IOP Conference Series: Earth and Environmental Science

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To cite this article: Koji Itonaga 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **294** 012028

IOP Conf. Series: Earth and Environmental Science **294** (2019) 012028 doi:10.1088/1755-1315/294/1/012028

Limits of decontamination in rural areas radioactively contaminated by TEPCO nuclear power plant accident and new concept for recover planning

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Abstract. This is an empirical study on the actual condition of pollution and decontamination in Iitate Village, Fukushima Prefecture, in the affected area of radioactive contamination released by Tokyo Electric Power Fukushima Daiichi Nuclear Power Plant caused by the Great East Japan Great Earthquake of March 2011. I have clarified the air dose rate in residential area, housing, field, and mountain area around housing. Although there is a decline in spatial dose due to natural decay and decontamination, it is not an environment suitable for residence and agriculture work. I investigated the housing which was released from evacuation. According to the survey in 2017, although the dose in the housing tends to be greater in high space, it is less than 0.6 μSv/h. However, the room adjacent to the forest has a dose of about 1.4 times that of the central room. The surface of the residential land is 0.65 μSv/h on average, exceeding the regulation standard value of the radiation control area. In the forest soil surrounding the residential land after decontamination, radioactive cesium is still 40,000 Bq/kg. Despite this contamination situation, the evacuation designation was cancelled at the end of March 2017 under unreasonable circumstances. Villagers who went back home had no choice but to produce vegetables in farmland where pollution continues, even though they were decontaminated. Radioactive Cs is also contained in decontaminated agricultural land. It is unreasonable to make agricultural products on land contaminated with Cs. Fortunately, the transition rate of Cs is extremely low, and it is not a problem for the elderly to eat. However, this absurdity continues. Products of contaminated forests cannot be eaten in the foreseeable future, and rich agricultural livelihoods have been lost. New land use planning methods, including the prohibition of land use of radioactively contaminated forests, are needed.

1. Introduction

Iitate Village, in the Fukushima Prefecture, was radioactively polluted in the long term due to the Tokyo Electric Power Fukushima Daiichi nuclear accident on March 11, 2011, and it became an area of catastrophe . Nonetheless, evacuation was canceled by the national policy on March 31, 2017, except for the difficult-to-return area (Nagadoro) in Iitate village. Since 1994, the authors have been conducting support research on Iitate Village from a sustainable rural planning viewpoint. With landscapes of forested mountains and gently rolling farmland, the village was home to about 6,100 people, and a model for integrating ecology, architecture, and design. The people of Iitate were planning their community around the theme of "Madei life", using a word that in the local dialect means "respectfully" and "carefully". After the nuclear accident, we conducted some resident consciousness surveys, many radiation dose rate measurements, many measurements of the availability of radioactive cesium (Cs), and dose rate measurement inside and outside the house. We also advanced development research on radiation reduction materials for houses. By our comprehensive research, decontamination limits have been presented. Forests accounting for about 80% of Iitate village cannot be decontaminated and return risk remains high.

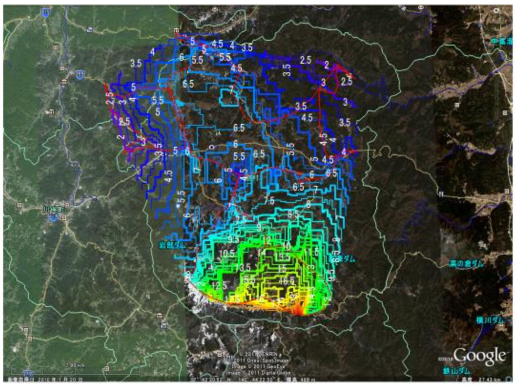

Fig.1. The contour map of the radiation dose of Iitate (Imanaka,Endo IISORA 2011/4/4)

Fig.2. Mountain of decontamination soil on the paddy fieldT in Iitate village, 2014.

In this state, evacuation was canceled in Iitate village. In an emergency, it can be said that "exceptional condition" is made by national policy and neglected.
This study reports the air dose rate in the houses in Iitate village, the Cs measurement result in the soil in the summer of 2017, and predict future reduction. Moreover, this paper reveal contradictions that evacuation was lifted.

2. Method and Object

Following 2014, from July 23 to 24, 2017, we measured a total of eleven houses: nine houses in Iitate village, one house in Namie Town, and one house in Kawamata Town, in the Yamakiya district. The measured items are the air dose rate inside and outside the house, and the adhesion amount of Cs to the soil depth of 30 cm in the residential area and the mountain in the back. Among the eleven houses, the one house in Namie Town was dismantled. One case of Iitate village is soil measurement only. All housing lots were decontaminated, and the effects and limitations of decontamination were also examined.
The space dosimeter used [ALOKA PDR - 111].
In-house measurements were taken at the center of each room, on the floor, 1 m above the floor, and near the ceiling. The residential area was measured at a point about 1 m away from the building wall, on the ground, 1 m above the ground, and about 2 m above the space. The Cs in the soil was measured by removing the core up to a depth of 30 cm in the ground. The sample soil was divided into 5 cm units and measured with a germanium semiconductor wave height measuring instrument (manufactured by Canberra, RI room in Nihon University).

3. Space dose rate inside and outside at decontaminated housing

3.1. Space dose rate in housing

The characteristics of the average value of the measurement results are as follows. On the first floor of the house, the space dose at the floor is the lowest, then 1 m above the floor, the ceiling in order, the upper part of the room tends to be higher(Fig.3).The second floor also has the same tendency. In the 1 m above the floor which is the living space height, the average is 0.34 μSv/h. Without radioactive contamination due to a nuclear accident, the usual air dose rate is about 0.05 μSv/h, and now it is nearly 7 times its exposure dose. Assuming that people are constantly living in the room in this state, the pollution situation exceeds 1 m Sv per year. According to Japanese law, the dose limit of the general public is 1 m Sv per year.

On the other hand, decontamination is effective. Places where the air dose rate in the room exceeds the radiation control area standard (0.6 μSv / h) are limited to the vicinity of the ceiling.

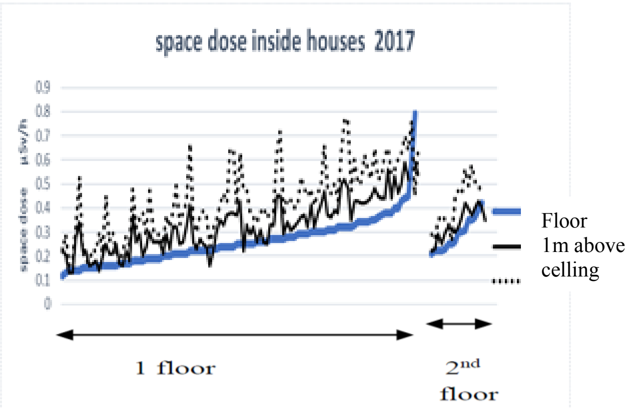

Fig.3. Spatial dose in the house after decontamination (by height from the floor) 2017

Table 1. Comparison of special dose rate by room μSv/h in 2017

Room location	on the floor	1 m above the floor	Near the ceiling
room facing the forest	0.28	0.37	0.49
central room	0.21	0.26	0.32
other rooms	0.25	0.32	0.41
average	0.26	0.33	0.43

On the floor, 1 m above the floor, and near the ceiling, the air dose rate in the room facing the mountain around the residential land, tends to be higher and the value of the room in the middle of the house tends to be lower (Table 1.). On the floor 1 m, the central room is reduced to 70% of the room facing the forest Please note that these houses are ones that are not renovated at the measurement stage. The situation of indoor pollution in new housing will be the next question to be investigated.

3.2. Spatial dose rate of residential land

Contamination continues even after the decontamination of peeling off 5 cm of the topsoil of the residential land and then placing the soil. Despite decontamination, the dose on the ground surface is the highest. The average value of the air dose rate on the ground surface is 0.65 μSv / h, exceeding the standard value of the legally required radiation control area. Later, I will explain in the situation of Cs remaining in the soil, the reason is considered the residual influence of polluted fallen leaves and residual Cs in the soil.

The dose rate at 1 m above the ground and 2 m above the ground, average 0.54 μSv / h, 0.59 μSv / h. The reason that the air dose rate of 2 m above the ground is higher than 1 m above the ground is presumed to be the influence of radiation from surrounding forests. The ground facing the forest has about 1.5 times the air dose rate compared to the ground faced away from the forest.

3.3. Correlation of Space Dose Rate in and outside the House

Outdoor and home dose rates are greatly associated, having a correlation coefficient of 0.8(Fig.4). In the same housing investigation result in 2014, the correlation coefficient is 0.85, and so on. Residential housing in 2014 included houses before decontamination. At that time, the air dose rate in decontaminated houses tended to be low. Reduction due to decontamination and natural decay is clear. The dose in the higher space tends to be larger both inside and outside the house. The reduction rate on the floor surface is high and the reduction rate on the ceiling surface is low. It can be estimated that the radiation from the surrounding forest is affecting.

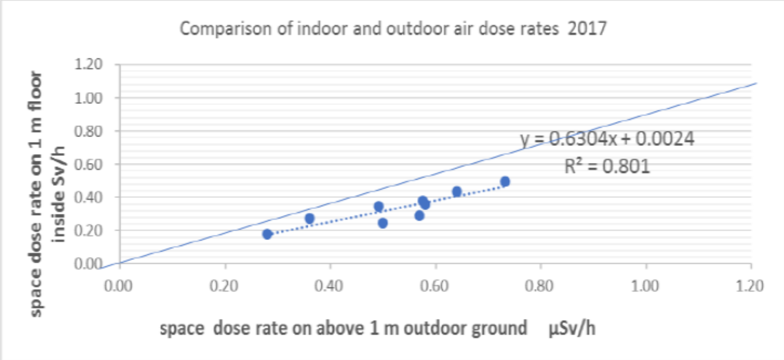

Fig.4 Comparison of indoor and outdoor air dose rates 2017

4. Content of radioactive cesium in soil of decontamination residential lot and mountain of the back

4.1. Residual amount of Cs of surface soil

Due to the high air dose rate even after decontamination, there is residual Cs in the mountain near the residential land. Within 20 meters of the mountain, adjacent to the residential area, fallen leaves, etc., of the surface layer are decontaminated. However, the topsoil of the mountain is not decontaminated. We measured the amount of Cs (Cs 134 + Cs 137) in the soil of 5 cm of the surface layer in the decontaminated residential area and the mountain. The ratio of Cs 134 to 137 is 1: 1 at the beginning of the disaster, roughly 1: 8 at the time of 2017 as six years later, the influence of Cs 137 is great in the future.

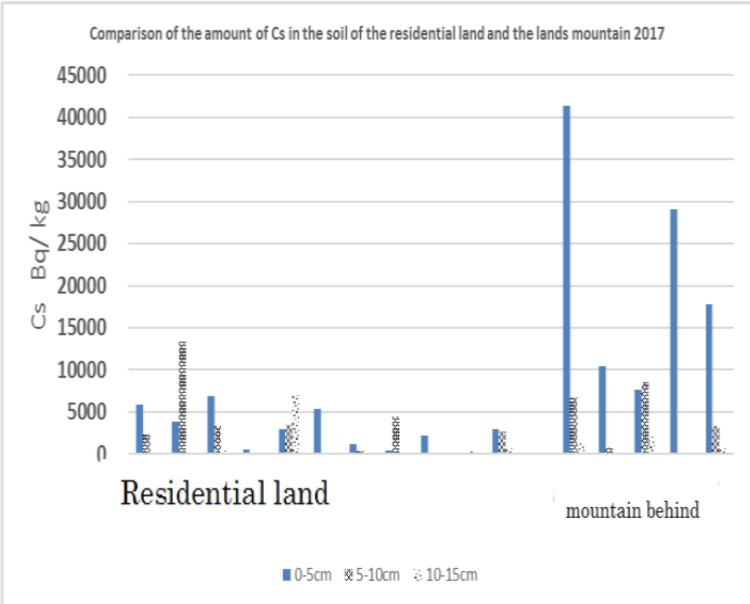

Fig.5 Comparison of the amount of Cs in the soil of the residential land and the lands mountain 2017

The depth of 5 cm of soil in the residential area ranges from 89 to 6844 Bq/kg, which is a recontamination of the surface layer of the residential land. The mountain was continually contaminated, and the maximum value of the surface layer of 5 cm was 41394 Bq / kg under the cedar tree. The average of Cs of the surface layer of the residential land is 2919 Bq / kg, and the average of the mountain is 17736 Bq / kg(Fig.5).

The surface soil of the mountain is a contamination of Cs six times that of the residential land. After the nuclear accident, the government formulated a law and set the radiation contamination countermeasure standard value at 8000 Bq / kg (its value is 80 times the value before the accident). Radioactive

contaminated soil with more than twice as much remains in the surface soil of the mountain near the residential land.
It is incredibly irrational for evacuation to have been lifted, which permits living reconstruction at such places.

4.2 Characteristics of residual radioactive Cesium by depth
As a result of analyzing the remaining amount of Cs by depth in 2017, 39% in the surface layer 5 cm and 37% in the 5 to 10 cm layer in the residential land became clear. In 2014, about 90% of Cs adhered to the surface layer of 5 cm, but in 2017 after decontamination, it is about 40% in the surface layer of 5 cm. It can be inferred that the permeation and fixing of Cs into the soil are getting deeper.
The reason for this can be inferred as follows.

① Penetrate according to the nature of the soil.

② Cs penetrated into the layer of 5 cm or less through the decontamination operation. Prior to the decontamination work, the wild boar caused soil disturbance to predispose earthworms, etc. As a result, Cs of the surface layer had entered the deep soil. After that, when decontaminating, the agitated soil was levelled. Only 5 cm of the surface layer was removed, and it can be inferred that Cs remained at a depth of 5 cm or less.

③ Even after being covered with new soil from decontamination, polluted leaves and contaminated rainwater from the surrounding forests have flowed to the new topsoil.

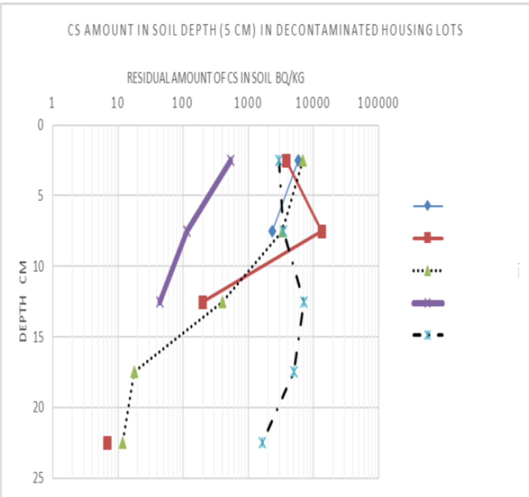

Fig.6 Cs amount in soil depth (every 5 cm layer) in decontaminated housing lot

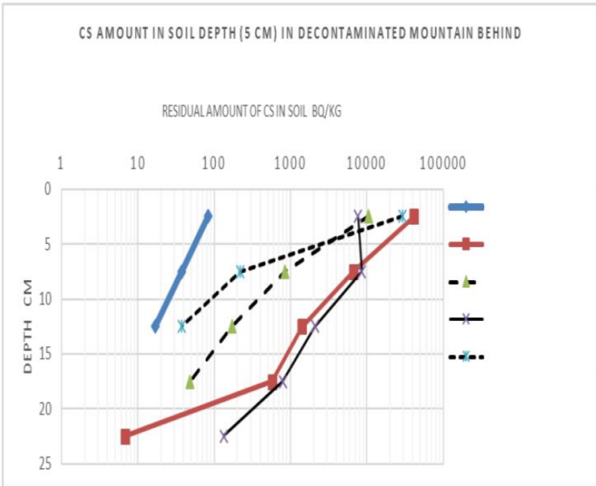

Fig.7 Cs amount in soil depth (every 5 cm layer) in mountain behind

At the area facing the mountain at the decontaminated residential land, decontamination of about 10 cm is desired.
Cs in the mountain soil adjacent to the residential area remains about 80% at the surface layer of 5 cm and 15% even under the 5 to 10 cm layer. There is a strong tendency to remain in the surface layer 5 cm as compared with the residential land. Also, Cs of about 3000 Bq/kg remains even in the 5 to 10 cm layer, so some decontamination measures are required.

5. Planned countermeasures in radioactive contaminated areas

5.1 Long-term future plan by dual district residence
Immediately after the disaster, the author made proposals for the creation of evacuation villages and proposals for two regional residential systems for villagers, village authorities, the media, etc. Cs 137

finally will become one tenth of the radiation dose in 100 years. As a design of time, the author proposed the "Two-district residence 100 years vision". It is not an early return policy, but instead creates a place outside the village for the "recovery of people, recovery of families, recovery of community". Unfortunately, the village community was not constructed, and more than half of the villagers secured housing based outside the village as TEPCO paid individual compensation to the victims. On the other hand, there were many villagers who destroyed houses in the village and some villagers built new smaller houses. Although the villager rate is less than 20% in January 2019, it can be inferred that the head of household residing in the two districts is equivalent. The revival of the village, which is controlled by the return policy of the village, is a high risk as a future plan, and is realistically not considered as a future plan. Considering that the half-life of Cs 137 of 30 years and the forests, which cannot be decontaminated, accounts for more than 70% of the village's area, a long-term future plan to revitalize the village is required. The establishment of two district residential systems in the legal system and multifaceted support measures are required.

5.2 Establishment of dual residential rights

Immediately after the disaster, the author proposed a "double residency card system" to the mayor of Iitate and the press. Finally, in September 2017, the Science Council of Japan also made a policy proposal on dual residential rights. This kind of legal institutional establishment is a requirement for continual awareness of the next generation's return and future restoration of afflicted areas.

5.3 Compensation for lost homeland and natural symbiosis residence rights

A salvation fee of 100,000 yen per person from Tokyo Electric Power Company was paid until evacuation was cancelled. For the villagers who have real estate in the village, the amount for building new houses outside the village was compensated. However, remorse fees for initial exposure, compensation for loss of home, and compensation for living destruction, which half of the villagers demanded through alternative dispute resolution (ADR), remain ignored. Even if two district residences are provisionally established, the residence right at the original place will not return. The harmonious lifestyle with nature, and living close to the earth, is deprived.

5.4 Establishing a permanent health care system and recuperation system

Immediately after the disaster, the author requested the village head to wear a dose badge for the children, but the village chief refused because the children worry more. In addition, the author asked the village authorities to request the government to set up a "Health Handbook" (a type of Exposure Personal Handbook) created in cooperation with the villagers shortly after the accident, but this was also turned down. In the villagers 'questionnaire conducted by the authors in 2012, "future health problems" was the villagers' prioritized concern. A permanent health insurance system is required, not only for children but also for adults. It is required to acquire the "Nuclear Emergency Personnel Health Handbook" (draft). Also, for the health of children and parents, it is necessary to implement a recreational system in a safe place.

5.5 Guarantee agricultural life and agricultural activities inside and outside the village

After the disaster, the author supported the creation of a communal vegetable garden in the refuge area of the villagers, and the continuation of traditional local cuisine. It is clear that working with the soil leads to the longevity of the elderly. Many villagers have built their living bases outside the village, regenerated devastated farmland and resumed agriculture. Their revitalization of agriculture is also encouraging for the evacuee villagers as well. It is also required to build a network of villagers who will resume agriculture at the evacuation destination, and to establish a network with consumers.
There are also villagers who have no choice but to cultivate in decontaminated farmland in the village. About 1000 Bq / kg of cesium remains in decontaminated farmland. Fortunately, the transfer rate to crops is extremely low. In order to avoid the isolation of elderly people, who have come back, cooperative vegetable gardens combined with group homes, and share houses are important.

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Researchers are required to continue measurement support. The author has started experimental cultivation of energy crops, such as sorghum in the village farmland in cooperation with villagers since 2014. The Cs transition rate is low, and the possibility of bioenergy production at the community level is recognized.

5.6 Land use regulation by establishment of "Land Use Management Law on Radioactive Contaminated Areas" (temporary)

What is the reconstruction of the nuclear-polluted earth? The contaminated ground is still in a catastrophic state. True reproduction of the earth takes over 100 years. Resilience means the resilience of the ecosystem, which is both short and long. Radioactive contaminated ecosystems will have very long-term recoveries. For humans it takes several generations, or more. Regeneration of the rural village lifestyle, on the basis of ecosystem, is forced to parallel the regeneration of this earth. The understanding that this is still catastrophic, and the establishment of a new system on land use and management is inevitable.

Rural planning studies, which the author specializes in, is planning to sustainably manage and utilize natural, agricultural and forestry resources by trusting a sound earth. Rural planning studies aim to comprehensively and systematically prepare environmental, social and economic environments through past, present and future times for human beings to live peacefully and securely. Long-term land use planning, and land use regulation methods are required on the ground, where radiation contamination continues in the long term. Unprecedented challenges are emerging.

Unexpected planning ideas, design skills, institutional designs and policy designs are questioned. Nevertheless, evacuation has been lifted and normal land use is under way. It is an abnormal situation. This itself is the defeat of urban and rural area planning studies. For the time being, it is required to collectively set up the living bases in the land where people can live with confidence after giving up settlement in their hometown, where radiation risk is too high for the time being. It is necessary to have a rural and urban regional plan reflecting the "two-district residence" of those returning to the village occasionally to live in.

Radioactive contamination is the pollution of the demons created by mankind. Considering the providence of natural collapse, avoiding dangerous conditions and places, pursing to Asyl (Where to evacuate), and exploring ways to return, while cultivating the power of reoccurrence are required. Forests are built over hundreds of years. The relationship with the polluted earth takes hundreds of years. For rural areas with forests that continue to be contaminated, land-use regulated areas are legally necessary for the immediate future (probably over 50 years). It is necessary to manage people's entry restrictions. As a result of free land use, there is a great concern of recontamination due to the enormous radioactive material called fly ash from forest fires. In addition, the method to regenerate polluted forests remain unestablished. In the meantime, it is necessary to clarify the land use restricted areas, and to conduct research and trial experiments on long-term regeneration methods. The development of a new nuclear disaster response and planning technique is required.

5.7 Establishment of "Radiation Contamination Pollution Law" (provisional)

The nuclear accident is nuclear pollution. At the time of the nuclear accident, radioactive contamination was not covered by the Basic Environment Law. The author appealed to the press, etc., that the basic law should include radioactive contamination due to the nuclear accident. The Basic Environment Law, the Air Pollution Control Law, etc., were amended in 2013, and radioactive contamination to air, water, earth, etc. is now subject to the law and an object to be monitored. However, pollution control values, including penalties, are not stipulated. However, there is no regulation, nor criminal punishment, for radioactive contamination. Under the current circumstances, evacuation was cancelled, and reckless reconstruction measures are being developed. The establishment of a "radiation contamination pollution law" (temporary) is necessary, and the national movement for that is occurring.

6. The philosophy and practice of researchers at catastrophe

6.1 Post Normal Science
The author is continuing to support activities by organizing Iitate-mura Society for Radioecology (IISORA) with researchers in radioactivity. The organization also includes villagers. In recent years, the theme has been "The responsibility of science and engineers and post-normal science". In Japan, before the nuclear power plant accident, there already was a pollution citizen science by Ui Jun, and an anti-nuclear citizen science movement by Takagi Jinzaburou. It is a scientific activity through the collaboration of citizens and researchers, which leads to Ravetz Jerome's "post-normal science" theory. The authors' construction of IISORA is an attempt of post-normal science, which seeks to solve the problems of prolonging radioactive contamination, and the uncertainty of damage.

6.2 Planning during catastrophe time
The growth trajectory of economy, energy and population since the industrial revolution has reached its peak. It is not a future image on the extension of the growth curve, but a gentle descent is in question. Unfortunately, the 3.11 nuclear accident has resulted in continuous catastrophe. First of all, we need to look at the reality that has led to long-term catastrophe. In order to avoid greater catastrophe and destruction of the future, a new catastrophic planning theory, with method development and institutional design, are required. In the former Soviet Union, which faced the catastrophe called the Chernobyl accident, the Chernobyl Law was enacted to clearly define and deal with the radioactive contaminated areas and victims legally. However, Japan has not yet been accredited by nuclear accident damaged victims. Under that circumstance, evacuation has also been lifted, giving priority to physical reconstruction projects and return policies. The Japanese government and municipalities are trying to overcome the catastrophic situation by systematically proceeding with the full evacuation release.
Jean-Pierre Dupuy discusses prudent coping at the time of future catastrophe with "Pour un catastrophisme éclairé". The author would like to extend Dupuy's wise catastrophe theory and present a catastrophic planning theory to deal with the prolonged catastrophe.
It is a planning theory which firmly recognizes with the current state of catastrophe rather than aiming for the sudden recovery (V type) from the catastrophe in a short time. Earth and forests that have been radioactively contaminated in the long term, only normalize in 100 years. The land use plan of the contaminated earth cannot be dealt with by the normal planning method before pollution. In order to avoid the endangering lives, it should be dealt with by non-residential planning theory, non-residential land use planning theory, and ultimately catastrophic planning theory. In addition to the participation of diverse stakeholders through post-normal science, long-term time and space design and their actions are required.

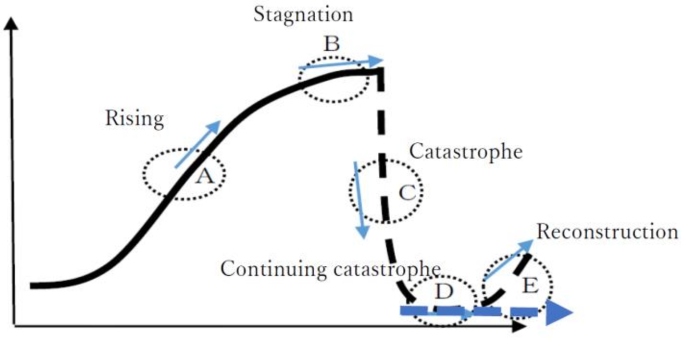

Fig. 8 Image of catastrophic planning theory

7. Conclusions
In Iitate village where the radioactive contamination by the nuclear power plant accident occurred, evacuation was lifted, but it is a situation where people cannot live with peace of mind. There is still a 4 to 5 time exposure risk of 1 m per year for the general public's dose limit. It is irrational to release the evacuation in a kind of "exceptional condition", the condition exceeded the standard of radiation control areas, which is the standard for avoiding radiation before the accident. Radioactive contamination at decontaminated residential land continues, indicating the limit to decontamination. The continuation of life in the mountain adjacent to the residential land where terrible pollution continues, is especially severe.
The villagers have been deprived of their symbiotic lifestyle with the mountains peculiar to rural villages, or "the right to reside in harmony with nature". Even if it is calculated from the half-life of radioactive

cesium, it will take more than 50 or 100 years before it can return to its prior state. It will take more than a hundred years to be able to safely live with the forests. The regeneration and resurrection of traditional rural life and culture will be held back a hundred years. This situation should be strongly recognized by the state, prefecture, village authorities and citizens. Measures and relief for victims of radioactive contamination (pollution victims from radioactive contamination) are increasingly needed.
For future measures, the following seven items can be pointed out.
①Long-term future plan by dual district residence
②Establishment of dual residential rights
③Compensation for lost homeland and natural symbiosis residence rights
④Establishing a permanent health care system and recuperation system
⑤Guarantee agricultural life and agricultural activities inside and outside the village
⑥Land use regulation by establishment of "Land Use Management Law on Radioactive Contaminated Areas" (temporary)
⑦Establishment of "Radiation Contamination Pollution Law" (provisional)
As long as the radioactive contamination is prolonged in the forest area, it is necessary to establish the Land Use Regulation Law and establish the "Radioactive Contamination Pollution Law" (provisional) in consideration of continuous catastrophic times.
As radioactive contamination is prolonged in the forest area, there is an increasing need for post-normal science, in which citizens and researchers collaborate in the long-run at the times of catastrophe.

Acknowledgments
This research is in support of Villagers of Iitate, who are fighting in a trial against Tokyo Electric Power for damage compensation. I appreciate the cooperation of everyone involved. These are the results of the following research grants. ① Foundation of scientific research expenses of MEXT (C) 15K 07655 (Representative Koji ITONAGA), ② It is part of two studies "Nihon University College Resources Science Department Strategic Infrastructure Formation Support Project" (Shared Koji ITONAGA).

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