Version 8

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Radioactivity and Radiation since the Accident at Fukushima's Nuclear Power Plants

How we on campus can cope with the incident

Department of Nuclear Engineering,
Tokai University, Kanagawa, Japan

What we explore in the following slides:

Emission of radioactivity as a result of the accidents

Radioactivity and radiation

Food intake restrictions

The following explanation emphasizes clarity. Accuracy may be compromised as a result. Since available information is limited, corrections may be made in due course.

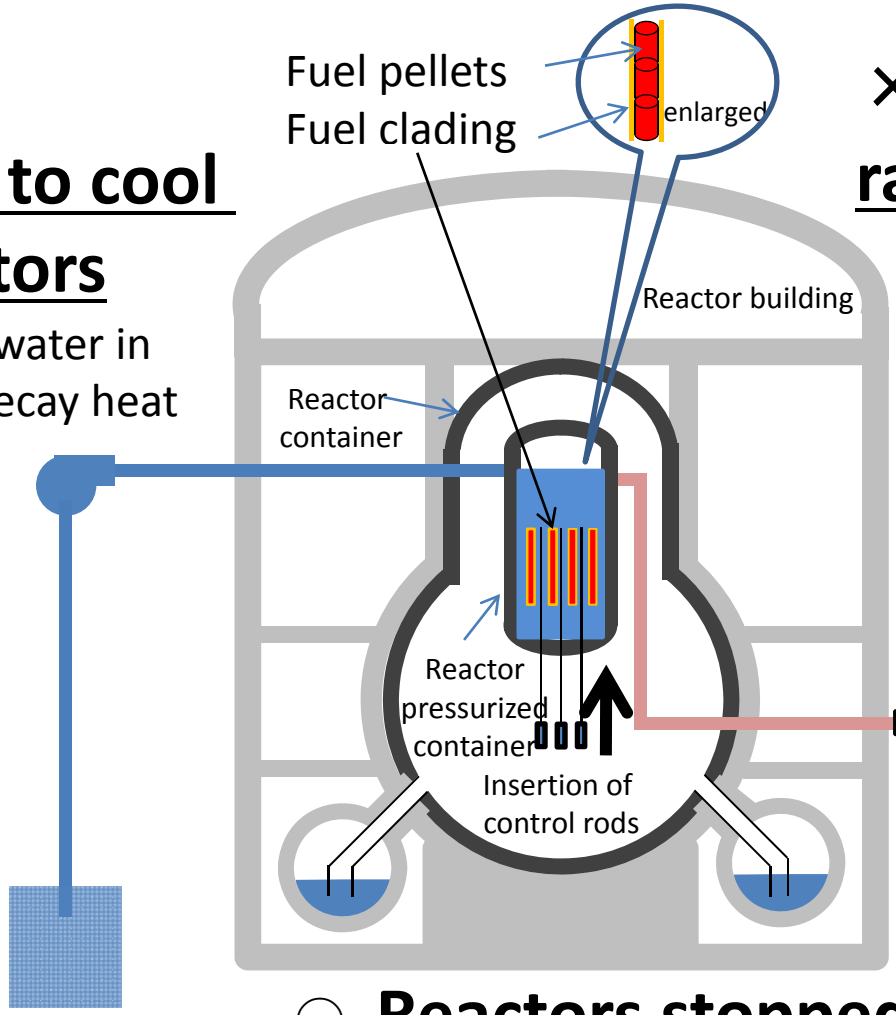
Radiation
as a result of the accidents

3 safety principles are compromised

× Unable to cool down reactors

By pouring water in to remove decay heat

Cooling pumps inoperative because of electricity loss



× Unable to isolate radioactivity

5 containers encapsulating radioactive substances have been harmed/destroyed

- × fuel pellets
- × fuel clading
- △ pressurized container
- △ container
- × reactor building

△ compromise very likely

○ Reactors stopped

Control rods have been inserted to stop nuclear fission reaction, in order to stop the reactors temporarily

Nuclear explosion has been averted

Why radioactive rays are being emitted

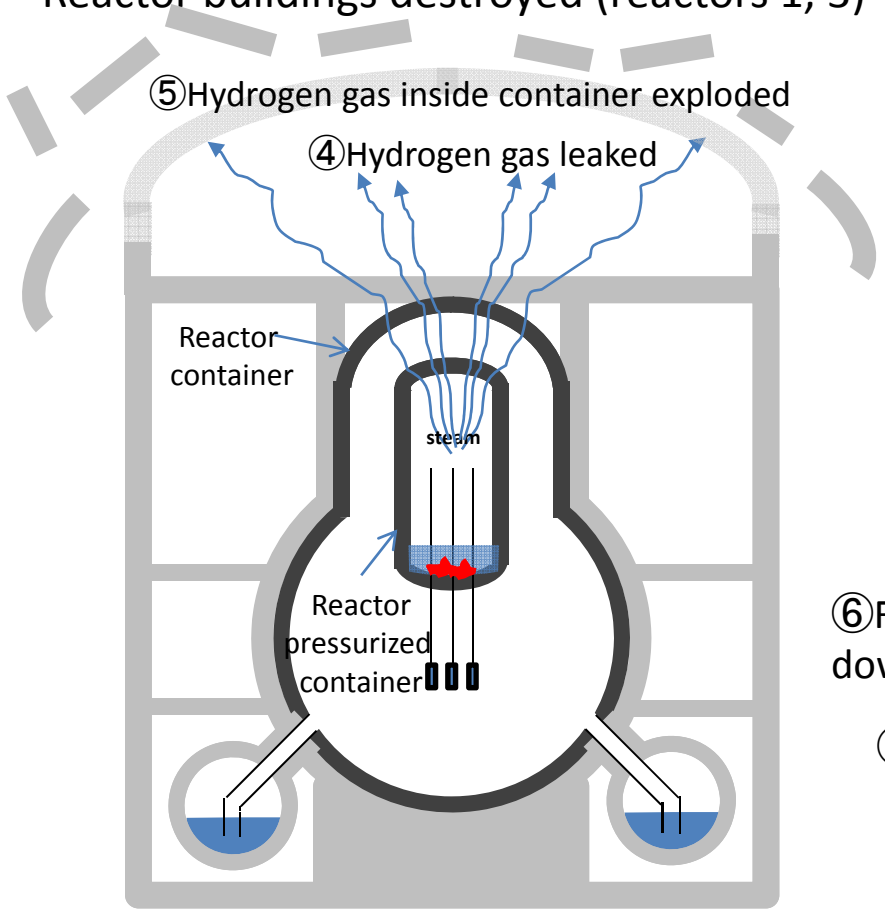
①Cooling functions lost, cooling water vaporized

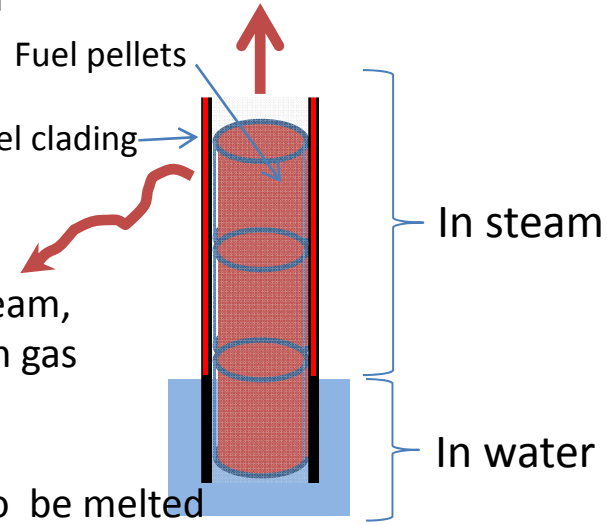
This is NOT a nuclear explosion

②Upper sections of fuel rods exposed to steam

Reactor buildings destroyed (reactors 1, 3)

⑦Nuclear fuel compromised because of high temperature: radioactive substances inside have been emitted





③Reaction with steam, producing hydrogen gas

⑥Fuels are supposed to be melted down (reactor 1, reactors 2?,3?)

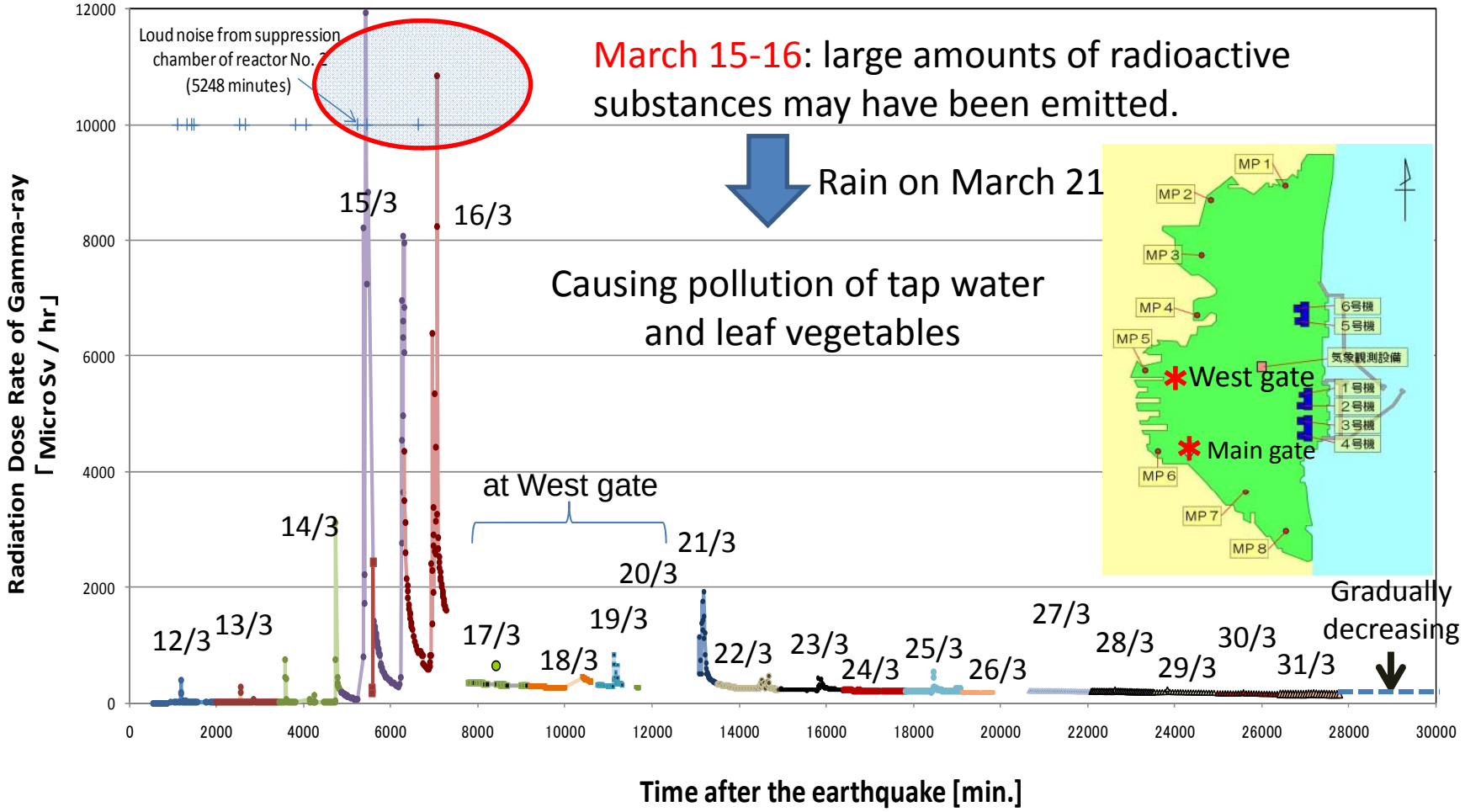
⑧Radioactive substances are leaked outside

Most of radioactivity is considered to remain inside the pressurized containers inside reactor containers

Radioactivity near the Power Station

(Power Plant Main Gate or West Gate)

Based on Nuclear and Industrial Safety Agency website data



Important: these are data at monitoring locations, which do NOT correspond to what humans are directly exposed to.

Effects of radioactivity and radiation

Radioactivity comes from radioactive substances

Radioactive substances

are substances which have

radioactivity

Iodine Caesium

^{131}I, ^{137}Cs

Strength of radioactivity

= Amount of radioactive substances

Unit: Becquerel (Bq)

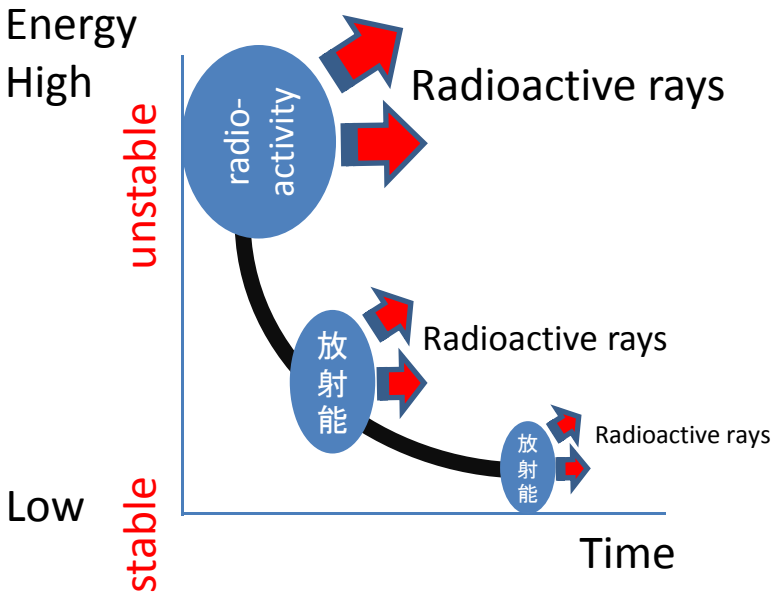
Radioactivity

means capacity to emit

radioactive rays

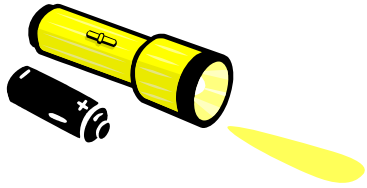
Strength of radioactive rays

Unit: Sievert (Sv)



Since radioactive substances are unstable, they tend to emit energy to become more stable.

Radioactive rays are emitted in the process. By emitting radioactive rays, the strength of radioactivity gradually diminishes.

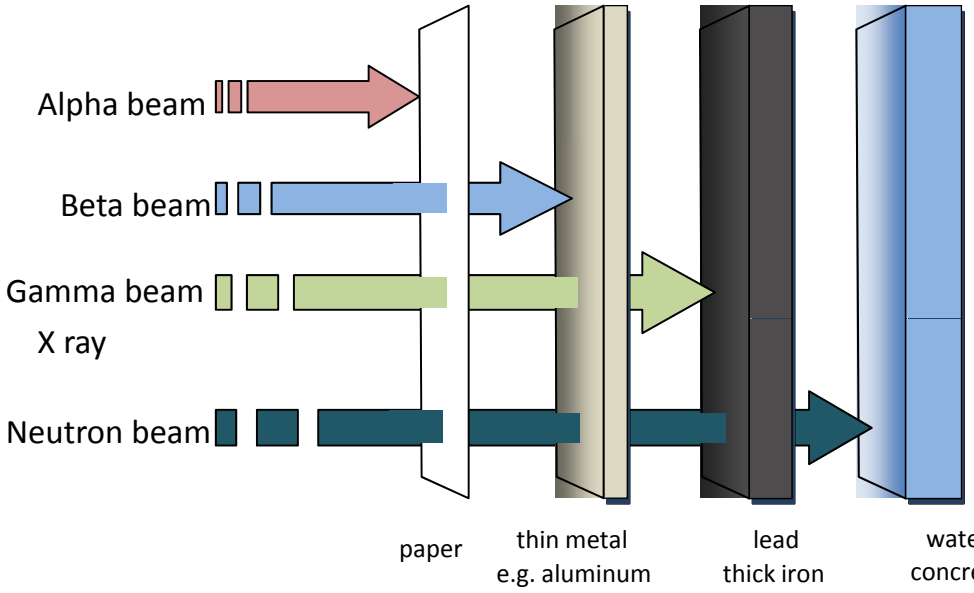


The Difference between Radiation and Radioactivity

Radioactive rays are emitted from radioactive substances

Radioactive rays consist of Alpha, Beta, Gamma and Neutron beams

Hardly any Neutron beams are observed even inside the reactors since there is no nuclear fission reaction taking place



Gamma rays are crucial, since they have larger penetration power.

Tokai University is located more than 200 km away from the reactors,

so radioactive rays do not reach the campus directly from the reactors!

Radioactivity is often synonymous with radioactive substances.

Radioactive substances covering small particles in the atmosphere (air) emit radioactive rays, which can cause a problem.

Microsievert

The Impact of radioactive rays depends on:

- How many radioactive rays are absorbed by the human body?
- Which radioactive rays?

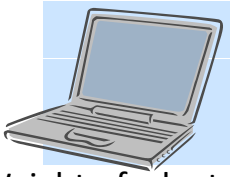
Sievert is a unit for the degree of radiation effect : it can be used for all kinds of radioactive rays.

"Micro" means one millionth (1/1,000,000). （Milli=1/1,000）

1 Sievert (Sv) → 1/1,000 → 1 Milli Sievert (**m**Sv) → 1/1,000 → 1 Micro Sievert (μSv)

For example (in weight):

Weight of a car: 1,000 kg (1 ton)



Weight of a laptop: 1 kg

1/1000,000

Weight of a 1 yen coin: 1 gram

Exposure doses and their effects on the human body

Levels of exposure dose relevant to daily life:

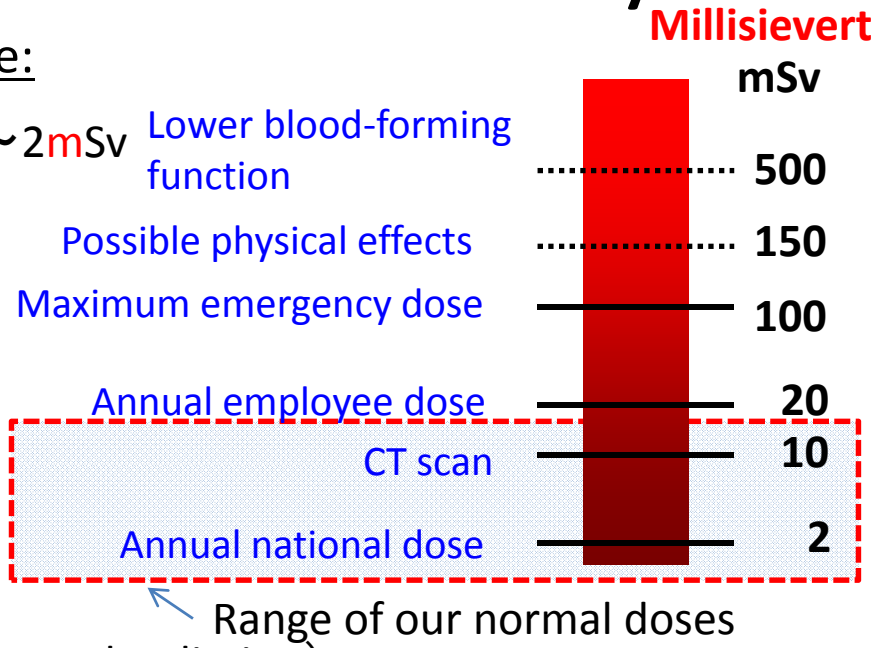
Annual dose of natural radiation per year: 1～2mSv

Chest X ray (per photo): 0.05mSv

Stomach X ray (per photo): 0.5mSv

Abdomen CT scan (per scan): 5-15mSv

International flights (per 12 hour flight): Approx. 0.05mSv



Maximum exposure（excluding medical and natural radiation）

Annual public exposure: 1mSv

Annual employee exposure: 20mSv (5 year average)

Emergency operation exposure: 100mSv (250mSv, current accident)

100mSv is considered a vital threshold for effects on the human body.

The website of the National Institute of Radiological Sciences has diagrams explaining effects of radiation on the human body according to levels of radiation.

The difference between dose (Sv) and dose rate (Sv/h)

Dose (Sv) is the accumulated total amount.

Dose rate means the dose exposure per unit time, corresponding to the strength of radiation.

For example, exposure per hour is Sv/h.

The figures broadcast for monitoring posts are dose rates.

Effects on the human body are basically determined by the total dose.

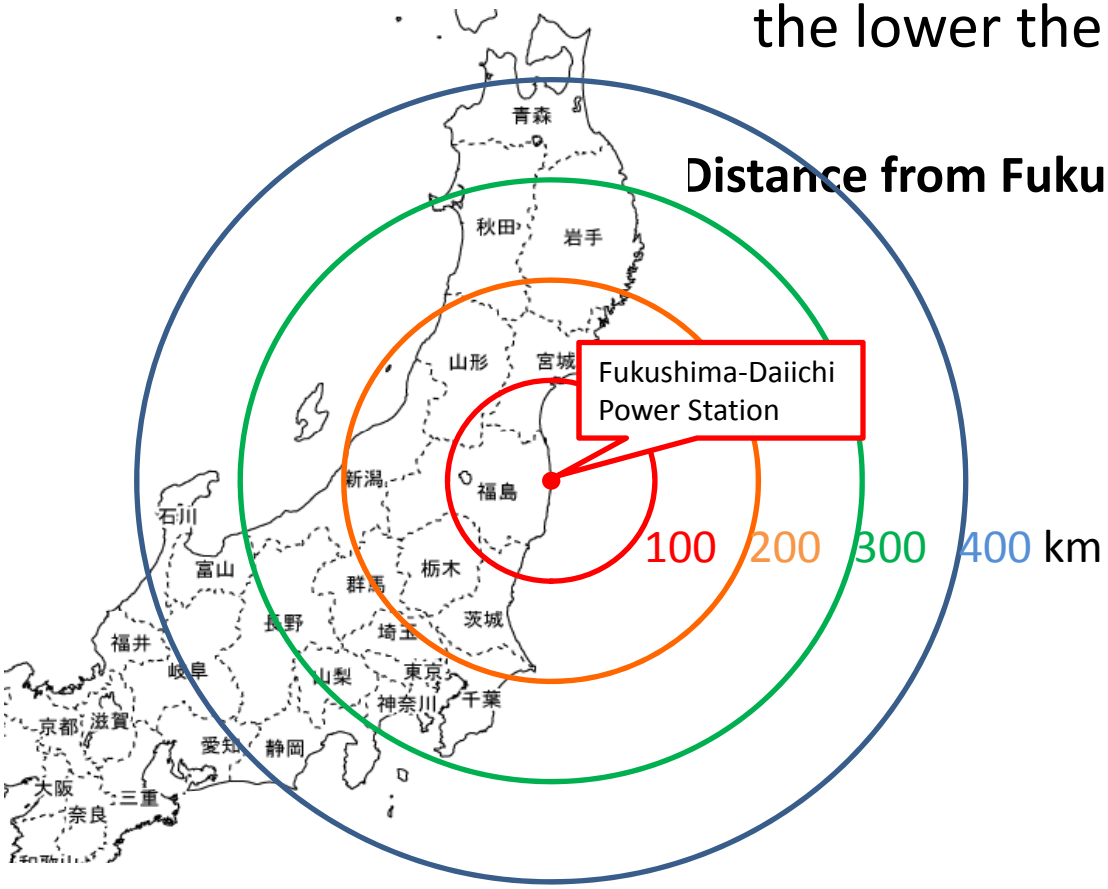
Total dose is obtained by multiplying dose rate by the amount of time radiation took place.

Dose = Dose rate × Time

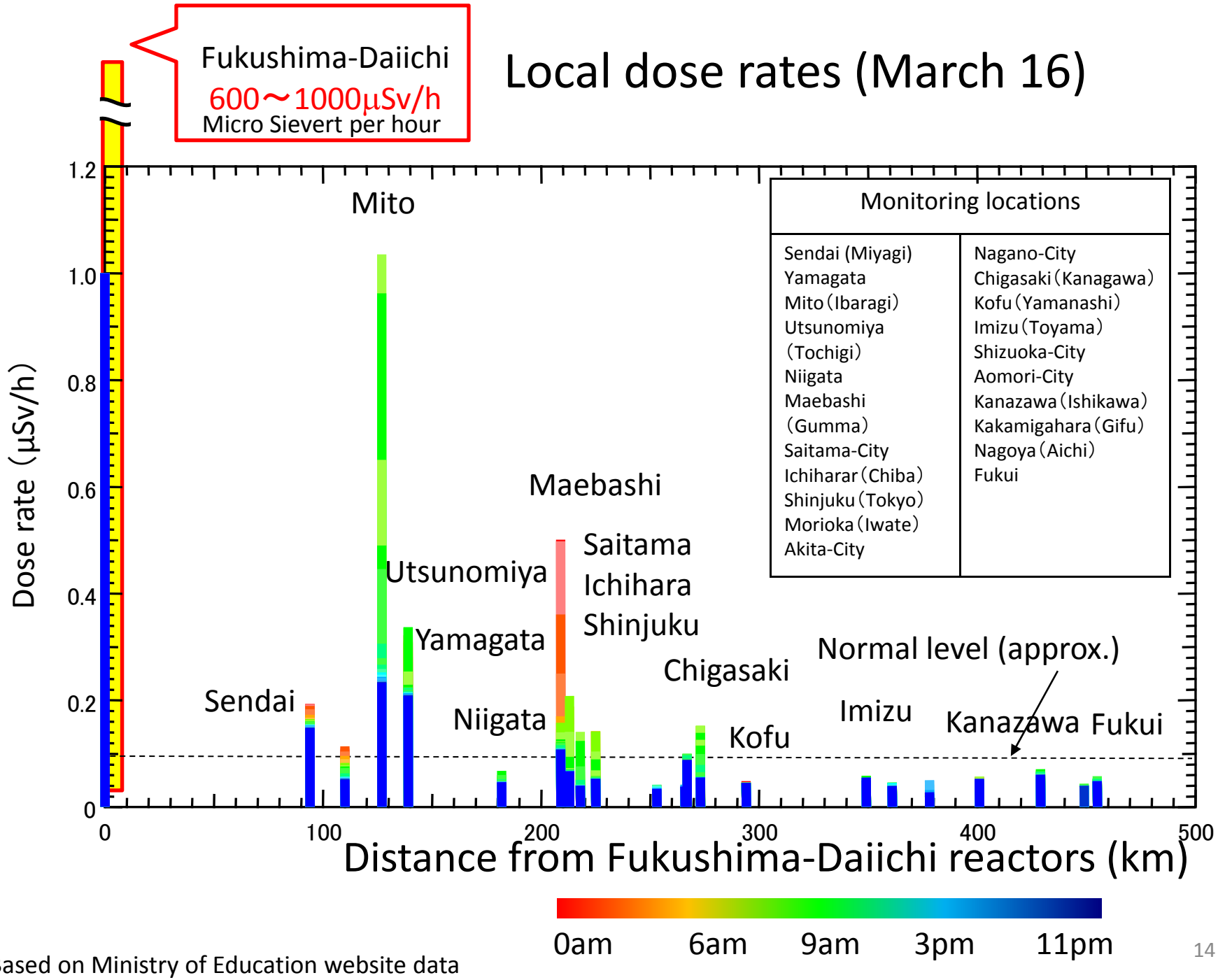
Dose rate and distance

As radioactive substances are emitted into the atmosphere and dispersed, their density is diluted.

Generally, the farther away from the source of emission it is, the lower the dose rate becomes.

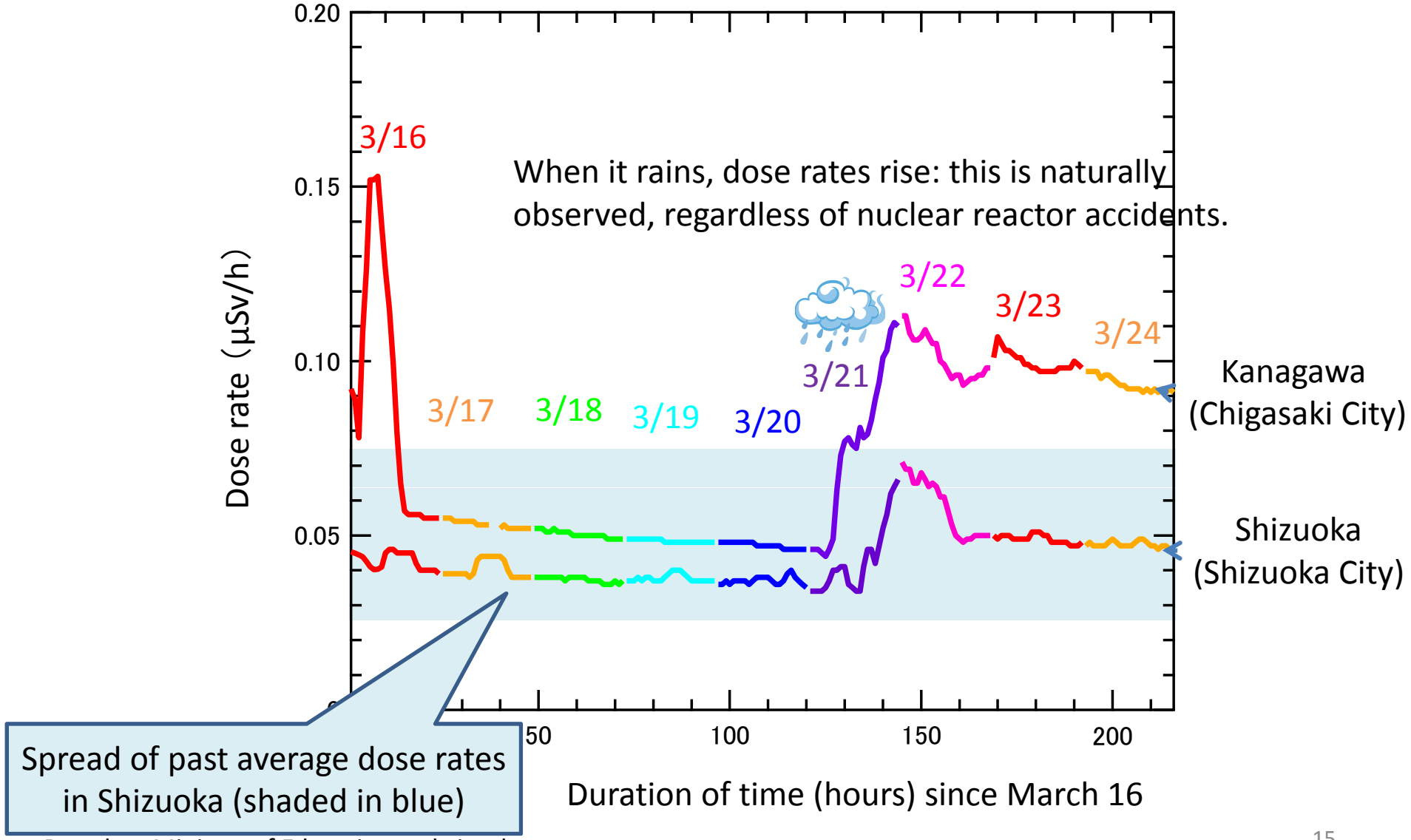


Local dose rates (March 16)



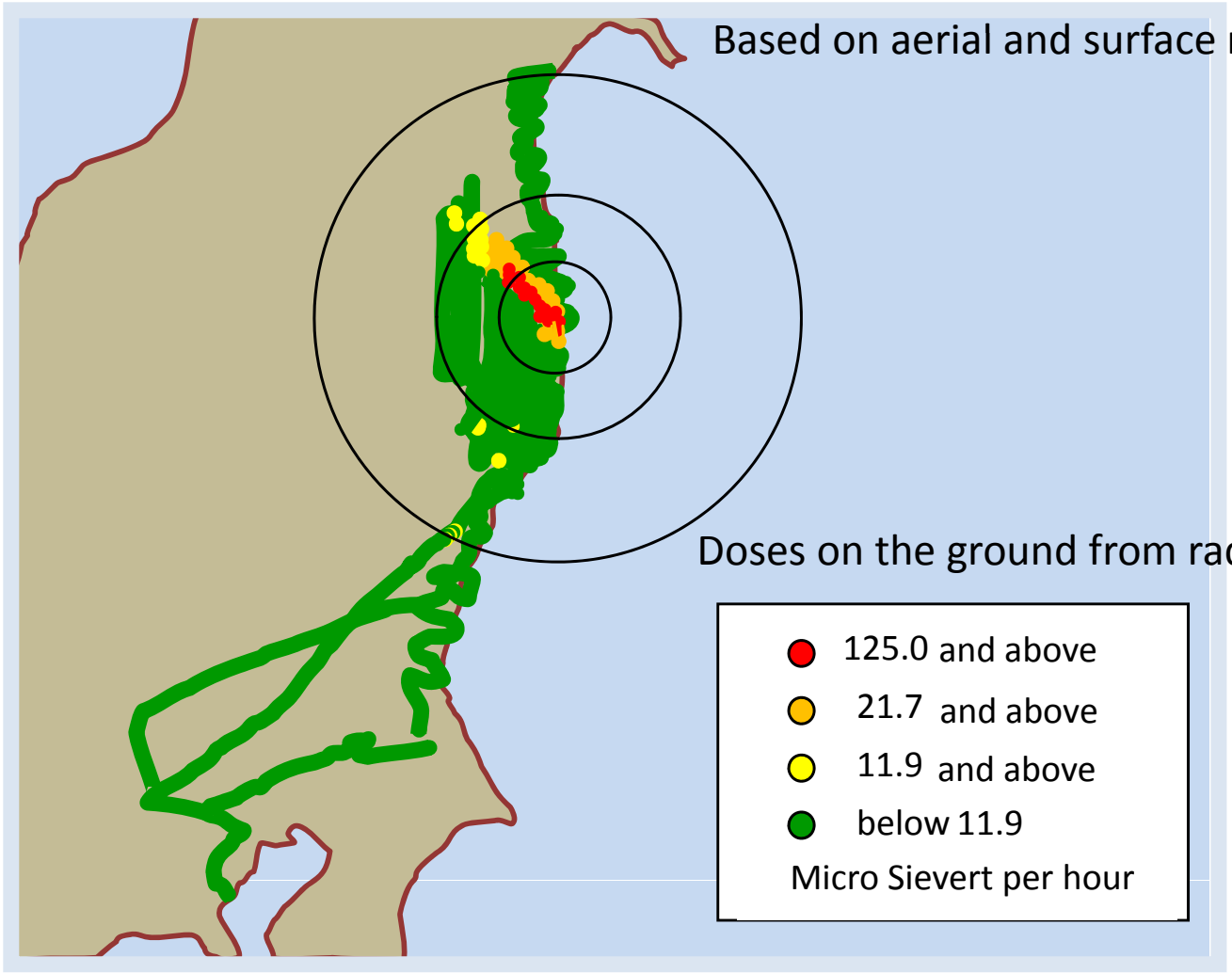
Based on Ministry of Education website data

Dose rates in Shizuoka and Kanagawa



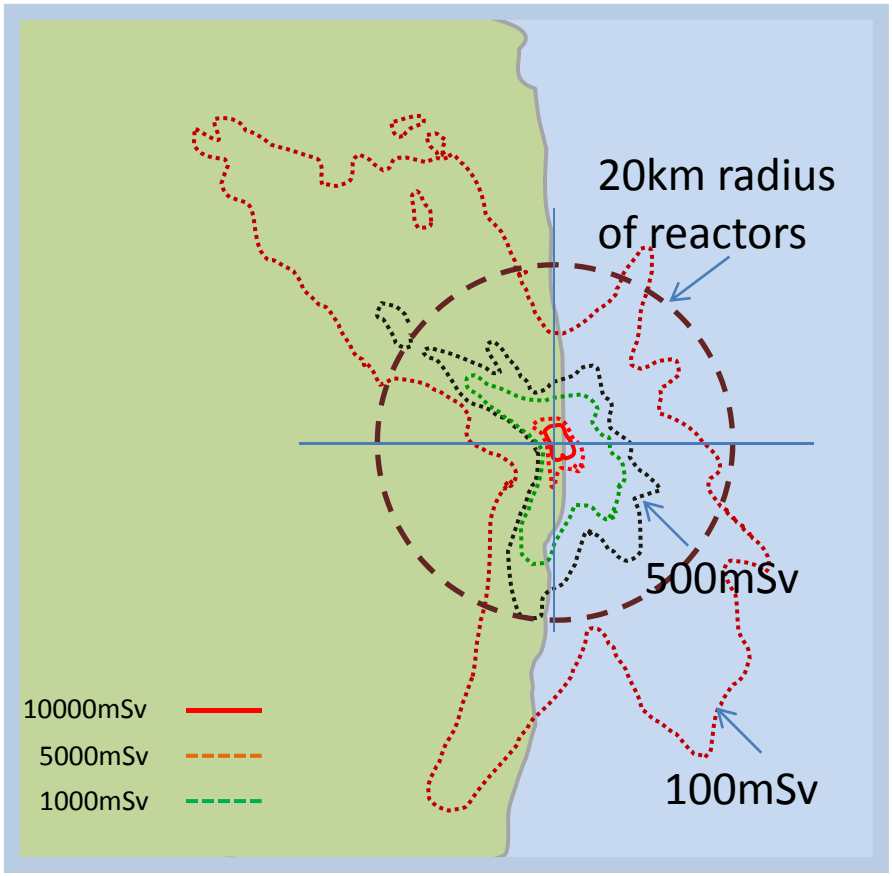
Based on Ministry of Education website data

Sample estimates of dose rates (US Dept. of Energy announcements)



Based on US Dept. of Energy data disclosed on March 22

Nuclear Safety Commission Announcements
(Exposure dose assumptions based on calculation)



Based on disclosed diagram: distribution of dose rates is therefore only approximate.

Estimated exposure doses (mSv) due to dissemination of radioactive substances based on:

- wind direction
- changes in wind speed
- changes in amount of emission (estimated)

Assuming:

Noon to midnight, March 12 ~ March 24

12 hours outdoors

for 12 days

Effects of radioactive rays differ from organ to organ: here effects on an infant's thyroid gland are evaluated.

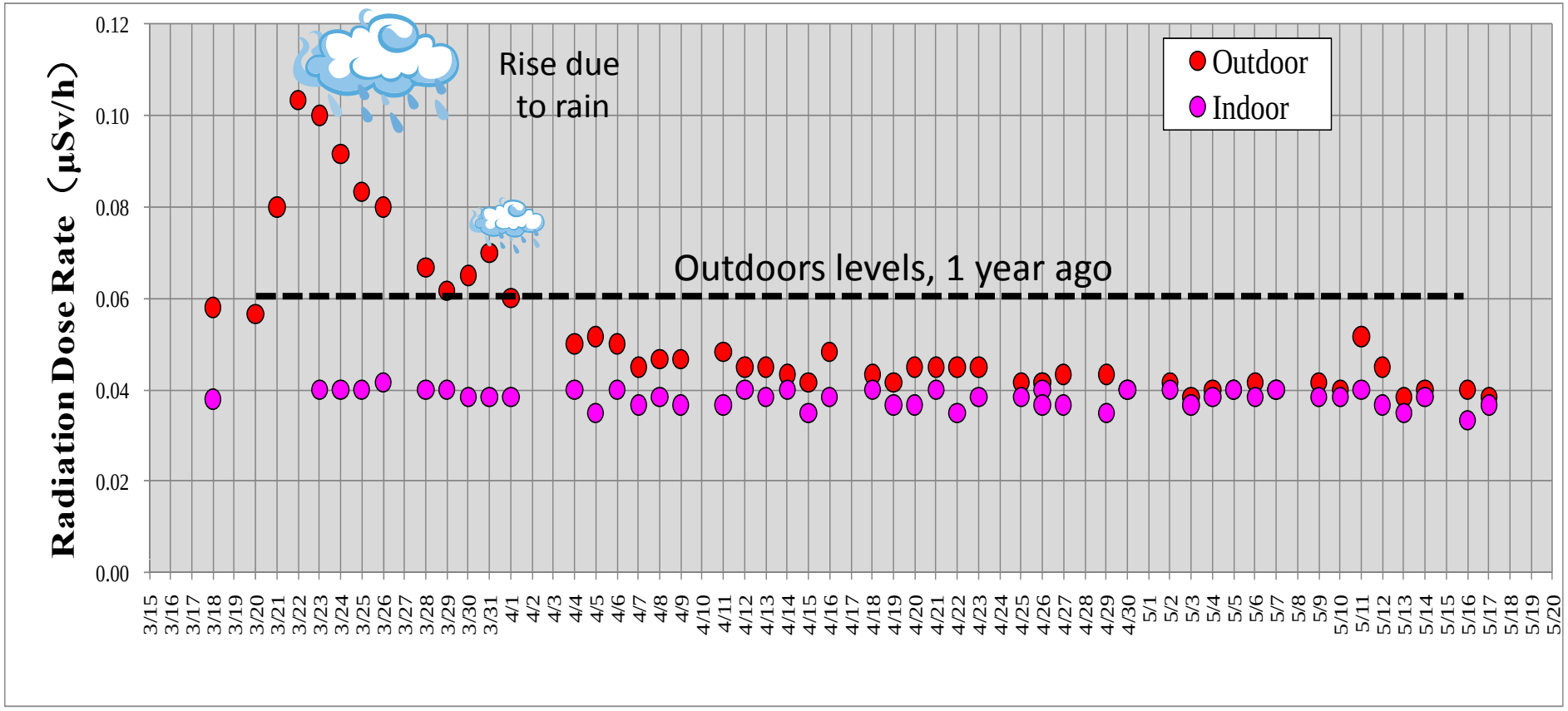
If indoors, the levels are $\frac{1}{4} \sim \frac{1}{10}$ of figures plotted on the map.

Maximum dose permitted for thyroid gland is 50mSv.

Based on Nuclear Safety Commission data, March 28, 2011

Radiation dose rates on campus:

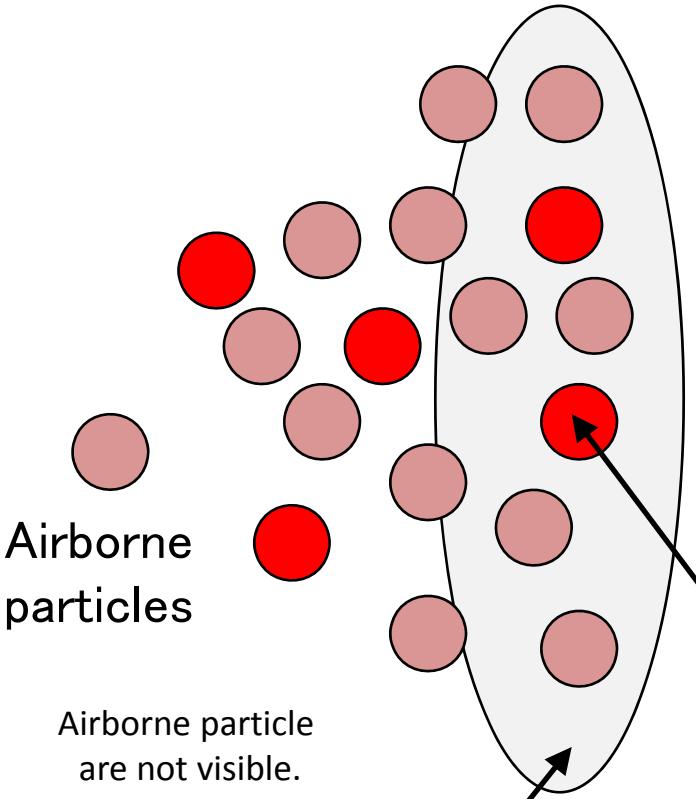
Tokai University analysis



There is no abnormal rise.

Radioactive substances in floating particles

We collected particles floating in the air using dust catcher



Airborne particles

Airborne particle are not visible.

Tokai University
Monitoring data

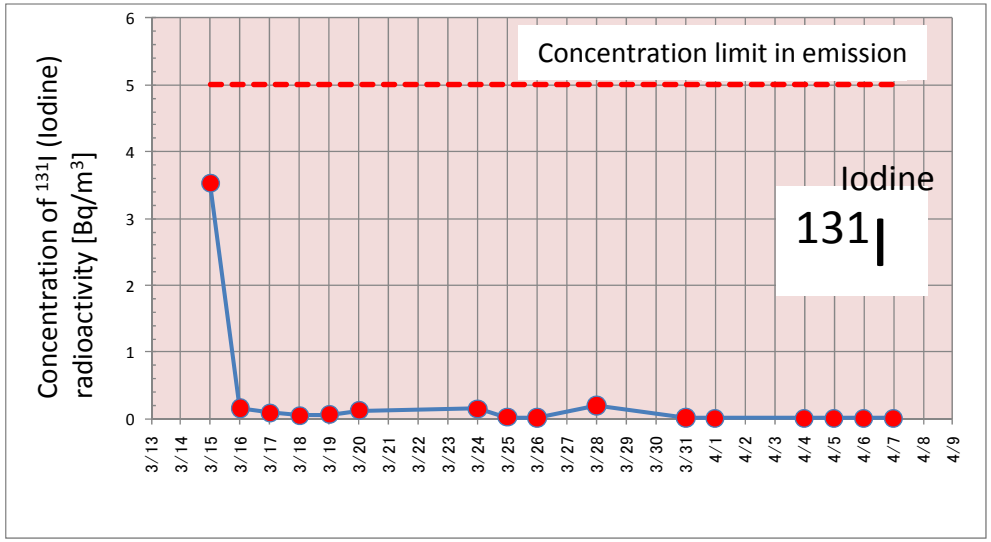
Air flow volume
$30m^3/hr$

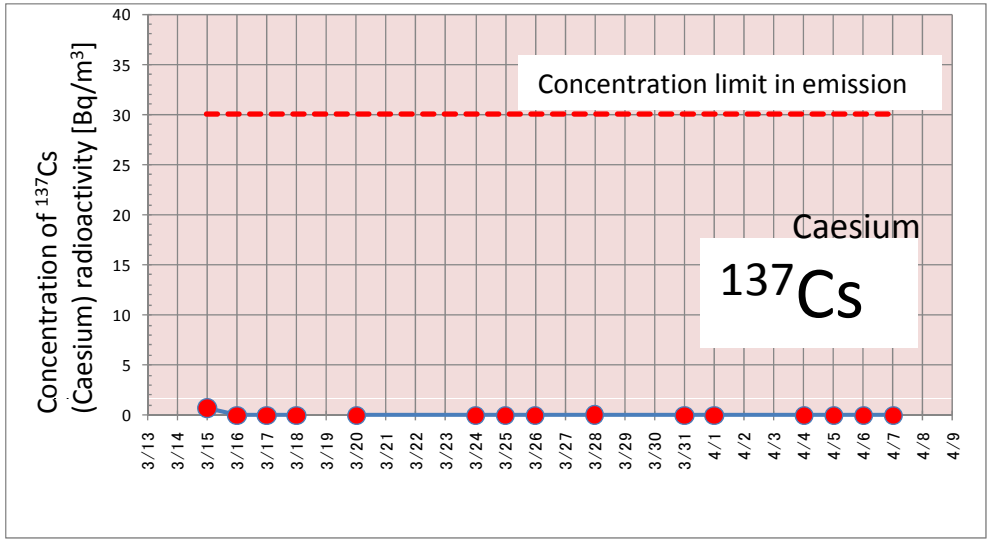
Airborne particles adsorb radioactive substances

Filter

Analyzed substances deposited on the filter 2 hours after collection process started

Analyses of some radioactive substances





Tokai University analyses

Concentration in airborne particles?

Unit: Bq/m^3

Amount of radioactive substances covering airborne particles in 1 cubic meter of air [Bq]

Results were compared with the concentration standards applicable to institutions handling radioactivity: the levels were very low.

Analyses are ongoing.

At Tokai University Campus

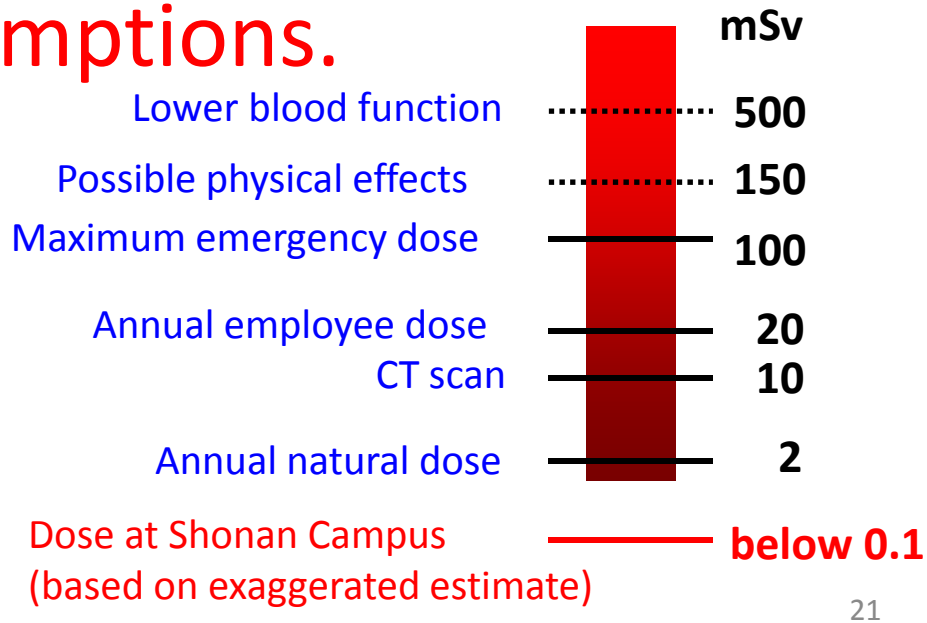
Based on monitoring levels at Shonan Campus, we have estimated the dose levels with wide(*) safety margins.

(*) Evaluation is only approximate, since various assumptions are made due to limited monitoring data

Compared with annual doses from natural radiation, it is estimated that

there was an increase of at most a few percent, using exaggerated assumptions.

This increase corresponds to less than 2 chest X ray photos.



The case of Chernobyl

Immediately after the accident in 1986, there was an evacuation within a 30km radius, followed by another within 100km radius to the northeast, taking wind direction into consideration.

Kiev, the regional mega city 130km south of Chernobyl, faced no evacuation because of favorable wind directions.

Tokyo metropolitan area is more than 200km away from Fukushima-Daiichi

Under current conditions, there is no need for evacuation

However, since the amounts of falling radioactive substances vary according to wind direction, all neighboring prefectures monitor trace amounts 24 hours a day.

Will effects of radiation doses become apparent?

There are assumptions that, within a range of small doses, there is an increased probability of cancer with doses of 100mSv by a factor of 1.05:

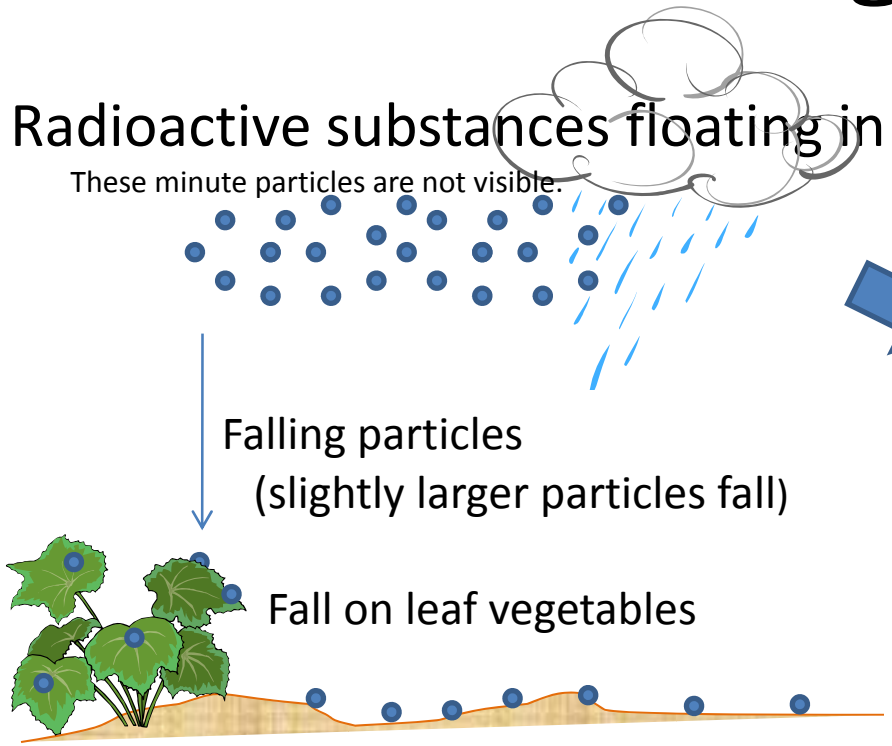
However, according to surveys of nuclear bomb patients conducted by Hiroshima's Radiation Effects Research Foundation,

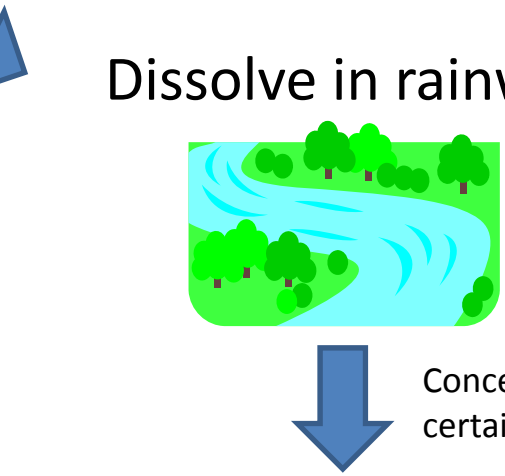
no increase of cancer cases have statistically been recognized under doses of approximately 150mSv.

There is hardly any effect of radiation at the levels monitored at Shonan Campus.

Restrictions on food intake

Pollution of water and leaf vegetables





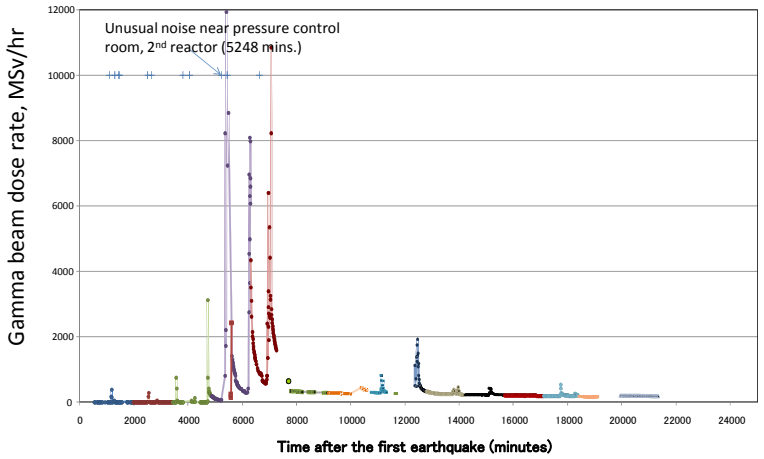
As long as there is no further supply of floating radioactive substances after rain, concentration levels will decrease.

As for root vegetables, other precautions are necessary.

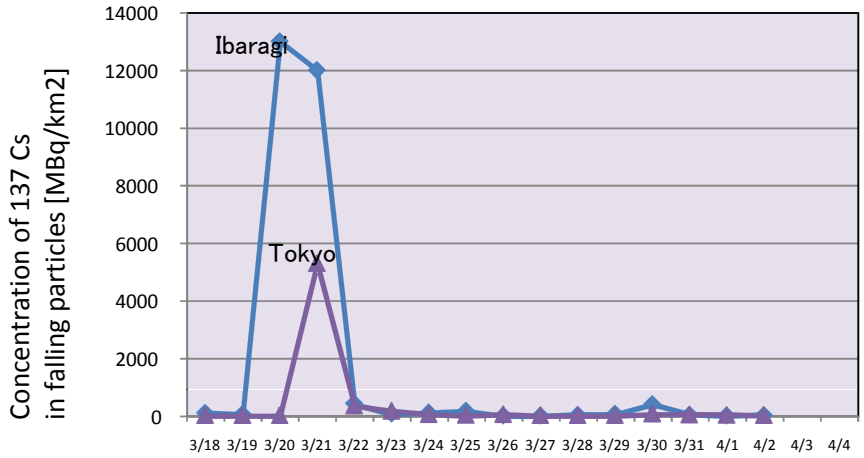
What will happen to polluted water and leaf vegetables?

It is estimated that between March 15 and 16, there was a large amount of radioactive substances emitted into the air.

Emission still persists after that, but the amounts are considered to have decreased substantially.



Concentration of radioactivity of falling particles is decreasing:



Based on Ministry of Education website data

Unless emission of radioactive substances rises extremely,

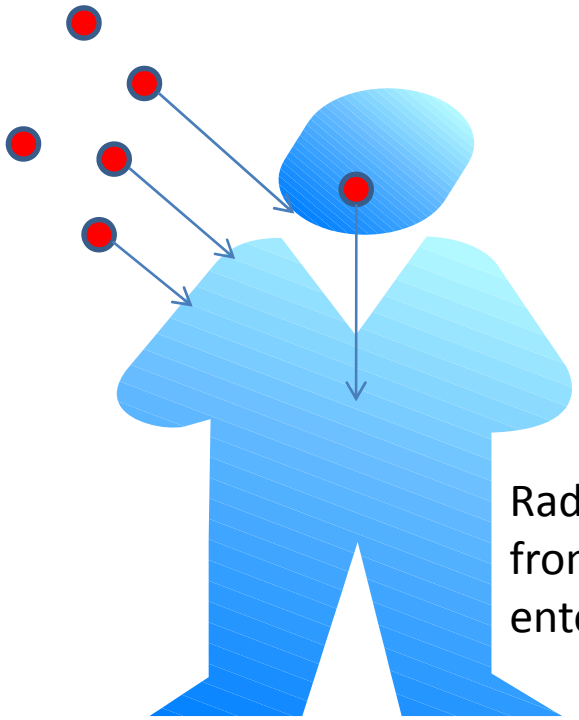
the levels of radioactivity in drinking water and leaf vegetables are to decrease gradually.

Internal and external exposure

2 kinds of exposure:

External exposure

Radioactive rays
from floating radioactive substances



Internal exposure

Radioactive rays
from radioactive substances
entering the body

Drinking polluted water and consuming leaf vegetables can lead to internal exposure

How long does radioactivity remain in the body?

Half-life: the time it takes radioactive substances to halve their radioactivity

	Physical half-life	Biological half-life	Effective half-life
^{131}I Iodine	8 days	120 ~ 140 days	**7.9 days**
^{137}Cs Caesium	30 years	about 90 days	**about 89 days**
Time it takes for radioactive substances to:	halve their radioactivity	reduce its radioactivity by 50% through ejection/excretion	halve as a result of natural reduction and ejection combined

The time in which the amount of radioactive substances inside the body declines by 50% is called effective half-life.

Effective half-life shows the effects on the human body.

^{137}Cs does not remain in the body for 30 years!

What are temporary restriction levels (standard value)?

These levels have been established under the National Food Hygiene Law to restrict the sale of food polluted by radioactive substances.

These have been established in haste after the current accidents, based on the "Guideline on restriction of food and drink intake" published by the Nuclear Safety Commission.

Guideline on restriction of food and drink intake

Item	Iodine	Caesium
Drinking water	300	200
Milk, milk products	300	200
Vegetables（Except root vegetables and potatoes）	2000	500

These levels were also applied to imported foods at the time of the Chernobyl accident.

The implications of temporary restriction values

Under the assumptions that:

Ingestion of the same amount everyday,

and that one consumes for a year.

Drink everyday

Eat every day

Temporary restrictive levels:

^{131}I (Iodine): thyroid gland dose → 50mSv

N.B.: Doses for thyroid gland only!

^{137}Cs (Caesium): Dose for the whole body → 5mSv

Levels of radioactive substances

What if one drinks tap water in Tokyo…

In Tokyo, at one point, tap water inspection revealed 210 Bq/kg of ^{131}I, in excess of the limits for babies (100 Bq/kg)

Based on the actual monitoring figures on the following page, it is possible to assume emergency doses for the thyroid gland of a baby: Drinking 1 liter of water everyday with the same radioactivity levels as found in water filtration plants leads to a rise of about 1.6mSv for thyroid gland . This apparently shows that the levels have stabilized at levels causing no serious problem.

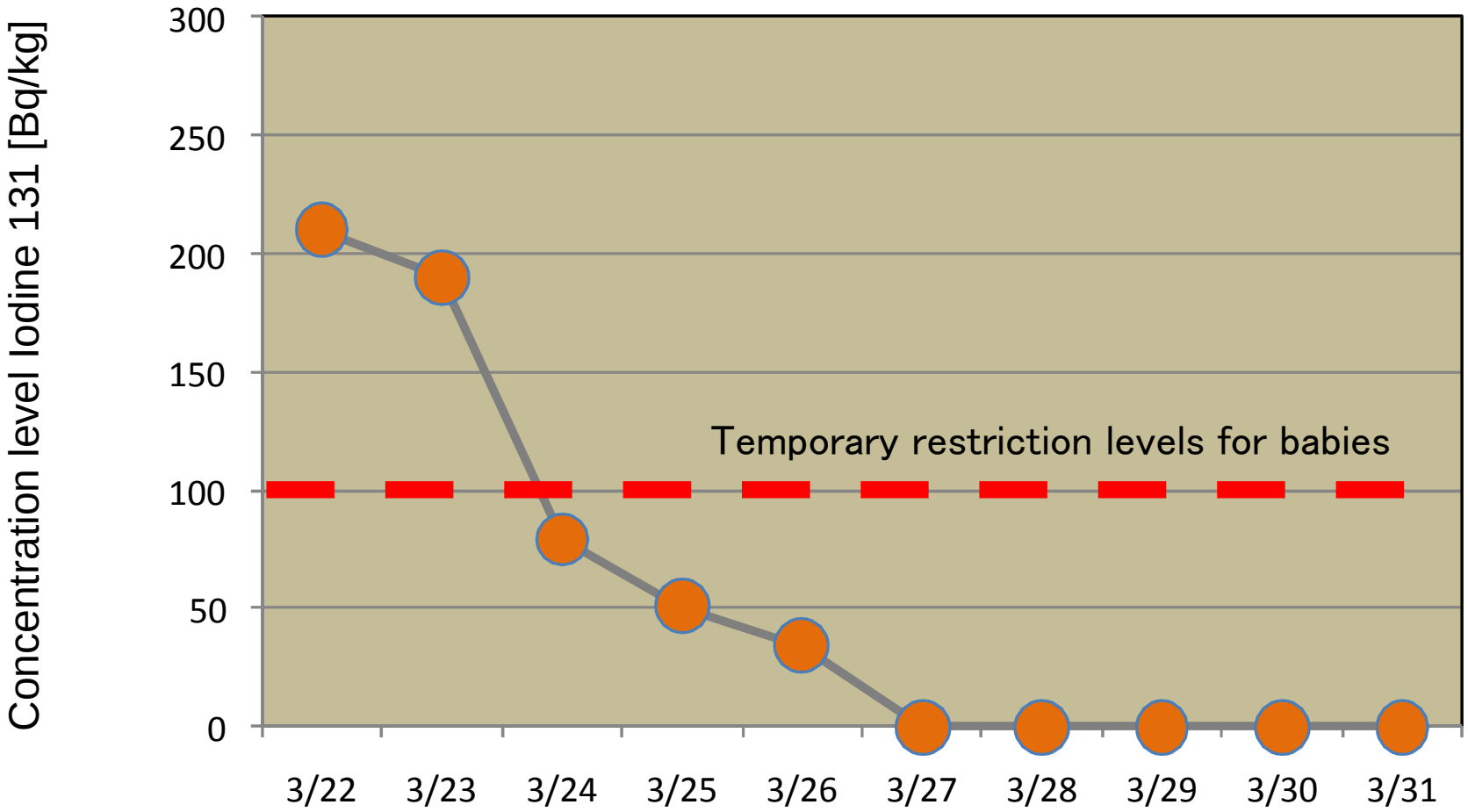
Even if one drinks 1 liter of such water (210 Bq/kg) everyday for 1 year,

Exposure doses for the whole body remains at about 1.7 mSv,
in view of long-term cancer risks.

Doses of this level are much lower than those causing cancer.

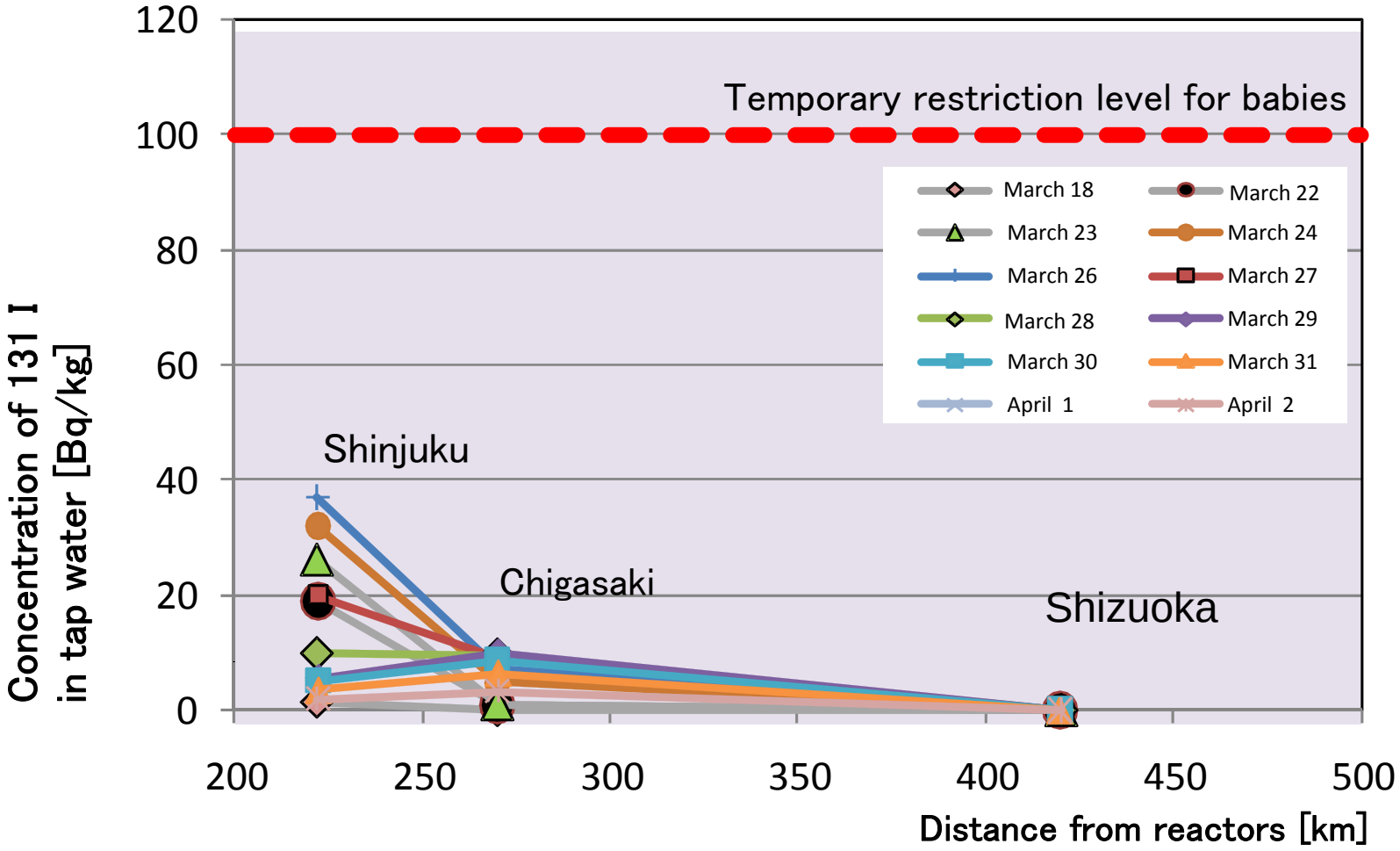
Current radioactive levels are below the temporary levels:
the effects of radioactivity can be ignored
even if one drinks tap water.

Levels of radioactive substances at water filtration plant (Kanamachi, Tokyo)



Based on Metropolitan Tokyo website data

Concentration of Iodine (^{131}I) in tap water



Based on Ministry of Education website data

Concentration in tap water

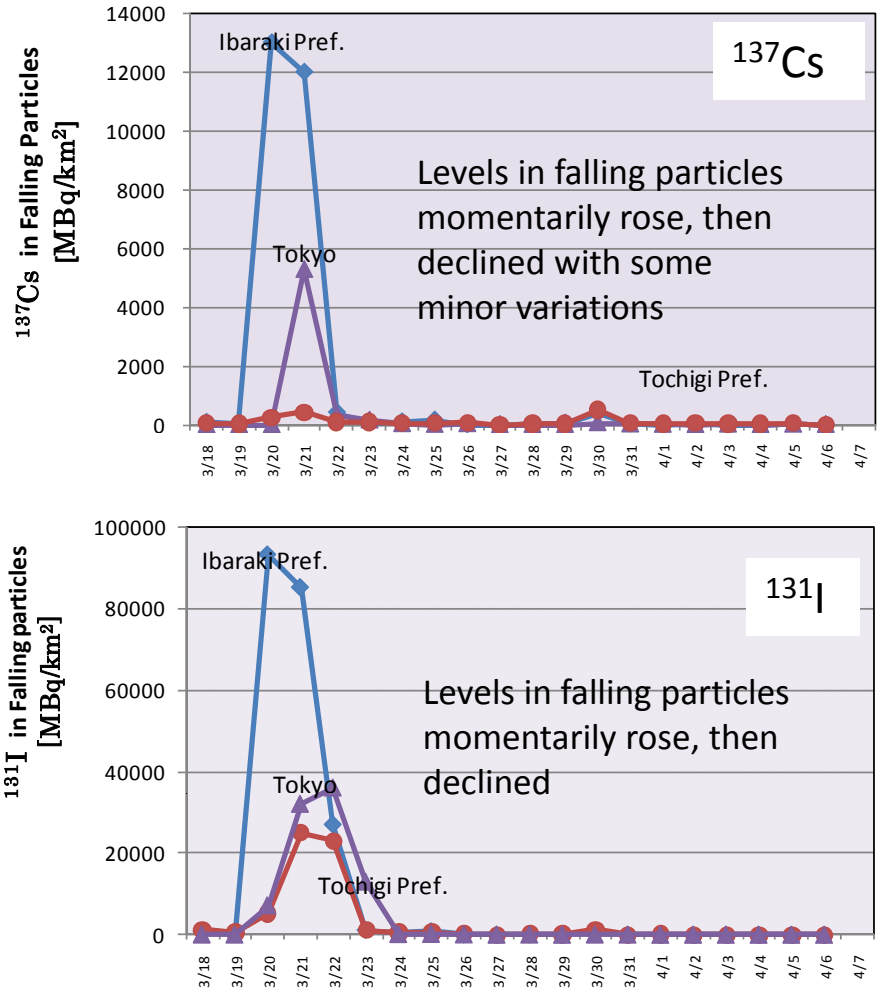
Tokai University analysis

	Location	Date	^{137}Cs [Bq/kg]	^{131}I [Bq/kg]
Tap water	Tokyo wards, Kawasaki, Atsugi, Zama, Hadano, Isehara (Kanagawa)	Evening March 24, Morning 25	Approx. 1 Bq/kg, same as mineral water sold on the street	
Rain water (for reference only)	City of Kawasaki	March 21～22	Approx. 11	Approx. 7
	City of Hiratsuka	March 21	Approx. 6	Approx. 4
		March 22～23	Approx. 30	Approx. 8

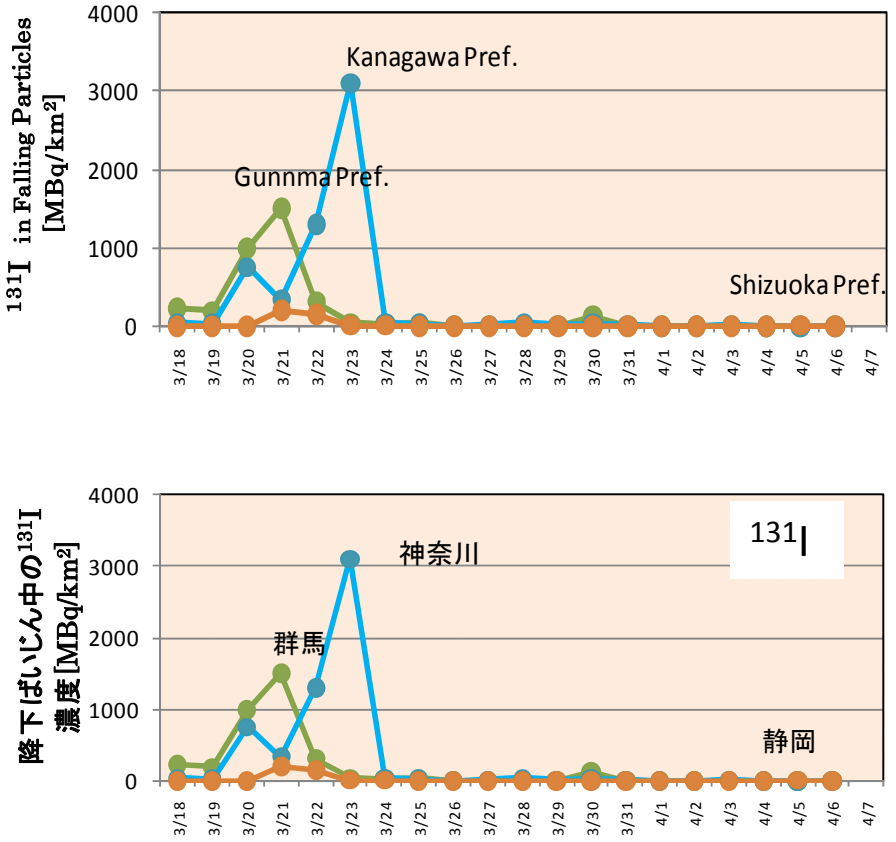
→Levels causing no problems

Currently below detection levels

Levels in falling particles



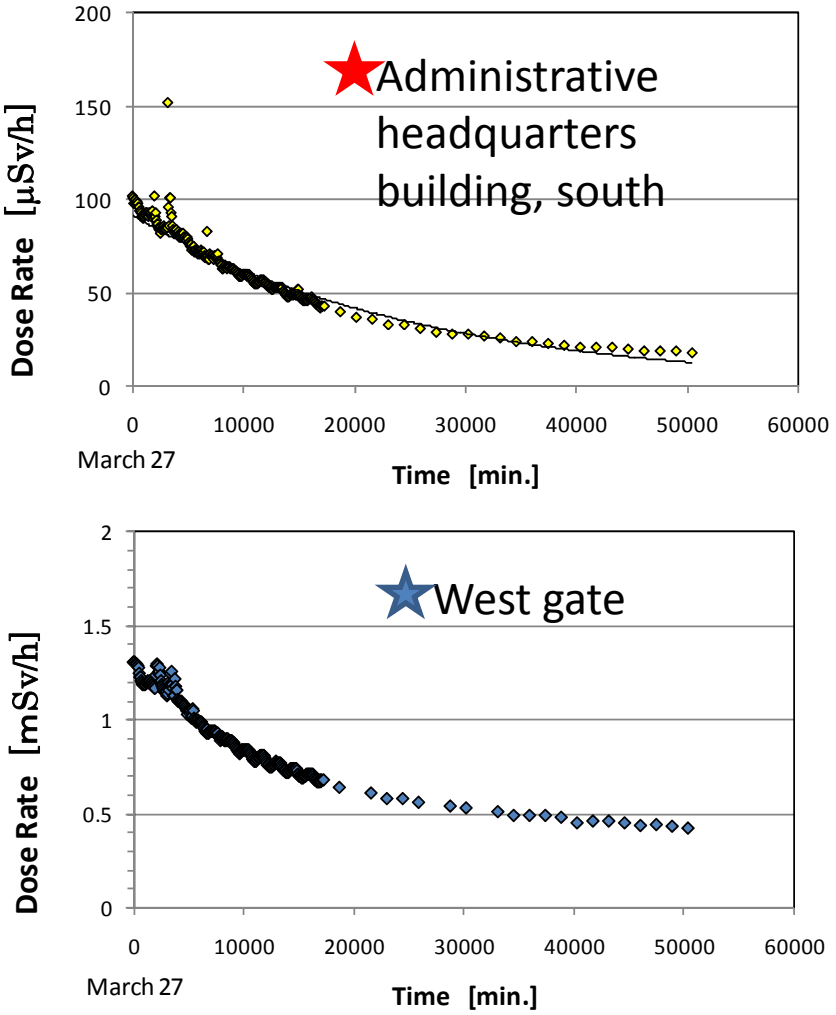
Levels in falling particles may temporarily rise depending on wind direction, wind speed and rain

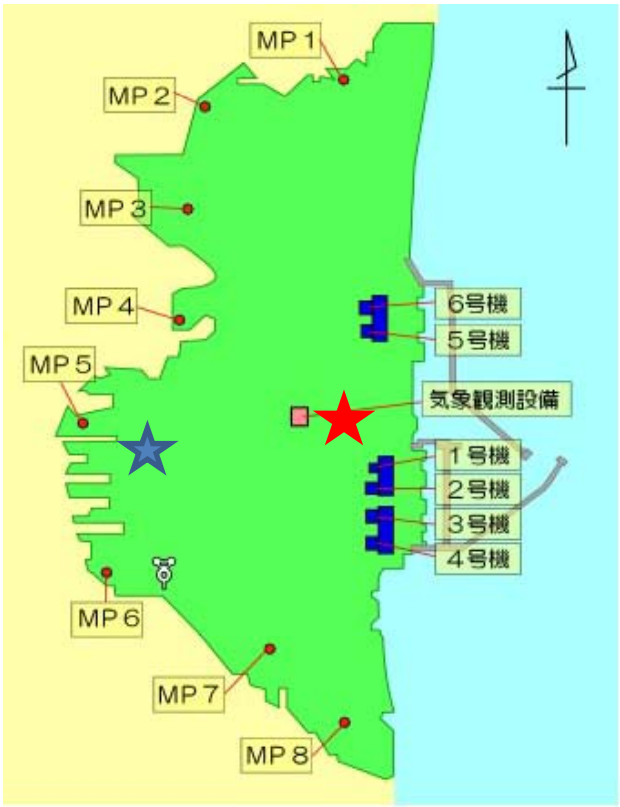


Based on Ministry of Education website data

Emission into the air

Since dose rates around nuclear power plants are gradually decreasing, emission of radioactive substances is declining





Summary

Effects of radioactive rays can be ignored

Effects of radiation in tap water at the faucets should not be a concern, since its levels are below the restriction levels even in neighboring areas.

As for leaf vegetables,

pollution above the temporary restriction levels should be considered a temporary occurrence, if emission of radioactive substances from power plants does not unusually rise.

The temporary restriction levels
have been set with
a considerable safety margin:

Consumption of
a small amount hardly
has any effect.