Chapter 1
The Overview of Our Research

Tomoko M. Nakanishi

Abstract The overview of our research projects for Fukushima is presented including how they were derived. Then, where the fallout was found, right after the accident, is briefly summarized for soil, plants, trees, etc. The time of the accident was late winter, there were hardly any plants growing except for the wheat in the farming field. Most of the fallout was found at the surface of soil, tree barks, etc., which were exposed to the air at the time of the accident. The fallout found was firmly adsorbed to anything and did not move for months from the site when they first touched. Therefore, the newly emerged tissue after the accident showed very low radioactivity. The fallout contamination was not uniform, therefore, when radiograph of contaminated soil or leaves were taken, fallout was shown as spots. Generally, plants could not absorb radiocesium adsorbed to soil. Further findings are described more in detail in the following sections.

Keywords Fallout • Research in agriculture • Research project • Research site • The way of contamination

1.1 Research Project

After the accident of Fukushima Daiichi nuclear power plant, thousands of measuring data have been piling up, especially in the web sites of government agencies. However, most of them are two kinds of the data. One is the radio activities of the places, including soil, air dust or sea water and the other is the measurement of the foods. These are just the monitoring data and it is difficult to find out the research

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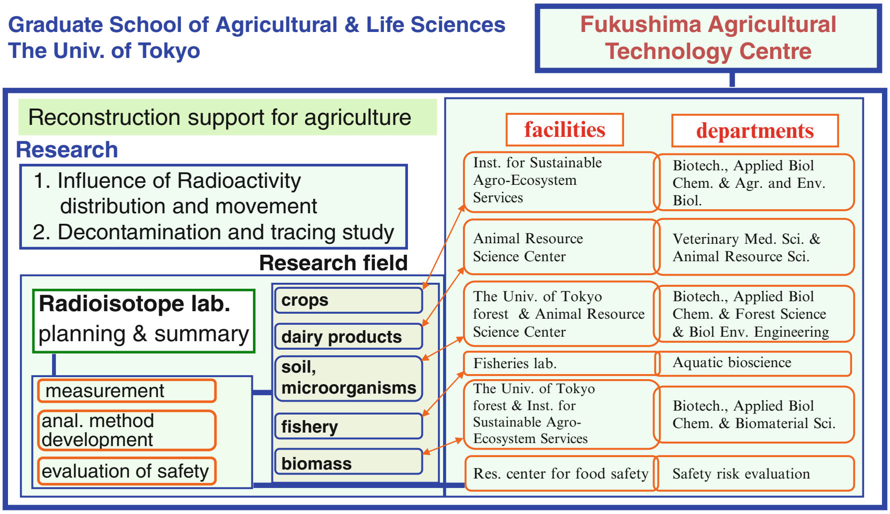

Fig. 1.1 Research project. About 40 academic staffs from all kinds of the facilities and departments of our Graduate School proposed research plans and they were classified into several groups. Wide ranges of the agricultural research have been going on

data related to agriculture, such as, how much amount of radioactivity was found or estimated when the plants were grown in the contaminated field or how much radioactivity was accumulated in mountains and what about the contamination of river water coming from the mountain, etc.

Right after the accident, many academic staffs in our Graduate School had started the research project for Fukushima. But soon we found that it was very difficult to pursue the research by individual researcher alone, since the target is very complicated and it is the study of nature itself. For example, when contaminated rice was found, discussion was needed not only from scientists of rice but also from those of soils or water flow. When our dean, Prof. H. Nagasawa, had asked us, right after the accident, what kind of the research we can do, about 40 academic staffs corresponded to our dean's request and proposed their research plans. In our faculty, wide ranges of the agricultural research have been going on, for plants, soil, animals, fish, etc. Many scientists are pursuing their own individual majoring field. Since the research plans proposed were from all kinds of the facilities and departments of our Graduate School (Fig. 1.1), they were classified into several groups as follows, and the research projects were started. However, there has not been any budget prepared for these projects. That means, most of them were started and developed based on voluntary activities.

(Research project group)

1. Influence of fallout (distribution and movement)
   (a) Crop plants and soils
   (b) Stock raising & dairy products
   (c) Fishery

(d) Environment, including wild life
(e) Radiation measurement & radiochemistry
(f) Science communication

2. Recovery of suffered agriculture (recovery from Tsunami effect)

(a) Crops production and soils (salt damage, farmland maintenance, etc.)
(b) Biomass production

These research project groups were sometimes merged or further divided along with the development of the research. It was our challenge and first trial to perform the research by the group of the scientists who had never discussed nor carried out the same project before, in such a wide range of research field. In this meaning, these projects are very unique, not only covering vast field of agricultural research but also consisted of so different types of the scientists.

1.2 Research Site

The main research sites were shown in Fig. 1.2. Since many staffs belong to the facilities attached to the Graduate School were participated, the research sites were distributed in wide range of the districts in Japan. A tremendous number of the samples collected at each site were sent to the radioisotope lab. of the Graduate School, located at the main university campus in Tokyo. Then, the radioactivity of the samples were measured by germanium semiconductor detector or NaI(Tl) counters and the radioactivity imaging was performed using imaging plates or real-time radioisotope imaging systems (Kanno et al. 2012; Kobayashi et al. 2012; Hirose et al. 2012), we developed.

Besides our facility sites, we started collaboration with Fukushima Agricultural Technology Centre, which is the largest agricultural research center in Fukushima prefecture, including Fruit & Tree Lab., right after the accident. This collaboration was in a large field of the research, including vegetables, serial plants or fruit trees, soils, etc.

We started field ecological study and decontamination research at Date city, Samegawa village and Iitate village. In the case of Date city, a big project has started to analyze the ecological circulation or movement of the radionuclides, including food chain of the wild lives. The flow of the radiocesium via water with respect to the feature of the landscape is also being studied.

The wild life researchers are performing their investigation as close as possible to the nuclear reactor site but it was prohibited to enter the place within 30 km from the reactor. They are collecting small animals or insects and studying the contamination level or distribution of the fallout. Then they analyzed the specific accumulation manner of the nuclides along with food chain.

Among our facilities, the highest radioactivity was counted at Animal Resource Science Center. Therefore, they prepared the haulage from contaminated grass and fed them to the cow to see how radiocesium is transferred to the milk. Several kinds

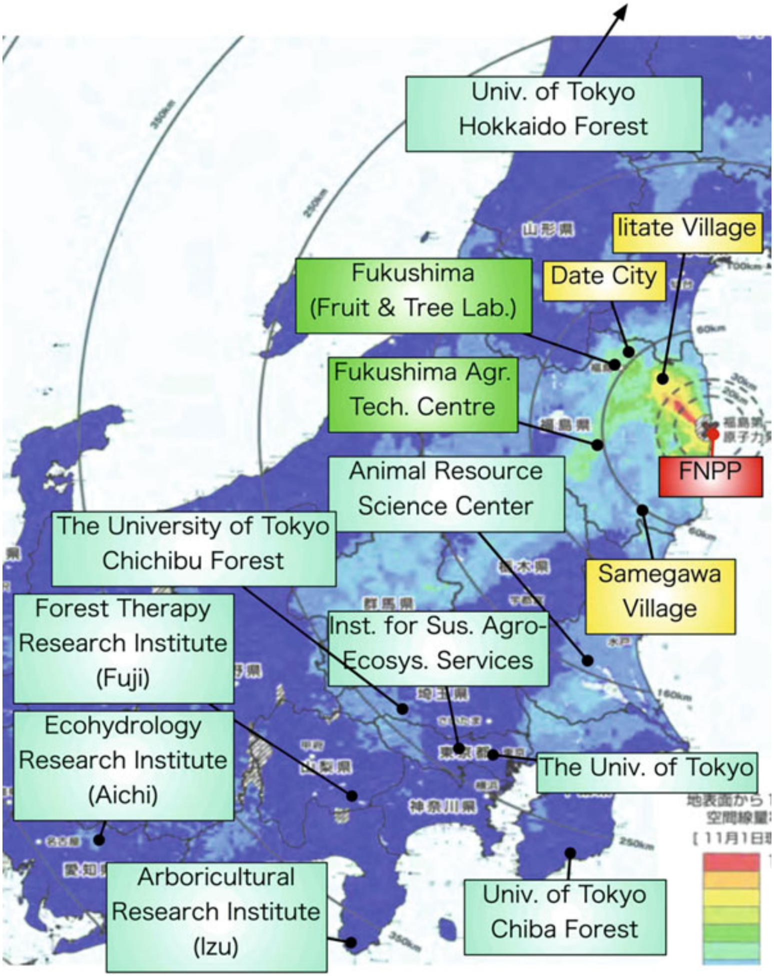

Fig. 1.2 Research site. The research sites were distributed in wide range of the districts in Japan. A tremendous number of the samples collected at each site were sent to the radioisotope lab. of the Graduate School, located at the main university campus in Tokyo

of highly contaminated stock animals were brought in from Fukushima prefecture to see what kind of influence can be seen in second or third generation. The wild animals captured at highly contaminated place in Fukushima were also brought in to find out the distribution of the radioactivity in tissue.

The researchers of marine biology are collecting the samples mainly at Ibaraki prefecture, adjacent to the Fukushima prefecture, to the south. They asked the fishery labor union to collect the fish from different depth in sea.

There is our farming land in Tokyo, called Institute for Sustainable Agro-Ecosystem Services. Though the contamination level was very low, since it is about

230 km far from the nuclear power plant, the influence of low level contamination to the agricultural products are studied. Especially for fruit trees, the radioactivity throughout the tree tissue was scrutinized. They found that the small amount of radioactivity can be transferred from bark skin to the xylem tissue, which was estimated as the main route for radiocesium accumulation in fruits.

In the case of The University of Tokyo Forests, litters or mushrooms were collected and the radioactivity was measured. It was noted that some kind of mushrooms selectively collected the very old radioactive fallout, about 40 years ago, when open test of atomic bomb was conducted.

1.3 Fallout on Soil

The initial information we got was as follows. In the case of soil, most of the radioactivity was detected in the surface, 2–3 cm of soil in the fields of Fukushima (Fig. 1.3). Many pipes were prepared on the ground and the radioactivity profile along with the depth was measured (Shiozawa et al. 2011). The left figure in Fig. 1.3 shows the radioactivity profile in the soil. When the farming soil was collected and the radioactivity images were taken by an imaging plate, radioactivity was found as spots. The radiograph of the soil showing that the contamination was not uniform in the soil suggested that the radioactive nuclides were adsorbed at particular site of the soil. The soil was crashed and separated to find out which part of the soil the radioactivity was accumulated. The highest radioactivity was measured in two fractions, the finest fraction, clay, and an organic layer, which was the debris of the fallen plant tissue and was not yet decomposed completely by microorganisms.

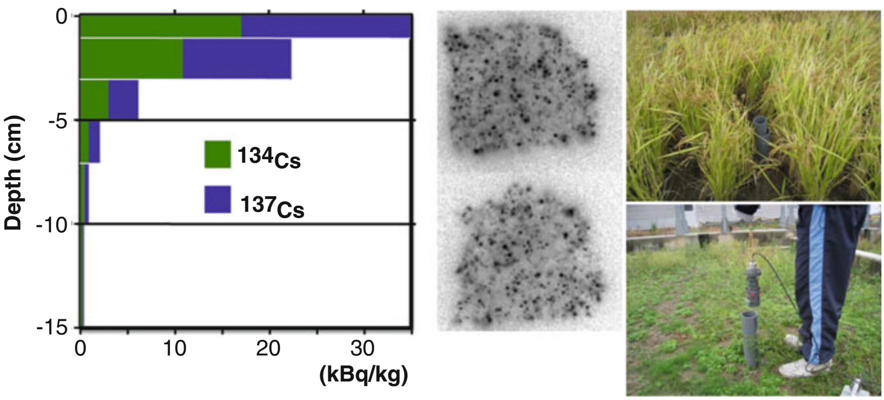

Fig. 1.3 Fallout on soil. Most of the radioactivity was detected in the surface of soil in the fields of Fukushima (*left*). The contamination was not uniform in the soil suggested that the radioactive nuclides were adsorbed at particular site of the soil (*middle*). Many pipes were prepared on the ground and the radioactivity profile along with the depth was measured (*right*)

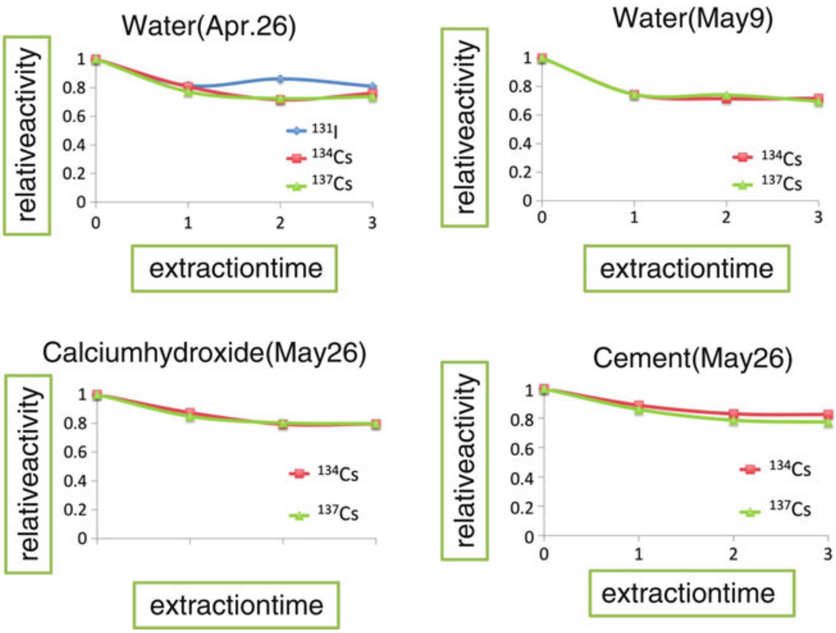

Fig. 1.4 Extraction of radioactive nuclides from paddy soil for a rice plant. Soil was washed under different treatments to find out in which condition the radioactivity can be removed from the soil

Then, the soils from different farming place were collected and were washed under different treatments to find out in which condition the radioactivity can be removed from the soil (Nogawa et al. 2011). As is shown in Fig. 1.4, the initial washing removed at most 20% of the radionuclides. However, further washing with solutions of caesium iodide, hydrated lime, fertilizer, and even cement did not remove any radioactivity, suggesting that most of the nuclides that remain in the soil were so firmly adsorbed to the soil that it is difficult to decontaminate the soil with chemical treatment.

Therefore, it was suggested that this thin contaminated surface soil can thus be collected and buried on site, leaving the land safe to work again, as the radionuclides are unlikely to be leached from the soil (Fujimura et al. 2012). The downward movement of the radiocesium in soil was further monitored.

1.4 Fallout on Plants

The way of contamination in the plants grown at the time of the accident was as follows. Two months after the accident, wheat grown in Fukushima had high levels of radioactivity, but the radioactivity was measured mainly in the older leaves, which had been expanding at the time of the accident (Tanoi et al. 2011). Leaves that emerged after the accident had far less radioactivity, and ears had only 1/2000th

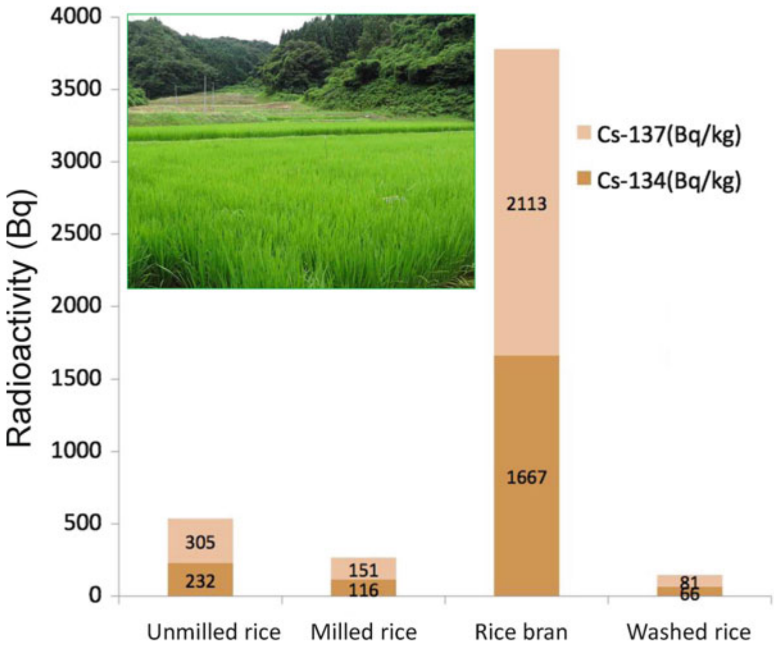

Fig. 1.5 Distribution of radioactivity in rice grain. Most of the radiocesium is accumulated in outer skin, rice bran. When the grain is milled, radioactivity is reduced to about half. By washing, the radioactivity was further reduced to about half

the radioactivity. These results suggested that the fallout adhered firmly to the leaf surfaces and that only very small amounts of the radionuclides had been absorbed and transferred to other organs. Radioisotope imaging has revealed the fallout as microscopic grains on the leaf surfaces, similar to the spot images of soils.

Since fallout was firmly adsorbed on soil, it was estimated that only small amount of radioactivity was absorbed by plant roots when grown in contaminated soil. However, in some rare cases, like that in Date city, the harvested rice grains showed high radioactivity, more than 500 Bq/kg (provisional regulation level), even though they were grown in the soil with low radioactivity, less than 5,000 Bq/kg. In such cases, the paddy rice field was surrounded by small forests and because of the landscape, the rice field was shaped as stepwise terrace (Fig. 1.5). To grow rice plants, a large amount of water is needed and the water is introduced as stream from the neighboring forest for this kind of the field. The water was conducted to the highest terrace of the field first and then it was introduced successively to the downward fields. However, the contamination level of the rice grain was different among the terrace fields. The highest radioactivity was not necessarily found in the rice grown in the field located at the highest level, i.e. closest to the mountain. The accumulation manner of radiocesium by rice grain was analyzed in laboratory using the contaminated soil (Nakanishi et al. 2012). Once radiocesium is dissolved with water, plants easily absorb and accumulate radiocesium but the problem is how fallout could be dissolved

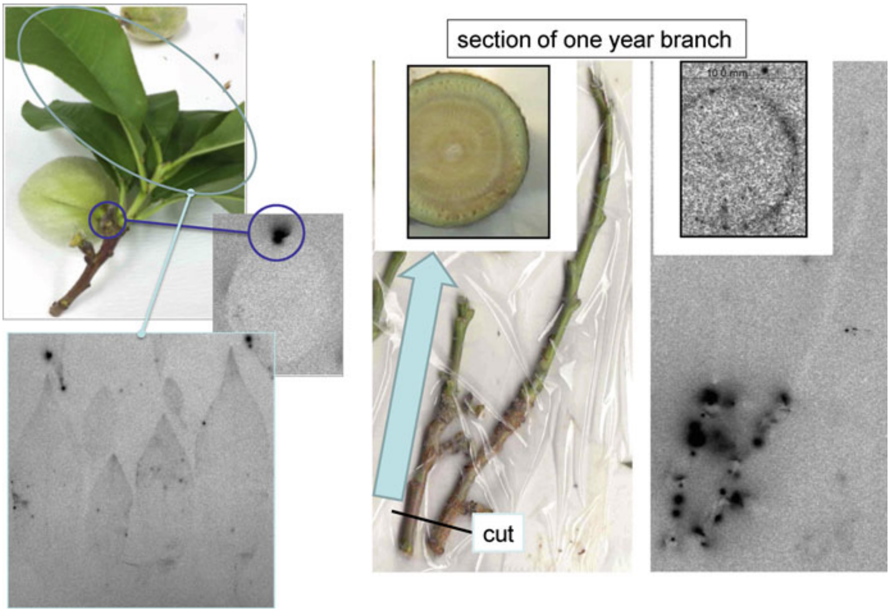

Fig. 1.6 Peach tree. The radiograph of fruit leaves and branches were taken by an imaging plate. In the case of a fruit, only bottom part, connecting to the branch, showed high radioactivity and the leaves emerged after the accident did not show any high radioactivity (*left*). In the case of branch, only the part already grown at the time of the accident was highly contaminated and newly emerged branch after the accident showed hardly any radioactivity. The section of the branch showed that only outer skin was highly contaminated (*right*)

as ions in water. The dissolved radiocesium ion could be derived from two ways, one from the litter in the mountain and the other from the organic matters in the rice field. Since water itself from the mountain is not contaminated, it was estimated that when the contaminated litter was decomposed by microorganisms, the radionuclides were adsorbed to the soil right after the decomposition. There must be some special condition to dissolve radiocesium in litter. In paddy field, organic matters at soil surface are decomposed especially during hot summer. The rice roots around this time grow horizontally to support the plants with developing ears firmly, therefore, the roots could be very close to the soil surface, decomposition site, to absorb radiocesium. Now further experiment is conducted to find out the source of the rice grain contamination.

Figure 1.5 shows the distribution of radioactivity in rice grain. Most of the radiocesium was accumulated in outer skin, rice bran. Therefore, when the grain was milled, radioactivity was reduced to about half. Then by washing, the radioactivity was further reduced to about half. To eat rice, water is added and steamed so that the radioactivity per kg unit is further reduced.

In the case of peach trees, the fallout contamination was found in the same way as that of wheat. That is, only the tissue already grown and exposed to the air, at the time of the accident, showed high radioactivity. Figure 1.6 shows radiograph of fruit, leaves and branches taken by an imaging plate. In the case of fruit, only bottom part of the fruit connecting to the branch showed high radioactivity. The radioactive nuclide was accumulated only at this part and did not move toward the fruit. The radiograph of the leaves showed that the leaves emerged after the accident did not show any high radioactivity. In the case of branch, radiograph showed that only the branch part already grown at the time of the accident was highly contaminated and newly emerged branch after the accident showed hardly any radioactivity. The dissection of the branch showed that only outer skin was highly contaminated. In the case of the other kind of trees, only bark was highly contaminated and pealing the bark was the most effective way for decontamination (Takada et al. 2012).

To remove radioactivity by plants was proposed, since plant roots excrete acids to mobilize nutrients. Plants grown in contaminated soil could therefore remobilize the radionuclides and accumulate them in their roots. However, in our common view, it is extremely difficult to find out or create the plants which accumulate high amount of radiocesium. In the case of phyto-remediation, the concentration of the accumulated target nuclides in the plant has to be much higher than that of soil. When phyto-remediation is taken into account, the most promising method now considered is to analyze the mobilization mechanism of adsorbed radionuclide in soil by the mushroom and introduce the function to the plants.

1.5 Others

On the university's farm in Ibaraki prefecture, about 160 km southwest of the Fukushima nuclear power plant, we fed cows with silage made from contaminated grass harvested in Ibaraki. After 5 days the milk contained about 1/100th the radioactivity; it had thus rapidly accumulated the radiocesium (Hashimoto et al. 2011).

On the university's farm in the Tokyo, about 230 km southwest of the nuclear power plant, we grew cabbage and potatoes in soil that had an activity of about 100 Bq/kg (15 cm depth). After 2 months, the radiocesium in the developed leaves before washing was 9 Bq/kg, much lower than the provisional regulation level of 500 Bq/kg (Oshita et al. 2011).

We have now expanded our investigations into a long-term study that will also cover trees and fisheries. In the following sections, further findings are described more in detail.

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