Chapter 12
Forest Problems

Takahisa Hayashi

Abstract Following the Fukushima-Daiichi Nuclear Power Plant accident in March 2011, large amounts of radionuclides were dispersed over the 50-km tract of land between the plant and the city of Date, where forested mountains make up approximately 90 % of the total area. During the weeks after the disaster, the fallout of radionuclides was deposited on trees and local residences in an aerosol or gaseous form partly dissolved in rainwater or snow. Radiocesium was incorporated into plant bodies through all the exposed surfaces, not only through the leaves but also via the bark. Trees, which can directly incorporate radionuclides, serve as one of the largest biological sinks of fallout radionuclides. Thus, they are capable of reducing the harmful impact of these radionucleotides on residents in rural land and others in Japan. The forest in the rural land became in an enormous biological sink of ^{137}Cs with a long half-life, 30.1 years.

Keywords Radiocesium • Migration • Decontamination trials • Social problems

12.1 Introduction

Fukushima Prefecture contains about 970,000 ha of forests with an estimated growing stock of about 100 million m^3. We are surveying and conducting research on forested areas belonging to Soma's regional forestry cooperative in the town of Shinchi, as well as the cities of Soma and Minamisoma. According to SPEEDI (the System for Prediction of Environmental Emergency Dose Information), a large quantity of radionuclides flowed from the Fukushima Daiichi Nuclear Power Station toward the city of Fukushima via the western parts of Minamisoma and Soma. The radionuclides lingered and accumulated when they reached the foothills of the area's mountains, which are more than 400 m in altitude, increasing the amount of radiocesium clinging to the outer bark of trees in forested areas nearby.

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When we started our research we aimed to investigate the behavior of radioiodine and radiocesium. Radioiodine is known to bind to the woody component in trees, and we therefore investigated the bonding mechanism at the molecular level. We found that the bulk of this radioiodine is taken in through the lenticels of the trees and then captured via bonding with the cell walls. Radiocesium, on the other hand, is absorbed through the leaves and bark, permeating to the wood (the part that will be used as lumber) from the inner bark. Some of the radiocesium also reaches the interior, made up of old tree rings (Fig. 12.1). Since the Chernobyl nuclear disaster in 1986, many papers have been published on the infiltration of radionuclides into forest trees, but the mechanism of the infiltration is still unknown. Although radiocarbon (^{14}C) is taken in and captured in the tree ring of the specific year, radiocesium is found to migrate to the corewood.

The radioiodine and radiocesium generated by the Fukushima Daiichi nuclear plant accident were incorporated into the trees over a vast area of mountain forests, which resulted in protecting humans, we hope. Although radioactive iodine-131 (^{131}I) has disappeared as a result of its short half-life, radiocesium-137 (^{137}Cs) in particular, has a long half-life of 30.17 years, and will therefore remain in the trees: this will turn the forests into enormous unnatural repositories of ^{137}Cs.

The amount of cesium incorporated into the trees in Fukushima Prefecture varies among areas. Here we discuss the relationship between humans and trees as revealed by analysis of the behavior of radiocesium within the trees.

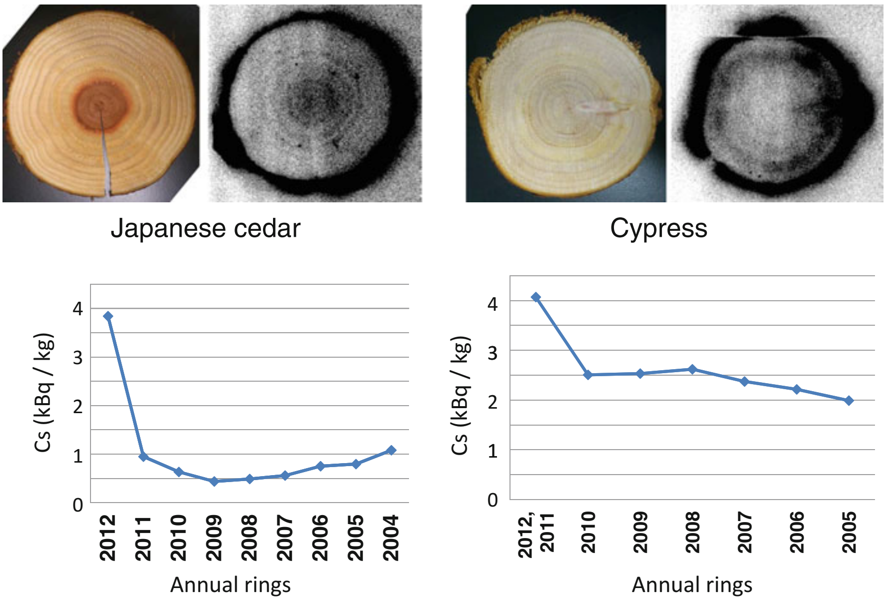

Fig. 12.1 Transverse sections of stems with autoradiographs and levels of radiocesium in the forest trees

12.2 Study on the Migration of Radionuclides Within Forests

We conducted a survey of radionuclide contamination in the forested areas of Minamisoma's Haramachi district. We divided the trees into leaves, branches, bark (outer and inner), and wood (sapwood and heartwood), and measured the radiation in each of these parts.

We also dug trees up and measured how much radionuclide had migrated to the roots (Figs. 12.2 and 12.3), although we could only dig up four trees in a day, even with ten people working from dawn till dusk. As a result of our perseverance, however, we were able to confirm that radiocesium incorporated into the trees from aboveground was infiltrated within the trees and migrated to the roots, from which some was secreted into the soil.

Figure 12.4 summarizes the distribution of radiocesium in forested areas and trees. Much of the cesium accumulated in the litter layer, and only 1 cm of the soil surface was contaminated. We found that most of the radionuclides were captured by the leaves and bark of the trees, as we had expected. However, the radiocesium had also migrated to the wood and roots of the trees to a considerable degree.

Thus, the forests of Fukushima have become enormous unnatural repositories of ^{137}Cs, in which the cesium is circulated to and from the trees via various living organisms (mushrooms, moss, ferns, insects, animals, etc.). We call this the cesium cycle (Fig. 12.5).

Fig. 12.2 Digging a tree up to measure radionuclides in the roots

Fig. 12.3 The dug roots of a tree

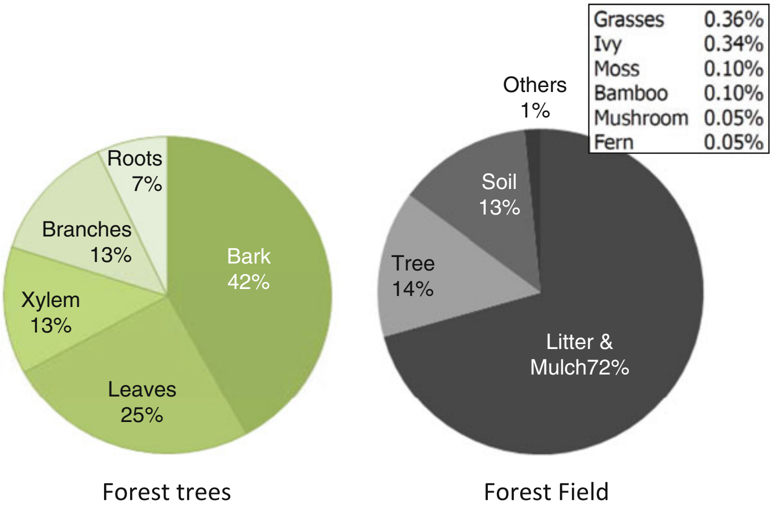

Fig. 12.4 Distribution of radiocesium in the forest in April after the nuclear plant accident

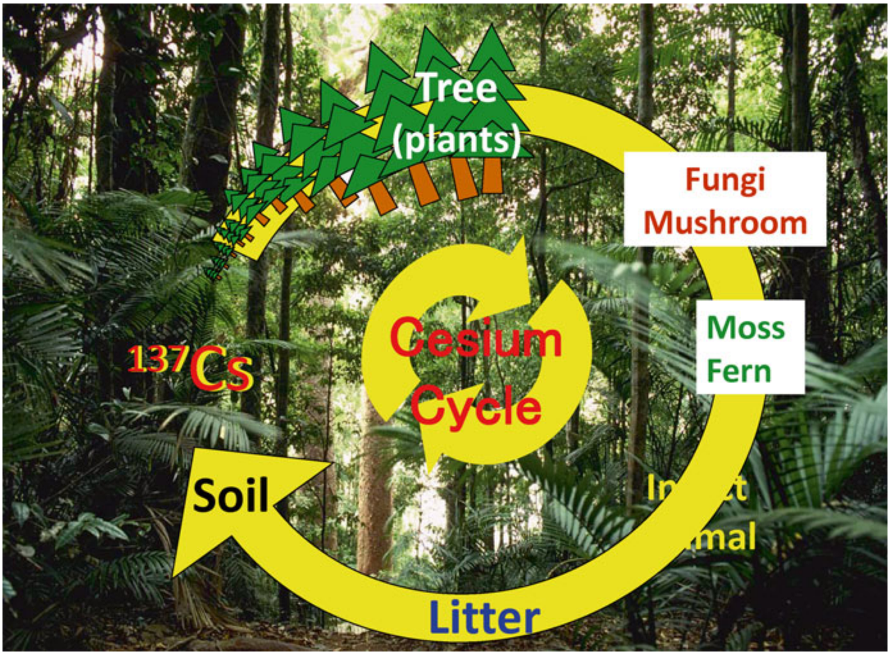

Fig. 12.5 Cesium cycle in the forests of Fukushima

12.3 Decontamination Trials

We conducted an experiment using a helicopter to scatter potassium (potassium fertilizer) and nitrogen (nitrogen fertilizer) from above (Fig. 12.6).

The aim of the potassium fertilization on the leaves was to inhibit the migration of radiocesium into the wood inside the trees. We found that the potassium did indeed inhibit the migration of cesium into the wood, but only to a limited degree.

We supplied nitrogen fertilizer on the leaves to promote the incorporation of cesium by the entire tree. As a result, the incorporation did increase, with as much as twice the amount of cesium absorbed in some cases. When trees were felled after scattering nitrogen fertilizer on the leaves, we verified that the trees had absorbed cesium from the soil, resulting in decontamination of the forest. This method could be used when contaminated trees are felled and cleared.

An alumnus of the Tokyo University of Agriculture (a graduate of the Department of Forestry) owned some forestland in Minamisoma's Ogai district, and we were able to use this forestland for testing purposes (Fig. 12.7). In 2012 we planted a variety of fast-growing trees there and took measurements to verify whether the planted tree species absorb radionuclides (Fig. 12.8). The results indicated that the willow and chinaberry trees absorbed radiocesium steadily (Fig. 12.9).

Fig. 12.6 A helicopter is scattering potassium and nitrogen

Fig. 12.7 Experimental forest field, given by Y. Takeyama, with a student in Minamisoma

Fig. 12.8 Students working at the forest field in Minamisoma

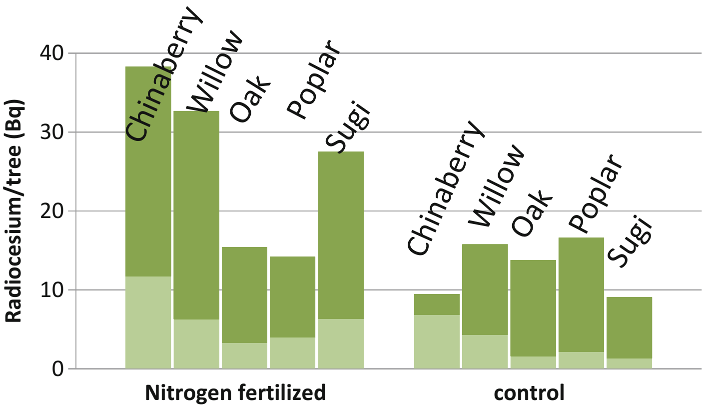

Fig. 12.9 Amount of radiocesium uptake for each tree. *Dark bars* show content of radiocesium in leaf and branch; *light bars* show content in stem

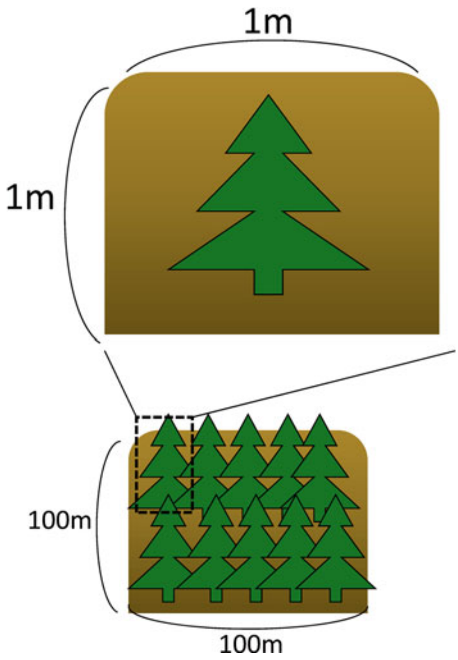

Fig. 12.10 Phytoremediation strategy in the forest field of Minamisoma by using chinaberry seedlings

To perform a simple calculation, about 2.5 billion becquerels (Bq) of radiocesium has accumulated in each hectare of this forest. As the half-life of cesium-137 is 30.17 years, it would take about 660 years for the radiation in the soil to fall below 100 Bq/kg if the forest in Ogai was left as it is without doing anything. If willow and chinaberry saplings were planted at intervals of 1 m and only the parts above ground were cut off every few years, the time taken to bring down the cesium-137 level would be shortened to 73 years (Fig. 12.10). If nitrogenous fertilizer was added simultaneously, the time taken could be further shortened to 54 years. These fast-growing trees regenerate by sprouting, so even if their stems are cut off, they always sprout again in the spring. We are therefore considering the possibility of harvesting such trees above the ground and burning them to generate energy, rather than planting new forests.

12.4 Compensation for Forestry Operators

Forestry operators are required to take their timber to market to receive compensation from Tokyo Electric Power Company (TEPCO) for damage caused by radioactive contamination.

Felled timber is transported to the timber logistics centers in the cities of Ishinomaki or Iwaki by the forestry association or companies in the timber industry

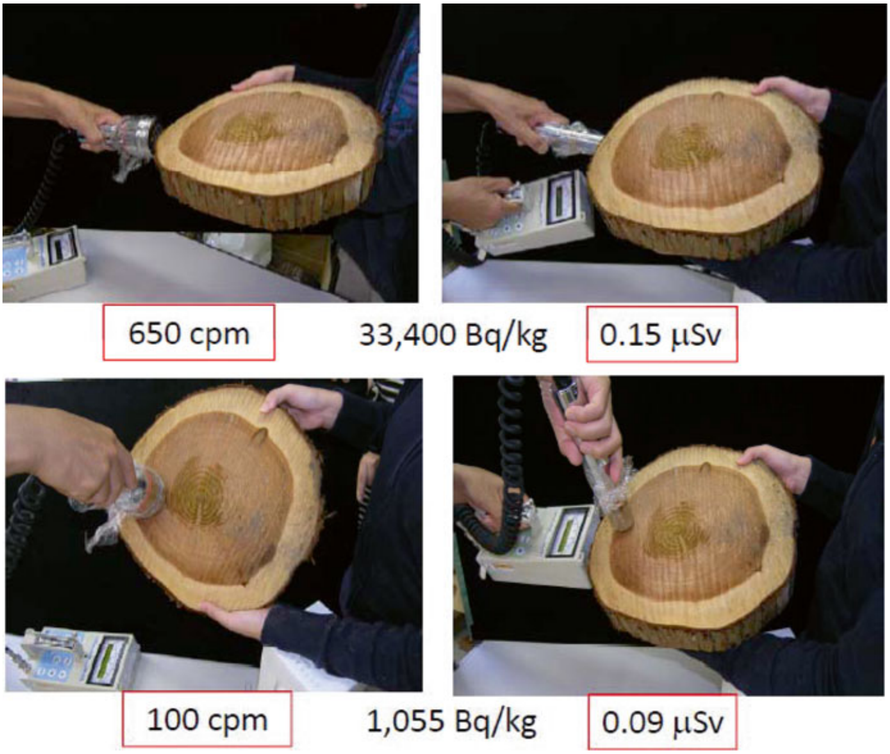

Fig. 12.11 Relationship between cpm, Bq, and μSv in wood

in Fukushima Prefecture upon request from forestry operators. If the price at which the timber sells is lower than the current market price or previous selling prices for the same timber, TEPCO pays the difference as compensation for reputational damage. This process requires submission of a large number of forms and supporting documents. In addition, at the timber logistics center in Iwaki, lumber has to be checked using a Geiger-Muller (GM) survey meter to verify that it meets the Fukushima prefectural forestry association's self-imposed limit of 1,000 cpm or less for surface radiation on lumber. The relationship between counts per minute (cpm), bequerels (Bq), and micro-sieverts (μSv) is shown in the wood (Fig. 12.11) and the wood cubics (Fig. 12.12).

If timber industry companies in other prefectures are requested to transport the timber, the felled timber is loaded onto trucks and transported to logistics centers, retailers, or large consumers in other prefectures, where it is sold. Although it is not known how much radiocesium is infiltrated inside the timber, this is not in violation of the law because the Forestry Agency declared the timber in Fukushima Prefecture to be safe.

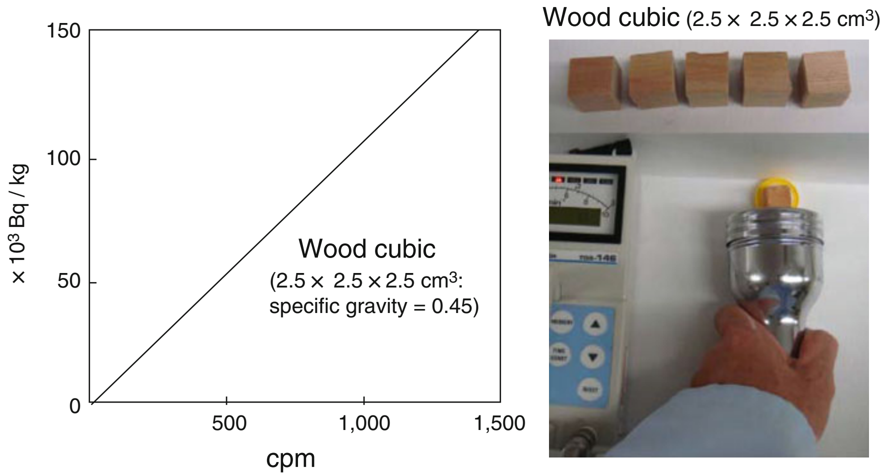

Fig. 12.12 Relationship between cpm and Bq in wood cubic

12.5 Issues Affecting the Wider Society

When traveling around the farming villages, it becomes apparent that people are using firewood (Fig. 12.13). When wood containing cesium is burned, fly ash (particulate matter) is generated, and this results in internal radiation exposure. Unfortunately, the reality is that people in these communities are not well informed about health and safety issues relating to radioactive cesium.

Meanwhile, in the forestry industry a sense of despair prevails over the contamination of forests by radionuclides. Up until the nuclear disaster, forests felled for timber were always replaced through afforestation. After the disaster, there was an increase in the number of forests abandoned without replanting (Fig. 12.14). This is particularly true in the forests in Minamisoma, and it reflects this sense of despair.

In August 2012, the Forestry Agency declared the timber in Fukushima Prefecture to be safe. This decision was based on the radioactivity measurements of 12 types of wood from tree trunks sampled from the prefecture in March 2012. The xylem of the Japanese red pine in Ohara, part of Minamisoma's Haramachi district, gave the highest reading at 497 Bq/kg. The Forestry Agency assessed that the impact on the human body would be almost nonexistent at this level of radioactivity. However, we ourselves also took measurements of timber samples from Ohara, and although some were below this level, we detected a higher level of radioactivity (1,000 Bq/kg or more) in many of the samples. Yet, despite this, no device capable of measuring radiation levels inside the timber (as opposed to on the surface) has been installed at

Fig. 12.13 Firewood used for heating bathing water and for cooking from the forests in Minamisoma on November 16, 2012

Fig. 12.14 Two forest fields with replanted trees (before the accident) and with no trees (after the accident) in Minamisoma

Fig. 12.15 Logging in the forest of Minamisoma on November 6, 2012

the logistics centers. Fukushima Prefecture needs a safe and reliable system capable of stopping the distribution of timber with a high radioactivity level.

Timber produced in Fukushima is being distributed throughout the country on the basis of the Forestry Agency's safety declaration. Visitors to the forests in Minamisoma may come across heavy machinery being used for logging (Fig. 12.15). This logged timber is being distributed throughout the country without any idea of how much radioactive cesium it contains.

Trees have to be planted in the forest, then grown for 60 to 80 years before they can be harvested and distributed as timber products. Because the forests are now contaminated by radiation, trees planted in the future may absorb large amounts of cesium-137. However, compensation for radioactivity in timber cannot be paid on an annual basis in the same way as it is for agricultural produce, so it remains doubtful how long payment of compensation will continue.

Furthermore, contamination of forests by radiation is not covered under the gS30 forest insurance scheme (Fig. 12.16). The national insurance scheme does, however, cover forest fires. After the Chernobyl nuclear disaster, many of the forests in the vicinity were set on fire deliberately to claim an insurance payout. When this happened, fly ash containing radioactive cesium was scattered, and even now people still seem to be living in fear of its effects. The Japanese are not likely to exacerbate the problems in Fukushima's forests by setting them on fire. However, they are at a loss over how to reconcile themselves to the situation.

Fig. 12.16 Forest insurance does not cover the contamination of trees

Fig. 12.17 The forests have become enormous unnatural repositories of ^{137}Cs

The forests of Fukushima absorbed the radioiodine and radiocesium scattered by TEPCO's Fukushima Daiichi nuclear plant. Instead of lamenting this fact, we should be grateful that the radionuclides were largely absorbed by the trees, and this is arguably what saved the residents of Fukushima from worse contamination. These trees absorbed a large quantity of cesium-137 with a half-life of 30.17 years (Fig. 12.17), and as I pursue my research, I, for one, view that as a blessing.