Chapter 1
An Overview of Our Research

Tomoko M. Nakanishi

Abstract The movement of radioactive Cs emitted from the Fukushima Nuclear accident has been studied by the academic staff of the Graduate School of Agricultural and Life Sciences, The University of Tokyo. The targeted items for research ranged widely, including soils, plants, animals, fish, mountains, water, etc. The relevant feature, with regard to the fallout, is that the radioactive Cs has remained at the initial contact sites and has hardly moved since. However, in the case of living individuals, such as animals, the amount of radioactivity has decreased with time at a much faster rate than the physiological half-life because of their metabolic activities. The biological half-life in animals was estimated to be within a period of 100 days. Soil plays a major role in fixing fallout. When fallout nuclides are adsorbed into the soil, plants growing there can absorb little of the radioactive Cs. In the mountains, radioactive Cs was gradually transferred from litter to soil and moved little even when washed with heavy rains. The method of contamination by radioactive nuclides is completely different from that of heavy metals.

Keywords Fukushima nuclear accident • Fallout • Radioactive Cs movement • Soil • Plant • Forest • The method of contamination

1.1 Research Project

Immediately after the Fukushima Nuclear accident, the academic staff at the Graduate School of Agricultural and Life Sciences, The University of Tokyo, organized several groups to research into the behavior of radioactive materials in the Fukushima prefecture. The researchers were divided into the following six large groups and they still continue their work today:

1. Crop plants and soils
2. Livestock and dairy products

T.M. Nakanishi (✉)
Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan
e-mail: atomoko@mail.ecc.u-tokyo.ac.jp

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3. Fishery
4. Environment, including wild life and forest
5. Radioactivity measurement
6. Science communication

Rice is one of the important cereal crops in Japan; however, most of the rice plants growing in the contaminated soil showed very low radioactivity in the grain, <500 Bq/kg, which was the initial regulation value. Adding K to soil proved to be an excellent and most effective way of preventing radioactive Cs uptake by plants. However, there were some exceptional cases where radioactivity in the rice grain was >100 Bq/kg, which has become the current revised regulation value for foods. Such cases are rare, and they have been studied by Prof. Keisuke Nemoto in an attempt to analyze the origin and chemical form of the radioactive Cs that is easily absorbed by rice plants in a paddy field. Rice is grown and harvested once a year; therefore, only one set of data is being collected per year. Thus, only a few data sets have been accumulated since the accident. This makes it difficult to estimate future contamination of the cereal crop until more data sets are available. In the case of crop radioactivity inspection, the Fukushima prefecture has established a system to measure the radioactivity of all the rice grains before its transfer to market. More than 10 million rice bags, each containing 30 kg of rice grain produced in Fukushima, were measured every year. The contaminated rice grain was not sold.

To measure radioactive Cs, we use pure Ge counters and Na(Tl)I counters in our radioisotope lab. An enormous number of samples of various types, mainly collected by our colleagues, were brought to this lab, and their radioactivity was measured by professional employees. Over 10,000 samples were measured per year.

Within a few months after the Fukushima Nuclear accident, most of the radioactive nuclides measured were radioactive Cs because other radioactive nuclides, such as ^{131}I, had decayed out because of their relatively short half-lives. Figure 1.1 is an example of measurements using a pure Ge counter showing the gamma-ray spectrum of rice grains. The gamma-ray energy used to calculate the nuclides ^{134}Cs, ^{137}Cs, and ^{40}K was 604.7, 661.7, and 1460.8 keV, respectively. The respective detection limits of the nuclides ^{134}Cs, ^{137}Cs, and ^{40}K were 0.7, 0.8, and 23.8 Bq/kg.

In our previous book (Nakanishi and Tanoi 2013), we reported that soil and plant contamination are different from that of animals. The features of these contaminations are summarized briefly below, with new findings that were not previously included.

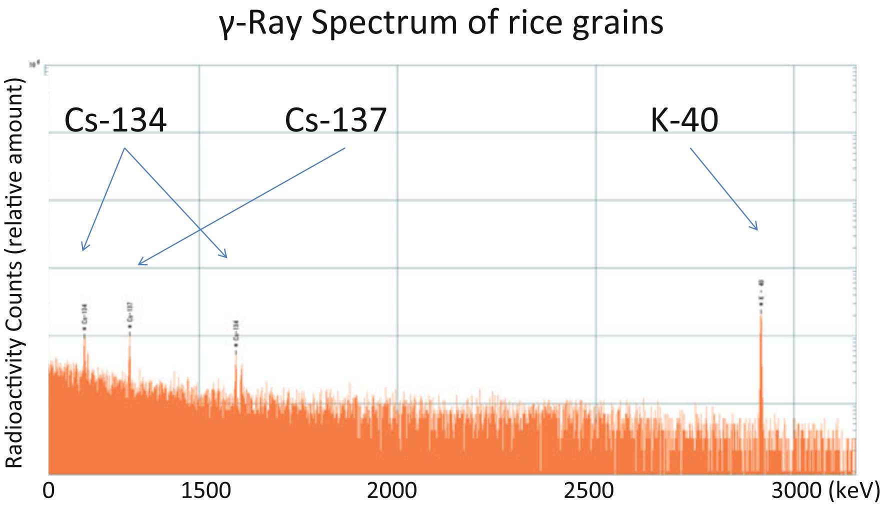

Fig. 1.1 An example of gamma-ray spectrum of rice grains

1.2 Fallout on Soil, Crops, and Trees

1.2.1 Soil

The role of the soil was the most important consideration in the movement of radioactive Cs which is adsorbed into the very fine clay and organic matter. When soil from the contaminated fields was collected and radioactivity images of the fallout were taken, they showed spot-like distribution even after several months. In addition, the fallout showed no movement. The radioactive Cs was difficult to separate from the soil by chemical treatment and could only be washed from the soil during the first few weeks after fallout; the adsorption of radioactive nuclides became stronger with time, thereby making them more difficult to remove.

Prof. Sho Shiozawa has been measuring the radioactivity of the soil along with the depth. He set several pipes vertically in the soil and periodically measured the radioactivity in the pipes along with the depth of the soil. He found that the downward movement of radioactive fallout is now about 1–2 mm/year, whereas in the first 3 months after the accident it moved approximately 20 mm/3 months and then, for the following 3 months, it moved approximately 6 mm/3 months. The speed of the movement is now much slower.

Prof. Shiozawa also measured the radioactivity at the surface of the basement soil of ponds, under the water, using a special waterproof survey meter prepared by himself. The radioactivity at the surface of the soil showed little downward movement with time, similar to land soil. There are two main radioactive nuclides detectable now: ^{137}Cs and ^{134}Cs. In most cases, the radioactivity of soil under water decreased with time, especially because of the relatively short half-life of ^{134}Cs, i.e., 2 years. The ponds he selected were collecting water from the mountains, and he recorded that little radioactive Cs was flowing into the ponds even after heavy rains.

He found only one pond where the radioactivity of the soil surface under the water was not decreased. He examined the location and environment of the pond, especially the surrounding upper mountainous area, and he found that there was a small village in close proximity to the pond where the people were always washing roads, houses, etc. using water. As a result of this activity, it seems that some of the radioactive Cs was removed from the concrete surfaces and flowed into the pond. In a few years, he will summarize and report these findings.

1.2.2 Crops

The Fukushima Nuclear accident occurred in March, and 2 months later, the ears of wheat crops developed and were ready for harvest. When the distribution of the radioactivity in the wheat was measured, to our great surprise, we found that it was more concentrated in the old leaves, which were exposed to the air at the time of the accident. The radioactivity of the leaves or ears that developed after the accident was comparatively very low. The fallout nuclides had hardly moved from the place where they had first landed, even after a few months.

When the radioactivity image on the leaves was magnified, the shape was still spot-like. If the radioactive Cs was incorporated into the leaves and had moved along the phloem or xylem, the vein should have been visible in the leaves. The behavior of the radioactive Cs emitted from the nuclear accident was different from the so-called macroscopic Cs chemistry we know. Because the amount of Cs deposited on leaves was so small, and most of them were carrier-free, the nuclides seem to behave like radio-colloids, or as if they were electronically adsorbed onto the tissue.

The radioactive Cs was adsorbed into the soil; therefore, it was unavailable for plant absorption. The real-time moving pictures taken by Dr. Natsuko I. Kobayashi were very convincing to many people. She grew rice plants both in water culture solution and in paddy soil which had been collected from Fukushima. Subsequently, ^{137}Cs was supplied to both the water culture solution and the paddy soil, and a comparison was made between the plants' absorption of ^{137}Cs. In water culture, the plants absorbed high amounts of ^{137}Cs within hours, and it was possible to trace its progress. Because in water culture, ^{137}Cs dissolved as an ion, it was easy for plants to absorb it. However, in the paddy soil, ^{137}Cs was trapped firmly by the soil and was unavailable to the plants. Using both ^{137}Cs and ^{42}K tracers, Dr. Kobayashi noted the effect of K on Cs uptake and the manner of translocation of Cs in the presence of K.

1.2.3 Trees

In the forests, leaves became highly contaminated at the time of the accident, and after falling to the ground and being decomposed by microorganisms, the radioactive Cs that was initially absorbed into the leaves became available to be absorbed by soil. It was found that radioactive Cs adsorption has been moving from the leaves to the soil in the forest. The radioactivity in the forest is also decreasing, along with the decay of ^{134}Cs, which has a half-life of 2 years.

However, as shown in our previous book, the radioactivity of mushrooms growing in the forest is not decreasing. Some of the mushrooms are still accumulating radioactive Cs that originated from the fallout of the nuclear test bomb during the 1960s.

In the case of fruit trees, the first question concerns the origin of the radioactive Cs in the fruit. It was taken for granted that nutrients are absorbed by roots and delivered to the whole tree. However, the fallout remained at the surface of the soil, away from the roots. Despite the active root of the peach tree being about 30 cm below the surface of the soil, where radioactive nuclides do not exist, the fruits still accumulated radioactive Cs and were slightly contaminated. Few people had considered that radioactive Cs moves into the bark from the trunk surface and could then be transferred to the fruits. Dr. Daisuke Takada performed numerous experiments to determine how radioactive Cs moves within trees, and now some of the new findings are described in this book.

1.2.4 Summary of Soil, Crop, and Tree Contamination

Most of the radioactive Cs remains adsorbed on the surface of the substances it first contacted, and the radioactivity image of radioactive Cs still maintains a spot-like shape, indicating its presence. It is very difficult to remove radioactive Cs from soil or plants (Fig. 1.2).

Below is a summary of the features of the fallout, i.e., information in the previous book:

1. The contamination in soil, crops, and trees were found as spots.
2. Emitted nuclides stay where they first landed.
3. They rarely move and stay as spots even after a few years.
4. Only a small portion of the fallout was dissolved in solution and moved.
5. The adsorption manner became stronger with time.
6. Supplying K as a fertilizer is the most effective and efficient way to prevent Cs uptake by plants.

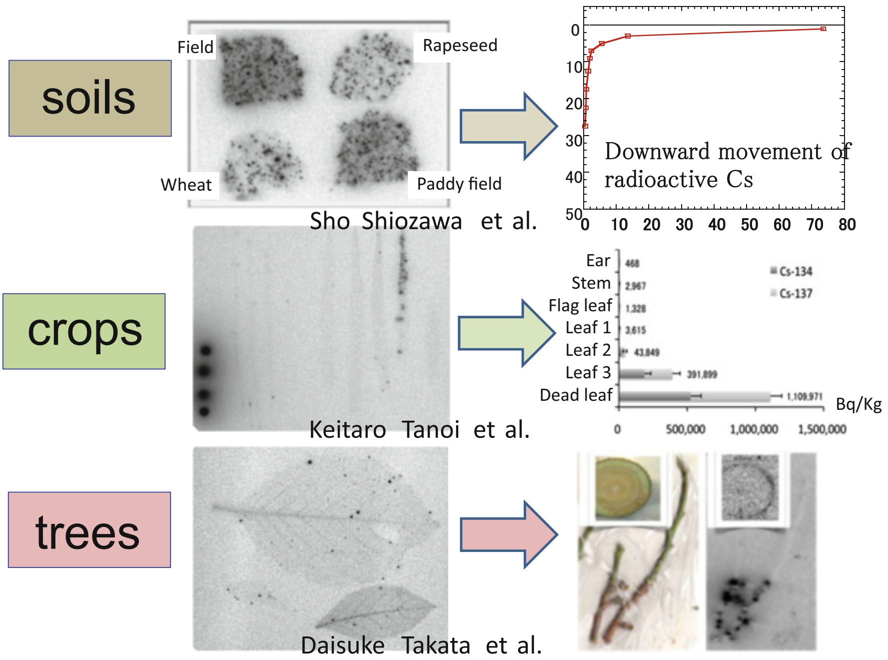

Fig. 1.2 Features of fallout for soil, crops, and trees. Radioactive Cs was adsorbed in spot-like distribution at the surface and rarely moved with time

1.3 Fallout on Birds, Fish, and Livestock

1.3.1 Birds

In the case of birds, it was difficult to identify their point of contamination because they can fly long distances. Associate Prof. Ken Ishida caught several birds in Fukushima and compared the contamination of their feathers to those caught in other areas. A radiograph of the feathers revealed the spot-like distribution of the radioactivity. This distribution pattern was similar to that found in soil or plants. Radioactive Cs was not removed by washing with chemicals. In the following year, the same species of birds were caught and examined; however, no radioactivity was measured in their feathers. The contaminated feathers seemed to have been renewed or replaced as contaminated birds were only found in the year of the accident.

1.3.2 Fish

The study of contaminated fish was conducted mainly with respect to food safety. First of all, Prof. Toyoji Kaneko showed how fish excrete Cs into the water, since they eliminate radioactive Cs faster than its half-life. He showed that fish excrete Cs in the same way as K from their scale cells.

Fish is a major food source in Japan and many products originate from fish meat. Prof. Shugo Watabe studied the safety of food products. He measured how radioactivity was reduced during food processing. He targeted a popular food called Kamaboko, produced from fish meat paste and found <5 % of the radioactivity in the original fish meat remained in the final products. He found that most of the radioactive Cs was removed during the process of washing the fine homogenated meat.

1.3.3 Livestock

In the case of animals, we found that radioactive Cs appeared in milk soon after contaminated feeds were given. However, when non-contaminated foods were supplied, the radioactive materials in the animals were metabolized and decreased. Similar results were found for animal meat, indicating that when contaminated animals are identified, it is possible to decontaminate them by feeding them non-contaminated feeds. In the contaminated area, natural mating of pigs and wild boars take place and the number of hybrid animals is on the increase. While eating, pigs and wild boars habitually dig in the soil and seem to inhale or eat a portion of the surface soil. In comparison, cows eat only plants. As a consequence of this difference in activity, radioactive Cs in the meat of pigs or wild boars is much higher than that of cows.

1.3.4 Summary of Bird, Fish, and Livestock Contamination

In the case of birds, fish, and livestock, radioactive Cs was found on feathers, muscles, and meat or dairy products, respectively. Radioactivity in living animal tissue was rapidly decreased by feeding non-contaminated foods. The biological half-life of ^{137}Cs was estimated to be <100 days because of the biological activity and metabolism, whereas the physical half-life of ^{137}Cs is 30 years. To summarize the findings, the common features of radioactive Cs fallout are shown in Fig. 1.3.

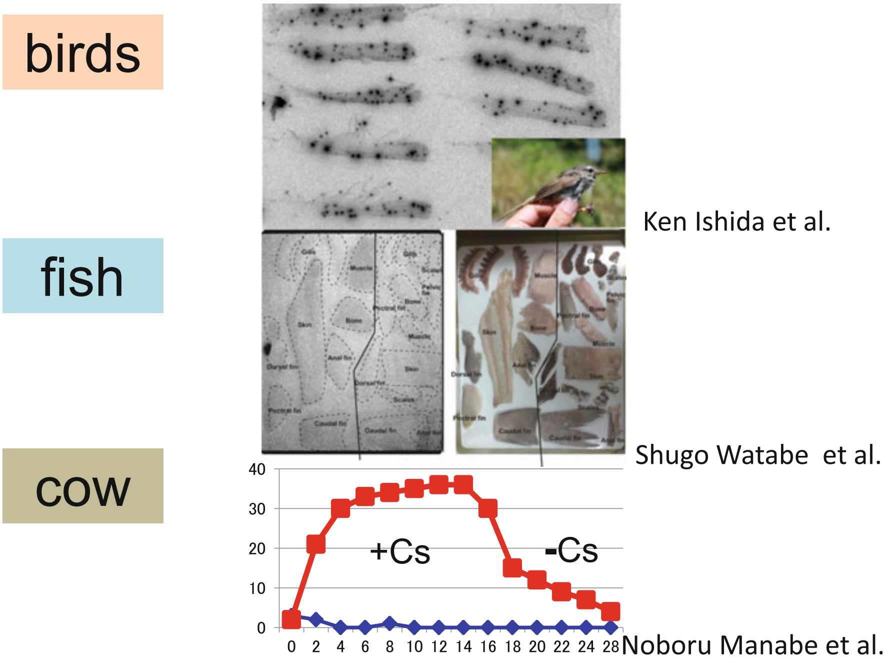

Fig. 1.3 Features of fallout for birds, fish, and livestock. In living individuals, radioactive Cs is decreased through metabolism. The biological half-life of ^{137}Cs is within 100 days

1.4 Radioactive Contamination

There is a great difference between radioactive contamination and contamination from heavy metals. Some 50–60 years ago in Japan, we experienced much heavy metal contamination in the environment causing disease to humans. These contaminants, such as Cd or Hg, became dissolved in water and spread in the environment. Subsequently, the contaminated plants, animals, or water were taken up by people as food and caused serious diseases. For this reason, we fear the movement of contaminants into the environment. In the case of radioactive nuclides, though they were emitted from the nuclear power plant, the radioactive fallout did not spread far away after the settlement. Therefore, it is important to know where the radioactive nuclides reside in the environment and how they move with time as well as what is the most effective way to shield the radiation.

At the same time, we need to understand the features of the fallout, including the types and amount of radioactive nuclides changing with time after the accident.

Because Japan is located in a monsoon area with many paddy fields used to grow rice, the agricultural environment is similar to that in other Asian countries. The climate and agricultural environment in Japan is different from those in Chernobyl; therefore, it is important to gather information regarding the movement or features of fallout specific to Japan from an agricultural point of view.

Reference

Nakanishi TM, Tanoi K (eds) (2013) Agricultural implications of the Fukushima nuclear accident. Springer, Tokyo