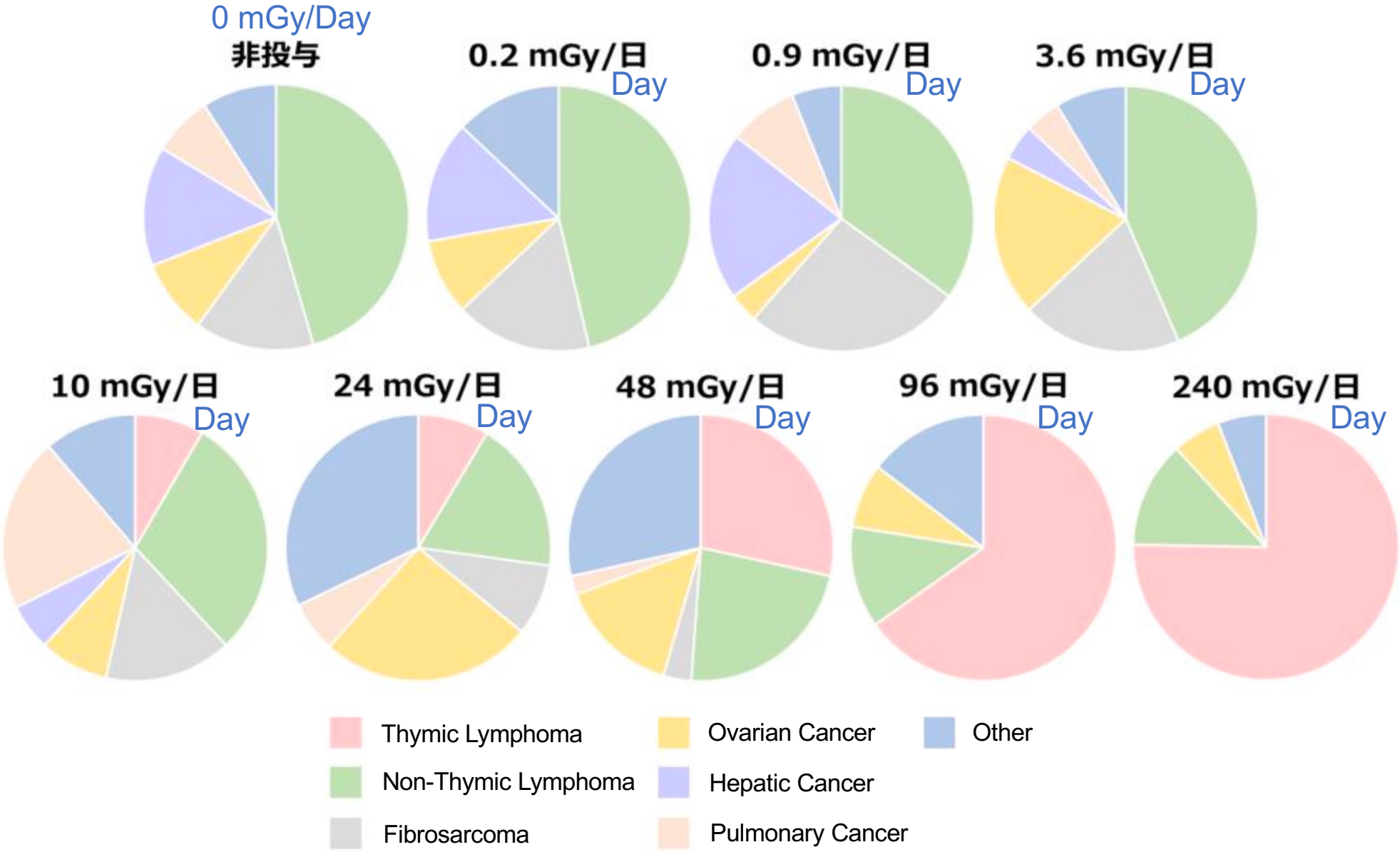
Population Bearing Cancer



There may be a threshold dose around 3.6 - 10 mGy/d.

Cited from The Japanese Radiation Research Society website（https://www.jrrs.org）

The Types of Cancers Developing in Mice Ingested HTO



Cited from The Japanese Radiation Research Society website（https://www.jrrs.org）

Examples of Tritium Intake in Humans

Case	Age (Sex)	Amount of ^{3}H Handled	Exposure Dose /Duration	Clinical Symptoms	Outcome	Amount of ^{3}H in Urine (Bq/mL)
A1	60 (M)	2.8 x 10^{14}Bq/7.4 year	3-6 Sv /7.4 year	Normochromic anemia → Pancytopenia	Death	1.9-41 x 10^{3}
A2	28 (F)	1.4 x 10^{14} (?) Bq/6.3 year	1.2-2.8 Sv /6.4 year	Normochromic	Survival	0.07-6.8 x 10^{3}
A3	61 (M)	-	-	Asymptomatic	Survival	0.37-3.3 x 10^{3}
A4	35	-	-	Asymptomatic	Survival	0.04-1.8 x 10^{3}
B1	-	-	-	-	Survival	-
B2		3.7-37 x 10^{13} Bq/3 year	10-20 Sv /3 year	Hyperchromic anemia → Refractory pancytopenia	Death	2-4.3 x 10^{3}
B3	-	-	-	-	Survival	-

[Source] Seelentag, 1973; Hirashima, 1988
Cited from ATOMICA (https://atomica.jaea.go.jp)