Environmental radiation in Fukushima and
Fukushima University Institute of Environmental Radioactivity

Prof Kenji Nanba
Deputy Director
Fukushima University Institute of Environmental Radioactivity

Japan Matters public lecture
Japan Desk Scotland
15 June 2014

Radiation

This table shows the average dose rates from natural environment (UNESCO 2008).

Source		annual dose (mSv)
Cosmic ray		0.39
Radiation from the earth		0.48
Inhalation	^{238}U (uranium), ^{232}Th (thorium)	0.006
	Radon	1.15
	Thoron	0.1
	sub-total	1.26
Ingestion	^{40}K (potassium)	0.17
	^{238}U, ^{232}Th	0.12
	sub-total	0.29
Total		2.4

Potassium 40 is a larger part of dose from food (0.17 out of 0.29 mSv). We need potassium as one of the important elements of our body, but some part of potassium is radioactive potassium 40. We always receive radiation from potassium 40.

Some explanation on the units, becquerel (Bq) and sievert (Sv):

Bq: How many nuclei decay in a second
Sv: the degree of radiation that human, or other animals, receive

As for ingestion from food, there is a relation between Bq and Sv. How much Sv will you receive when you eat food containing XXX Bq? There is an equation:

Sv = (Bq) x (effective dose conversation factor)

The effective conversion factors are known for every radioactive nucleus.

For example, if you eat 100 Bq of Cs (cesium) -137, this corresponds to

$100 \times 1.3 \times 10^{-8} = 1.3\ \mu Sv = 0.0013\ mSv$

If we want to know the safe level of radio cesium uptake, we can compare it with potassium 40. Potassium 40 in a human body is 70 Bq/kg. If you are 70kg in weight, you have about 5,000 Bq per body. How much radio cesium do you need to take to have the equal level of potassium 40? An adult needs the uptake of 29 Bq of radio cesium every day. Now the food uptake standard in Japan is 100 Bq/kg. In Europe, this is 600 Bq/kg. You can remember that potassium 40 corresponds to 0.17 mSv per year. So, with the uptake of this amount of cesium, I can feel relatively safe.

Fukushima
After the earthquake of 11 March 2011, a series of explosion happened at Fukushima Daiich Nuclear Power Plant. The radiation level in Fukushima city jumped to a very high level in the evening of 15 March, when it was raining. The rain brought radioactive substances in the atmosphere down to the surface of the environment.

After we found the deposition of radioactive substances, we, some members of Faculty of Symbiotic System Science, Fukushima University, started to measure radioactivity in Fukushima Prefecture. Our result and other investigations carried out by the government showed that the contamination was higher in north-west direction viewed from the nuclear power plant.

Among the major radio nuclides Cs (cesium) -134 and Cs-137 have relatively longer life (half life is 2.065 year and 30.17 year, respectively), compared with Iodine-131 (8.021 days) and tellurium-132 (3.024 days).

Radiation protection
To protect ourselves from radiation, we have to pay attention to two kind of radiation dose: external dose and internal dose.

- To avoid external dose
  - Lower the ambient dose rate (decontamination)
  - Relocation (evacuation)

- To avoid internal dose (inhalation or ingestion)
  - Avoid food that has (may have) radioactive substances above the regulation level

Inhalation is much less for radio cesium, but food can be a serious problem.

Decontamination
In May 2011, the first decontamination activity in Fukushima Prefecture was carried out at Fukushima University Junior High School's ground, where radiation level was 3 μSv per hour, which were considered by some specialists too high for small children.

The major source of gamma ray is radio cesium, and radio cesium exists only in the surface of the ground. The surface of the ground was scraped by about 5cm, which removed radio cesium, and the removed surface soil was laid deep in the ground and covered by 50cm depth of uncontaminated soil. Radiation would not come out into the atmosphere, and people on the ground can be protected from gamma ray source, radio cesium.

Gamma ray will be reduced by 90% when it goes through 230m of air, 27cm of water, or 20cm depth of soil, and by 99% when going through 40cm depth of soil. If radio cesium is shielded by 50cm depth of uncontaminated soil, this would shield more than 99% of gamma ray from the removed surface soil.

Before the removal of the top soil of the ground, the dose rates were 3.0 or 2.9 μSv per hour, which corresponded to more than 10 mSv per year. After the removal, radiation dose rates became lower than 0.3 μSv per hour. The surface soil removal is the most potent way of decontamination, but most of the contaminated soil removed from agricultural fields is stored in temporary storage sites on the ground. These will be moved to an interim storage site, which the national government plans to construct in Okuma town where Fukushima Daiichi Nuclear Power Plant is located.

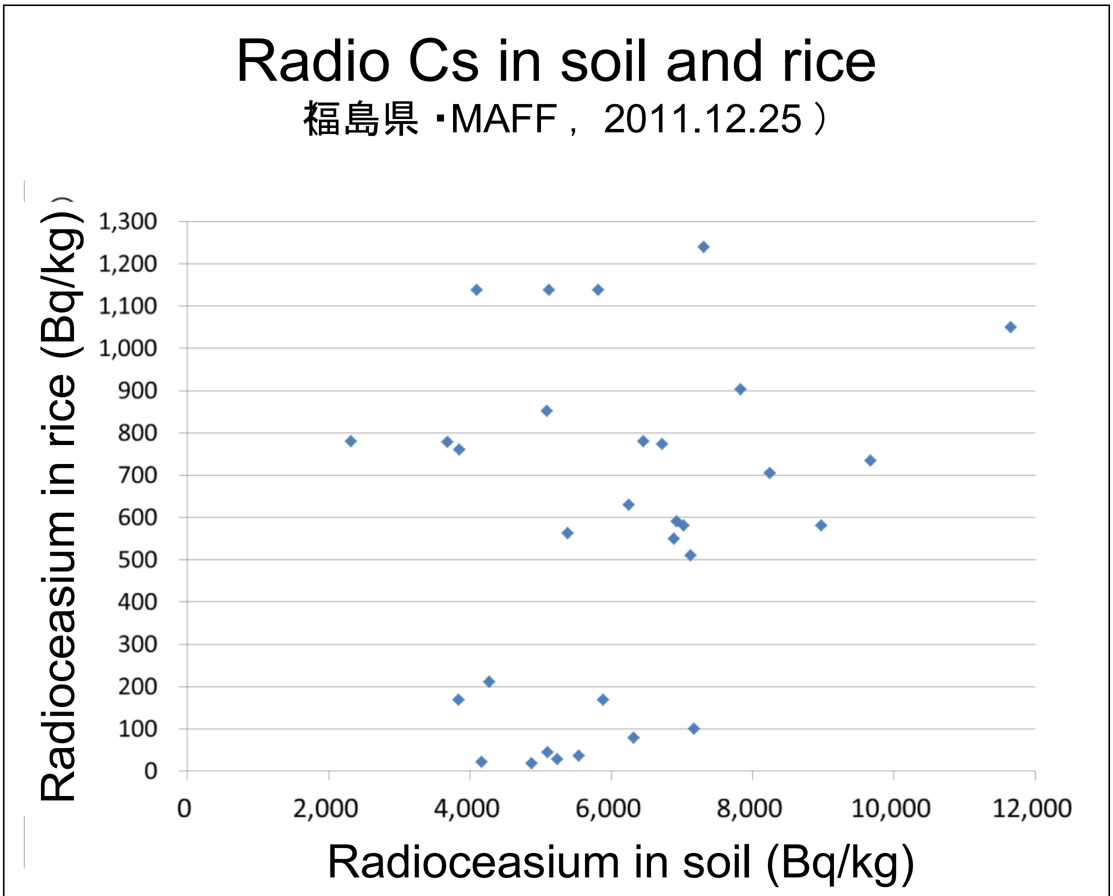
The movement of radio cesium in the environment

1. Release --- from reactors (accident, vent + wind) (meteorological)
2. Deposition → on soil, tree, building etc.
3. Migration Hydrological action
   --- Erosion, translocation, sedimentation
   Meteorological action
   --- Re-suspension with wind
4. Transfer Ecological action
   --- Plants may absorb through roots, leave or trunk.
   --- Animals eat the plants.
   --- Animals predate other animals. <food chain>

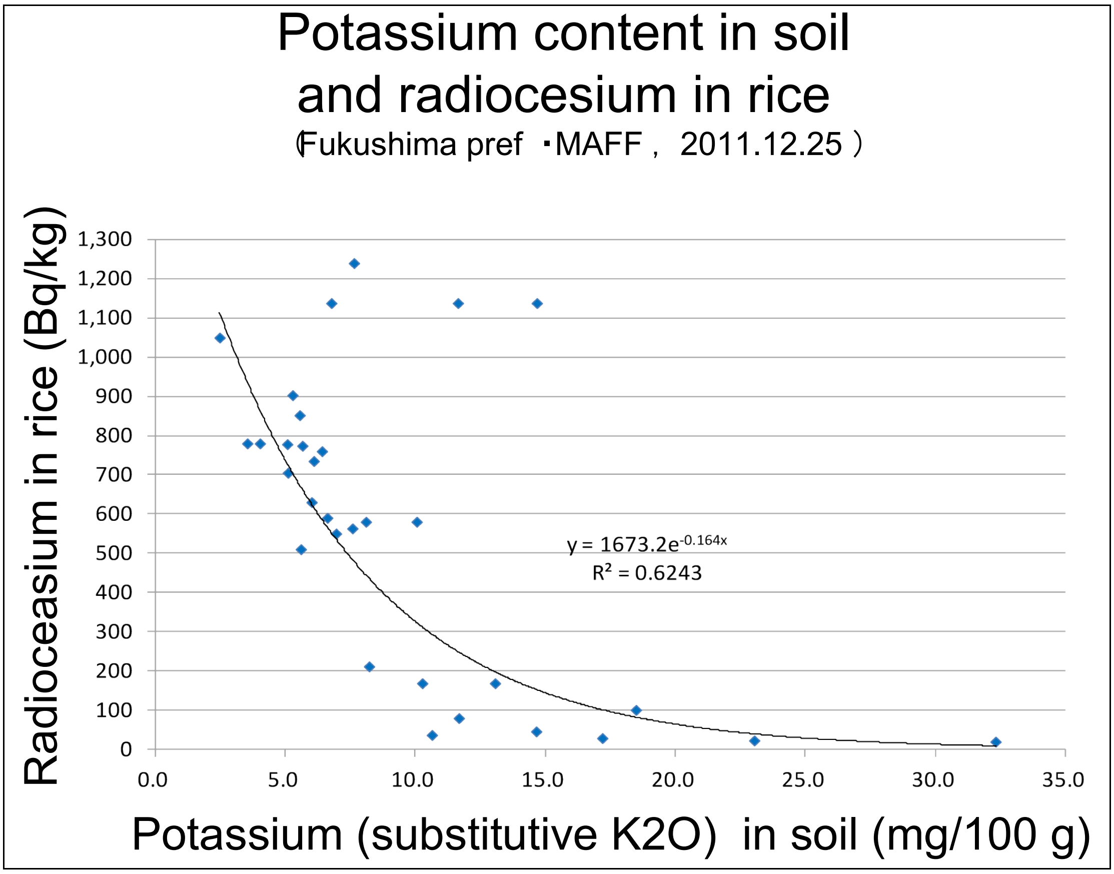
Cesium (Cs) is in the same column with potassium (K) in the periodic table, which means that cesium, as an element, has similar characteristics with potassium. Plants and animals need potassium in their body. Because cesium is similar to potassium, however, plants and animals may take cesium through the same route as potassium that is an essential element.

Rice

Farmers in Fukushima were allowed to plant rice in 2011 as far as radio cesium in soil was lower than 5,000 Bq/kg. The government believed that this was a safe level, but things were not as they expected. As shown below, some rice exceeded the safe food uptake level of 500 Bq/kg, even though the radiocesium in soil was lower than 5,000 Bq/kg. We can't see a proportional relationship between soil and rice.



What determined radio cesium level in soil is now partly known. It is potassium.



As shown above, if potassium concentration is 20 mg/100g, radio cesium in rice should be less than 100 Bq/kg. Because the food uptake safety level was to be lowered from 500 Bq/kg to 100 Bq/kg in April 2012, the prefecture government forced farmers to fertilise soil with potassium, together with zeolite.

In 2012, the prefecture government decided to measure all the rice produced in Fukushima. As rice is shipped in a bag of 30kg, this amounted to about 10 million rice bags, using belt conveyer automatic measurement equipment. As shown below, 99.78% had radio cesium at lower than the detection level. In 2012 the rice production in Fukushima Prefecture was effectively controlled by the prefecture government and farmers.

Cs-134 + Cs-137 in rice produced in 2012 in Fukushima Prefecture

(unit: Bq/kg)

	below detection level (< 25)	25 ~ 50	51 ~ 75	76 ~ 100	Total
no. of bags tmeasured with belt conveyer equipment	10,124,449	20,062	1,381	72	10,145,964
%	99.78%	0.2%	0.01%	0.007%	99.99%

Fresh water and marine fish

Lake Hibara in western part of Fukushima Prefecture, where radiation level is lower than other areas in the prefecture, is popular for fishing *Wakasagi*, a small fish with 7 to 8 cm in length, through a hole made on frozen icy surface of the lake in winter. The measurements carried out by the prefecture government show that the radio cesium concentration in the fish decreased from above 800 Bq/kg in 2011 to about 290 Bq/kg in 2012.

The radio cesium concentration level, however, does not show uniform trend. For example, the radio cesium concentration in *Himemasu*, a kind of trout with 20 to 30cm in length, in Lake Numazawa, also in the western part of Fukushima Prefecture, increased between 2011 and 2012. Even in 2014, the level exceeded 100 Bq/kg, the food safety regulation level.

Radio cesium concentration level is different among fish species, or in different lakes. But, if we look at fishes from the same river, we can say something about the difference.

We have been carrying out research into three different fishes in Abukuma River, which runs through Fukushima City to the Pacific Ocean. The radio cesium concentration decreased for *Ayu* (Plecoglossus alitivelis), while it didn't decrease for *Yamame* (landlocked Oncorhynchus masou) and *Iwana* (Salvelinus leucomaens). One thing we suspect is that *Ayu* is a bottom grazer, eating algae on rock surface, while *Yamame* and *Iwana* are predator or carnivorous, eating insects in water or fallen insects from the terrestrial part of the river. Some of these predators may have eaten insects or small animals which have a high concentration of radio cesium. We are measuring water from the river as well, to show the source of radio cesium in fish. This can be a very good tool to trace the food chain.

Our other investigation shows that the highest level of radio cesium concentration in the dry river bed is found at the depth of 15cm from the surface.

As for marine fish which have been monitored by prefectural government, the level of radio cesium is high among those caught just south of the Fukushima Daiichi Nuclear Power Plant. The water current ran from the north to the south at the time of the accident, and the most contaminated sands were along the coast south of the nuclear plant. Some fish didn't show the concentration of radio cesium and commercial fishing, although it is called test fishing, was resumed in June 2012 for three species, and now for more than twenty species.

You can check the level of radio cesium in vegetables, fruits, cereal, sea foods, etc from Fukushima Prefecture Government's web site at:

http://www.new-fukushima.jp/monitoring/en/ (in English)

Institute of Environmental Radioactivity at Fukushima University (IER)

Aims:

Help the local residents, local farmers, and local government administration (decision making, managing river and forest environment …)

Share the experience and findings among experts of relevant field of science from various countries

Aims in the long run:

Promote the restoration of Fukushima
Prepare for a future emergency situation that may happen somewhere in the world

Monitoring human health and understanding the natural process:

Transfer of radio cesium
- Hydrological
- Ecological

Influence of radiation
- human health influence
- social influence
- psychological influence

Decision based on a balance between risk and benefit

Science literacy
- Basic knowledge
- Avoid confusions by rumours or pseudo-science