Report on "Radiation Disaster Recovery Studies"

Course Radioactivity environmental protection
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○Regarding"Radiation Disaster Recovery Studies"

(Describe your thoughts, the process you engaged in and your research progress regarding Recovery from Radiation Disaster.)

1. Thoughts regarding Radiation disaster recovery

The Fukushima accident that occurred on March, 2011, has caused the multi-effect to human life, that is usually simplified into three aspects, environment, social and health aspect. Since it has been 9 years from the time of the accident, we have witnessed the recovery from radiation disaster activities and its achievements. In this report, the philosophy of recovery after the disaster, key activities in the Fukushima recovery process, some key challenges in the Fukushima recovery process, and the proposed future scenario for Fukushima recovery are shortly discussed.

The recovery from disaster, in my opinion, is a process to re-establish a sustainable human-environmental system. It should create something new, a system that is better, stronger, more resilient than before, it is not just a process of returning situation like before the disaster. The most important goal is to prevent the disaster from happening, if it is a human-caused disaster, and how to create enough capacity for disaster response to minimize the effect from the disaster when the disaster happened. A thorough risk mitigation is a key activity to be carried out for preventing the human-caused disaster. A very broad aspects are needed to create enough capacity for disaster response. It spans from enhancing technological capacity to human and society capacity, governmental and post-radiation disaster management capacity etc.

The Fukushima disaster that was caused by triple disaster (earthquake, tsunami and radiation) has caused a complex post disaster problem, and the radiation disaster becomes the most challenging part of the post disaster recovery. The key activities for Fukushima recovery from radiation disaster consisted of (1) protection of human health by establishing and increasing radiation monitoring and measurement capacity, (2) infrastructure rebuilding and environmental decontamination activities and (3) returning the evacuees to their home town or even inviting non Fukushima people to live in Fukushima and re-starting the social activities such as school, businesses etc.

However, these recovery activities were not a smooth process. There are many challenges faced during the process of recovery that complicate the recovery process. The challenge of recovery from the radiation disaster in Fukushima was caused by the weakness of radiation disaster response capacity. This may be caused by the nature of nuclear accident as a rare accident with a big effect. In one side, the government did not have enough post radiation disaster management capacity to respond to the radiation disaster. In the other side, Fukushima peoples did not have enough radiation disaster literacy when the disaster happened. It further caused the additional challenge related to social aspect such as public anxiety regarding the effect of radiation, problem of communication between government and public, public distrust to government and scientists etc., that turned to be the most challenging problem.

Many initiatives have been dedicated to solve these social problems. Dialogue that involves many parties (Fukushima peoples, scientists and government) is a good tool that has been used for establishing mutual understanding, for example Fukushima Dialogue initiated by ICRP and ETHOS in Fukushima. Other initiatives, such as individual consultation program, dissemination of information program through magazine, homepage, public seminar etc., have increased the correct public understanding about radiation. They facilitated the evacuees to independently decided to return or not return to Fukushima. Furthermore, some incentives and facilities are provided to facilitate the re-establishment of social life and businesses by providing. However, resolving of these social aspect related challenges will be a long process to be undergone.

Another challenge is regarding the decontamination activity. The radionuclides such as ^{137}Cs exist in the environment for a long time. Removing the contaminated soil is the option that has been done so far. However, it is difficult to be applied for special area like forest. On the other hand, how and where the collected contaminated soil will be disposed as final disposal is still a very challenging issue.

For the future, a multi-stakeholder approach (government, business, and society) should be a platform for any decision and policy, such as regarding final disposal area of contaminated soil etc., and for information dissemination and public discussion forum. Fukushima peoples, especially peoples reside in Fukushima, should be the main actor in the multi-stakeholder approach, rather than treat them as a victim of a disaster. Furthermore, there should be a clear plan of Fukushima recovery in the future with clear key success indicators in each stage. This plan should be made and evaluated by using a multi-stakeholder approach. Finally, the recovery process is not going to rebuild Fukushima as before the accident. The recovery process should be intended to build more resilient and stronger Fukushima that is not only important for Japan, but also for whole world especially the nuclear world.

2. Engagement in the recovery process

As a PhD student, I engaged in the recovery process as a scientist. I conducted research that related to the Fukushima accident and finally I produced some scientific evidences. The scientific evidences should be one of considerations for any policy and decision that will be made for recovery process. My research topic is about ^{137}Cs migration from forest catchment to water body and its contribution to air dose rate that may be useful for decontamination activity of Fukushima area.

3. Research progress

I have conducted environmental monitoring of Fukushima area, especially catchment area of water body since 2016. Since that time, I have collected samples from two area which are Hibara lake area, Yamagun, Fukushima and Ogi reservoir area, Kawauchi village, Fukushima as well as conducted air dose rate measurement. I conducted measurement of radionuclides concentration in soil and sediment of study area especially ^{134}Cs and ^{137}Cs. I conducted the resulted data analysis to investigate how Cs moved in environment, the influencing factors etc. So far, I have published 4 scientific papers in peer reviewed journal.

○Title of Doctoral Thesis

^{137}Cs Migration from Sloped Forest Catchment to Water Body and Its Contribution to Air Dose Rate

○Summary of Doctoral Thesis

(Describe so as to be easily understood, by relating it to"Radiation Disaster Recovery Studies".)

The Fukushima Daiichi Nuclear Power Plant (FDNPP) accident that occurred on March, 2011, caused a substantial amount of radioactive materials released to the environment. Among the radioactive materials released to the environment, radiocesium (^{134}Cs and ^{137}Cs) beside radioiodine (^{131}I) is the most major released volatile radionuclide having a direct impact on land contamination. The longer ^{137}Cs half-life (30.2 years) in comparison to ^{134}Cs (2.06 years) and ^{131}I (8 days) has made the ^{137}Cs as the main radionuclide of interest to be studied. Forest area covers more than 60% of the contaminated zone and has higher radiocesium inventory in comparison to the other land use, that is a disadvantage as forest is one of source of food. Furthermore, forest can be source of radioactive particulate contamination for lower area like water body (river, lake, reservoir etc.) that can contaminate water resource. The understanding of radiocesium migration behavior is key to the assessment for the long-term radiation hazard risk and its countermeasures. The radiocesium distribution and migration in terrestrial environment after FDNPP accident have been widely investigated, however, there are still some questions about the factors that influence the migration. Furthermore, alternative method to estimate future radiocesium migration and air dose rate derived from radiocesium is still needed. This research aims to investigate the factors that influence ^{137}Cs migration from forest catchment to water body, to introduce a new method for investigation of ^{137}Cs migration and for estimating the

future air dose rate derived from ^{137}Cs.

The study area is in Ogi reservoir catchment area, Kawauchi village, Fukushima, which is located about 18 km southwest from FDNPP. Air dose measurement and soil and sediment core sampling were conducted on March 15 and 16, 2018 in a steep sloped forest and transition zone of the catchment area and reservoir. The air dose rate was measured by a portable gamma survey meter with a NaI detector (ALOKA MYRATE PDR-111) about 1 m above the ground. The soil and sediment core samples were cut each 2 cm and 1 cm increment, respectively. The samples were dried at room temperature and further dried in oven (105^{o} C, 24 hours). The prior dry sieving (2 mm sieve) was performed using electric horizontally rotating sieve (SKH-01, AS ONE). The activities of ^{134}Cs and ^{137}Cs were measured by gamma spectroscopy with HP Ge detector and multichannel analyzer (GEM 30-70, ORTEC), at energy peak of 604 keV and 662 keV for ^{134}Cs and ^{137}Cs, respectively. Physicochemical property of the soil (pH, Organic Matter content, Silt and clay fraction, Exchangeable cation, Cation exchange capacity and base saturation) was also measured.

The initial study was conducted in Hibara Lake, Yama District, Fukushima. The results show the shallower accumulation of ^{137}Cs in the sediment layer of lake closer to flat area but deeper accumulation of ^{137}Cs in the sediment layer of lake closer to slope surrounding area. The result shows the importance of slope for ^{137}Cs migration. And the result also shows the higher activity concentration of ^{134}Cs and ^{137}Cs in silt and clay fraction of soil (particle size $<75\mu m$) than sand fraction, suggesting that the radiocesium migration occurred through soil fine particle migration.

The factors that influence radiocesium retention and migration were investigated. The results show that the radioactive contamination is strongly retained in sloped forest area after 7 years. It was due to the vertical migration as a dominant mode of radiocesium migration in forest. The high abundance of organic matter and less fine particle in soil surface were factors that cause the radiocesium vertical migration in forest. The role of soil bacteria was analyzed in migration of the radiocesium by laboratory experiment. The result shows that soil bacteria have an ability to absorb Cs. Furthermore, soil bacteria are also capable to desorb Cs from soil matrices, probably through the decomposition of biomass and organic matter in the soil.

The ratio of ^{137}Cs in soil to ^{137}Cs in sediment ratio for investigation of radiocesium migration was introduced for the first time. It was assumed that ^{137}Cs in sediment is related with ^{137}Cs in soil. When ^{137}Cs in soil decreases with time progress, ^{137}Cs in sediment will increase with time progress. The time dependency of soil to sediment ratio was shown, suggesting the potential of the ratio for analyzing ^{137}Cs migration in future.

The ratio of air dose rate 1 m above the ground to ^{137}Cs inventory in the soil for estimating the future dose derived from ^{137}Cs was reported. It is by considering that there is a relation between ^{137}Cs in soil and air dose rate. It is known that the ratio decreased in short time and then became relatively stable after Chernobyl nuclear accident. We firstly applied the ratio to the FDNPP accident. We discussed the ratio from the point of vertical migration of ^{137}Cs that will be affected by the increase of distance between ^{137}Cs and the detector or geometry change and soil shielding effect. The ratio will be relatively stable or less changeable after the immobilization of ^{137}Cs in soil layer especially in soil mineral layer.

○Other theses published in academic research journals

1. *Radiation Measurements*, (2020). https://doi.org/10.1016/j.radmeas.2020.106424. (IF: 1.5, Peer Review)

   Air dose rate to ^{137}Cs activity per unit area ratio for different land use 7 years after the nuclear accident -Case of the slope catchment, Ogi reservoir, Fukushima-

   T. Basuki, W. C. Bekelesi, M. Tsujimoto, S. Nakashima

2. *AIP-CP*, accepted (2020) (Peer Review)

   Examination of Cs tolerant bacteria interaction with Cs+ in aqueous solution and soil by using ^{137}Cs tracer

   T. Basuki, K. Inada, S. Nakashima

3. *Radiation Safety Management*, 19, 23-34 (2020). DOI 10.12950/rsm.190924 (Peer Review)

   Investigation of radiocesium migration from land to waterbody using radiocesium distribution and soil to sediment ratio: A case of the steep slope catchment area of Ogi reservoir, Kawauchi Village, Fukushima

   T. Basuki, W. C. Bekelesi, M. Tsujimoto, S. Nakashima

4. *Journal of Radioanalytical and Nuclear Chemistry* (2018). DOI 10.1007/s10967-018-5809-1 (IF: 1.1, Peer Review)

   Deposition Density of Cs-134 and Cs-137 and Particle Size Distribution of Soil and Sediment Profile in Hibara Lake Area, Fukushima: an Investigation of Cs-134 and Cs-137 Indirect Deposition into Lake from Surrounding Area

   T. Basuki, S. Miyashita, M. Tsujimoto, and S. Nakashima

Additional publications

1. *Environmental Monitoring and Assessment*, (2019) 191: 27. DOI 10.1007/s10661-018-7160-y (IF: 1.9, Peer Review)

   Assessment of natural radioactivity in coals and coal combustion residues from a coal-based thermoelectric plant in Bangladesh: Implications for radiological health hazards

   M. A. Habib, T. Basuki, S. Miyashita, W. Bekelesi, S. Nakashima, K. Techato, R. Khan, A. B. K. Majlis, K. Phoungthong

2. *Radiochimica Acta* (2018). DOI 10.1515/ract-2018-3044 (IF: 1.3, Peer Review)

   Distribution of naturally occurring radionuclides in soil around a coal-based power plant and their potential radiological risk assessment

   M. A. Habib, T. Basuki, S. Miyashita, W. Bekelesi, S. Nakashima, K. Phoungthong, R. Khan, M. B. Rashid, A. R. M. T. Islam, K. Techato,