The Fukushima Project Headquarters was established in May 2012 to support restoration and revitalization of Fukushima Prefecture following the nuclear accident at the Fukushima Daiichi Nuclear Power Plant (NPP). The headquarters manages three research projects and five sections. The projects are Radiation Effect Accumulation and Prevention Project, Project for Environmental Dynamics and Radiation Effects, and Project for Human Health. The headquarters also manages other research activities related with these projects. Background to the establishment of the headquarters and these projects are introduced briefly here. Details of each project are given in the following section.

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However, a year after the accident the situation has changed from the emergency stage. The emission of radioactive materials from Fukushima Daiichi NPP was almost stopped. The Japanese and municipal governments started decontamination work in a few areas. The emergency evacuation preparation zone was opened and some residents began coming back to their homes from temporary evacuation places. In years to come, more and more people will begin living in their homes as before the accident. But there is a concern that they may be exposed to low dose radiation from the surrounding environment, especially mountain and forest areas which have undergone hardly any decontamination. Many parents raising young children and pregnant women are uneasy and nervous about the health effects of radiation and contamination of foods, water, playgrounds for children and so forth in daily life. NIRS recognized that the needs and concerns of these people should be address to assist them in the next stage of recovery from the NPP accident. Therefore, the Fukushima Project Headquarters was established to manage and support all activities of NIRS assisting in the restoration of the areas affected by the NPP accident in Fukushima Prefecture.

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Fukushima Project Headquarters

Masami Torikoshi, Ph.D.
Deputy Director
E-mail: torikosi@nirs.go.jp

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tion Project researchers are focusing on clarifying the DDREF for fetus and infant because many parents of young children and many pregnant women may be concerned about what extent radiation affects the health of children and fetuses. There are two ways to approach the DDREF; one is the direct way in which the factor is determined by animal experiments with mice and rats, and the one is an indirect way in which the mechanisms are investigated for why a low dose and a low dose rate exposure have smaller effects on human health. What most people want to know is whether they can reduce the effects of radiation on their health or not. NIRS researchers have found that dietary mice have a longer life time than mice which are not on a diet. This finding is independent of being exposed to radiation or not. This study will be done again with expanded experimental conditions to cover various cases.

Most people are concerned with whether health effects will actually appear in the future, and if yes what they will be and when they will appear. There is no way except by an epidemiological study to directly clarify how exposed radiation doses affect human health. In the Project for Human Health, we started an epidemiological investigation with the cooperation of first responders who worked at Fukushima Daiichi NPP controlling the accident in the early stage. We will monitor their health for a long time by referring to their certificates of health and by asking for their medical history and information about their lifestyle such as smoking and drinking habits, etc. The information is being collected in a database to analyze the correlations between health conditions and the doses they received. If correlations are found between occurrence of some disease and the dose, we will inform this fact to the persons or the organizations to which they belong. Our final goal is to use the information for health care to prevent occurrence of disease or to find it at the early stage. Furthermore, we expect that future radiation protection activities will apply these epidemiological study results as a basis for responsible laws.

Fukushima Medical University is one of the largest medical centers in Fukushima Prefecture. It is carrying out a long-term health management survey for all people of Fukushima Prefecture. One section of this project is in cooperation with NIRS researchers and will estimate the external exposure dose which residents in Fukushima Prefecture received during the first four months after March 11, 2011.

Many residents from evacuation areas are afraid that they will be exposed to high radiation dose again, or that they will ingest radioactive materials from foods and water. Radionuclides may migrate to residential areas from the surrounding environment such as mountains and forests with time. In order to estimate long-term radiation doses of the residents from the surrounding environment during their daily life, we started dose estimation oriented collection of environmental samples as one mission of the Project for Environmental Dynamics and Radiation Effects. In addition, high contamination levels of the environment suggest possible effects of radiation on non-human biota and ecosystems. Although drastic effects such as the “red forests” in contaminated Chernobyl areas have not been observed, long-term studies are required to estimate the environmental effects. We are collecting biological samples such as pine, wild mouse, and salamander in heavily contaminated areas, and are planning to estimate radiation effects using different endpoints (e.g. growth rate, reproduction and chromosome aberration).
Tremendously large quantities of radionuclides were released into the environment following the nuclear accident at the Fukushima Daiichi Nuclear Power Plant in March 2011. In such a situation, it was quite important to study the environmental effects of the accident as well as the effects on human health; this importance reflects the change in the way people now think about the environment. During the past two decades, the need to evaluate the influence that radiation has on the environment itself has been pointed out by researchers while the interest in environmental problems has increased worldwide among people in general, although the way of thinking that “environment should be protected by the radiation protection system of humans” has been supported for many years by the International Commission on Radiological Protection (ICRP). The frameworks on environmental protection against radiation have already been established in international organizations such as ICRP.

Garnier-Laplace et al. calculated radiation exposure dose of rodents inhabiting Iitate Village, Fukushima using soil monitoring data reported from the Ministry of Education, Culture, Sports, Science and Technology and the dose evaluation tool (ERICA Tool) developed by a research project of the EC. They suggested a possible decline of the fecundity based on the criteria of the environmental protection framework of radiation given in ICRP Publication 108. It is essential to make a radiation effect study on the wildlife inhabiting Fukushima Prefecture to answer the question of whether or not the environment is really affected by radiation. Many researchers are trying to demonstrate environmental effects (on individual health, population size, biodiversity of species, and ecosystems) of radiation derived from the Fukushima NPP accident. However, there are only a few reports which have proved any biological effects of radiation in the wildlife. It seems difficult to find easily any biological consequences in wildlife of Fukushima Prefecture except for wildlife inhabiting the very restricted highly contaminated areas. In highly contaminated areas within the exclusion zone, genetic effects such as chromosome aberration and gene mutation, higher tumor incidence, population size reduction by reproductive failure may happen.

Based on the radiation sensitivity, we selected several animals and plants from many types of wildlife as research objects since it is reasonable to consider that radiation effects can be more easily observed in more radiosensitive wildlife. Wild mice, salamander, medaka fish, Japanese cedar and pine tree were chosen because these animals and plants are known to have comparatively large genome size and consequently radiosensitive characteristics. They are also commonly found throughout Fukushima. In particular, we are focusing on the study of radiation effects seen in wild mice caught in Fukushima (Fig.1). Tanaka et al. demonstrated the increased chromosome aberration in lymphocytes of laboratory mouse (Mus musculus) exposed chronically at a dose rate of 20mGy/day, but they saw an extremely slight effect at a dose rate of 1mGy/day. The highest value of the dose rate we measured in Fukushima with an ionization chamber type survey meter was 60-80 μSv/h. Rough dose estimation predicts that wildlife inhabiting the ground surface of such a highly contaminated location may receive a dose of more than 1mGy/day by external exposure only and an elevated level of chromosomal aberration might be observed in wild mice there. Therefore, we are trying to demonstrate the chromosomal aberration in wild mice (mainly two species, wood mouse (Apodemus speciosus) and small field mouse (Apodemus argenteus), both are unique species in Japan) captured in a highly contaminated area of the exclusion zone. As shown in Table 1, the methods applicable to laboratory mice to detect unstable or stable chromosomal aberration cannot be applied to wild mice because of genetically distant relationship. Only C-band staining can be applied to small field mice (Fig.2). At present, centromere FISH probes for wood mice and small laboratory mice are being developed. The multi-color FISH with centromere FISH probes in combination with the telomere FISH probe is expected to make the detection of unstable chromosomal aberrations possible and much easier. The study is taking place now; however substantial results will not come until next year.
This year, we started to give a chronic low-dose rate exposure to a Tohoku salamander captured in Fukushima. This is being done in the long-term irradiation facility of NIRS. Fertilized egg, wintering larva and adults are now being chronically irradiated at various dose rates. The effects of irradiation will be examined on hatching, growth, fecundity, etc.

Even if some kind of changes are observed in wildlife inhabiting highly contaminated areas of Fukushima, it will be necessary to demonstrate that the changes that occurred are really due to radiation exposure. Evacuation from the highly contaminated areas has made the study of radiation effects on the environment more complicated and difficult because human activities had largely influenced the environment. To that end, it is necessary to measure radioactivity concentration in the wild animals and plants themselves and in the environmental media they were inhabiting to calculate the radiation exposure dose or dose rate as precisely as possible.

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<tr>
<th>Laboratory mouse</th>
<th>Wood mouse</th>
<th>Small field mouse</th>
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<td>Unstable type (Dicentric) Centromere-FISH</td>
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Table 1 Interspecies Comparison of method to detect chromosomal aberration

References


Fig.1 Wood mouse captured in a Fukushima forest

Fig.2 Dicentric chromosome detected by C-band staining in the lymphocyte of a small field mouse

Table 1 Interspecies Comparison of method to detect chromosomal aberration

Unstable type (Dicentric) Centromere-FISH C-band Stable type (Translocation) FISH or Multi-FISH

Laboratory mouse ○ ○ ○
Wood mouse × × ×
Small field mouse × ○ ×
A lot of workers were involved in emergency response and stabilizing operations and many continue to be involved in recovery operations and associated activities not only at the site of the Fukushima Daiichi Nuclear Power Plant but also in the surrounding areas. These workers include employees of Tokyo Electric Power Company (TEPCO) and its contractors, policemen, fire fighters, members of Self-Defense Forces, etc. According to the available data published on the website of TEPCO, the maximum and average cumulative effective doses until December 31, 2012 among TEPCO and its contractor workers were about 680 and 12 mSv, respectively, which are much lower than those among the Chernobyl recovery operation workers as shown in Fig.1. For TEPCO and its contract workers, a long-term health care system was designed by the Ministry of Health, Labour and Welfare (MHLW) of Japan, and it is implemented by law. Under this health care system, data on radiation doses and health examination results for these workers are stored in a database at the MHLW. However, less attention has been paid to radiation exposures and associated health risks among the other emergency and recovery operation workers, and information on the levels of radiation doses among them is not officially available.

Numerous epidemiological studies have been conducted by
using the national registries for Chernobyl emergency workers as well as for the general public in Belarus, the Ukraine, and the Russian Federation. These studies show that there are increased risks of several diseases including leukemia and cataracts among workers who received higher doses, and thyroid cancer among people who were exposed during childhood and adolescence at the time of the accident. For the emergency workers of TEPCO and its contractors as well as for the general public, the World Health Organization has published two reports on preliminary dose estimation and on health risk assessment resulting from the accident in Fukushima Daiichi NPP. Although the level of radiation doses for the workers involved in the accident seems to be too low to detect any demonstrative increase of health effects, workers’ health is likely to be a matter of social concern as well as a matter of each individual’s own concern. There has no such survey for the emergency and recovery operation workers while the Fukushima Health Management Survey for residents of Fukushima has been initiated by Fukushima Prefecture in order to monitor their long-term health, promote their future well-being, and investigate health effects of chronic exposure to low dose radiation. In cooperation with experts in various fields from other institutes and universities in Japan, we have designed a follow-up project for those workers involved in emergency and recovery operations after the Fukushima Daiichi NPP accident as shown in Fig.2.

Data collection from workers’ employers on internal and external doses received during emergency and recovery operation work, as well as on results of health examinations which are routinely or specially conducted in occupational settings

Questionnaire survey on life style factors, medical exposures, disease history, etc.

Ascertainment of vital status and cancer incidence by using officially available data

Promotion of individual’s health management

Clarification of the health effects of low dose radiation

Proposal for planning of radiation protection measures for emergency situations

Long-term data management

Data tabulation

Information dissemination including health consultations and newsletters

Statistical analysis on radiation doses and health effects

NIRS Database

Fig.2

Based on the lessons learned from studies of recovery operation workers after the Chernobyl accident and other occupational studies which have often shown mixed results, life style factors including smoking, and other possible confounders should be taken into account. In the planned study, we will collect such data using a questionnaire at the beginning of the follow-up and subsequently every 3-5 years. Information on disease history for both cancer and non-cancer diseases will be also collected through the same questionnaire. Mortality and cancer incidence are the main endpoints of the follow-up, so various available sources including vital statistics, cancer registry data, etc. will be used to ascertain the endpoints. These data will be stored in a database at NIRS and be analyzed. Information on the progress of follow-up and related topics will be provided to the workers through newsletters.

In FY 2011-2012, we had discussions with persons in charge of health care of emergency and recovery operation workers at relevant organizations about the importance and feasibility of follow-up, and made an agreement with two organizations for conducting the follow-up. In addition, we have designed the structure and functions, especially in terms of security of the database for long-term follow-up. So far, more than 600 workers have been registered in our database, and most of them have completed the baseline questionnaire survey. Additional workers will be included in the follow-up in FY 2013. The findings from the follow-up study are expected to be reflected in workers’ health care, as well as in planning of radiation protection measures for emergency situations.

References


Introduction

After the Fukushima Daiichi Nuclear Power Plant accident, the interest in doses from radioactive nuclides released by the accident has been increasing especially among Fukushima residents. Also, the involved organizations have recognized that it is very important to estimate the doses of residents for proper health management of individuals. NIRS started to develop the external dose estimation system for Fukushima residents at the end of March 2011. At first, this system was developed for the evacuees who had lived in the restricted area, the deliberate evacuation area and the evacuation-prepared area in case of emergency. On the other hand, the Fukushima Prefectural government and Fukushima Medical University decided to do a health management survey for all Fukushima residents (about two million people) at the end of May 2011, to support management of their health conditions which were affected by the accident.\(^1\) External dose was considered to be one of the necessary items for health management, and the NIRS external dose estimation system was adopted in the survey. Here we briefly describe the algorithm of the NIRS external dose estimation system and the present statuses of the system and the survey.

Algorithm of the NIRS external dose estimation system

In our system, the external effective dose between March 12 and July 11, 2011 can be estimated by superimposing the individual behavior data of each day on the daily dose rate map of that day. The data flow in the external dose estimation system is shown in Fig.1. The behavior data of Fukushima residents were supplied by Fukushima Medical University. These data included: 1) place, \(i\); 2) time to stay at \(i\), \(t_i\); 3) time to move from \(i\) to \(i+1\), \(t_{move,i+1}\); and 4) type of building at \(i\), \(k_i\). In practice, \(t\) was divided into the time to stay in the building at \(i\), \(t_{in,i}\) and the time to stay outside at \(i\), \(t_{out,i}\).

Daily external dose rate maps used in our system were composed of divisions of approximately 2 km \(\times\) 2 km (2.5 min in latitude \(\times\) 1 min in longitude) based on the second mesh (7.5 min in latitude \(\times\) 5 min in longitude) defined by the Geospatial Information Authority of Japan. The maps were constructed based on two kinds of data. One kind is the hourly effective dose rate maps simulated by the System for Prediction of Environmental Emergency Dose Information (SPEEDI) with the source term calculated by the MELCOR code by the Nuclear and Industrial Safety Agency (NISA),\(^2\) which was used from March 12 to 14, 2011. These data were an alternative to monitoring data, because the number of measurement points was not sufficient to construct the dose rate maps in that period. Since the dose rate maps used in our system were daily maps, they were averaged over a day. Also, the area outputted by this SPEEDI simulation was limited to 98 km \(\times\) 98 km, which is painted in green in Fig.2, and had the divisions of 1 km \(\times\) 1 km. Therefore, the dose rate maps generated by SPEEDI were reconstructed by dividing in proportion to the area size of our system with commercially-available mapping software. The other kind of data was monitoring data released by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which was used between March 15 and July 11, 2011. These data were supplied as a set of numerical values by MEXT. The monitoring data, which were scattered in the map, were converted to spatially-continuous data by using the Natural Neighbor method and then the daily dose rate in each division of approximately 2 km \(\times\) 2 km was obtained by averaging the values in that division. Since the monitoring data by MEXT did not cover some seaside and boundary areas between Fukushima and Niigata Prefectures (pink-colored areas in Fig.2), the values of their neighbor on the right or left were used alternatively. As a result, our system can estimate the dose received in the area painted in pink and blue in Fig.2 after March 15, 2011. Unfortunately, the monitoring data on March 15 were not sufficient to construct the dose map. On the other hand, these SPEEDI results could not simulate the available monitoring data completely. Therefore, the dose rate map on March 16 was used for that on March 15. We confirmed
Fig. 1  Data flow in the NiRS external dose estimation system. (Sci. Rep, 3, 1670, 2013)

Fig. 2  Areas of dose rate maps used in the NiRS external dose estimation system. (Sci. Rep, 3, 1670, 2013)
that the alternative approach did not lead to a significant underestimation by comparing results with the available monitoring data. In fact, it led to an overestimation at most points. Moreover, two corrections were performed for daily dose rate maps between March 15 and July 11, 2011: background subtraction and conversion from ambient dose equivalent to effective dose for adult. The background dose rate of 0.03 μSv/h (in effective dose) was used for the background subtraction, which was the median value reported by Fukushima Prefecture before the accident. The monitoring data were multiplied by the conversion coefficient from ambient dose equivalent, $H^*(10)$ to effective dose for adult, $E$. The conversion coefficient was calculated for the main radionuclides discharged from the Fukushima Daiichi NPP, which was expected to contribute to the external dose, based on $E/\phi$ for isotropic irradiation (ISO) and $H^*(10)/\phi$ shown in ICRP Publication 74. As a result, the value of 0.6 was adopted as the conversion coefficient in our system, which was the rounded value of 0.59, the maximum value among the radionuclides. Finally, the effective dose rate maps (for adult) were obtained as a function of time and location, $d(h,m)$, where $h$ and $m$ are the date and the division number, respectively, in a time series from March 15 to July 11, 2011 in all parts of Fukushima Prefecture and a part of four neighboring prefectures (Miyagi, Yamagata, Tochigi, and Ibaraki).

The external effective doses were calculated for three different situations: staying indoors/outdoors and moving from one place to another. When a person stays indoors, the dose reduction should be considered because buildings have a shielding effect against radiation exposures depending on their material and thickness of the walls. In IAEA TECDOC 225, representative reduction factors for cloud, $r_c$, and ground, $r_g$, sources are shown. From March 12 to 14, radionuclides in the plume released from the power plant contributed to the dose rates in the environment. On the contrary, on March 15 radionuclides on the ground were major sources of the exposure dose rates because of rain or snow falls in Fukushima. Therefore, in our system, the reduction factors for cloud source in TECDOC 225 were used between March 12 and 14, and the factors for deposited radioactivity were used between March 15 and July 11, 2011.

Dose rates during a move may change depending on the location. In our system, the dose during a move is simply calculated as the product of averaged value of effective dose rates in the regions before and after the move and the time of the move. Then, the effective doses on the date, $h$, for stay and move ($E_{stay,h}$, $E_{move,h}$) can be expressed as the following equations, respectively,

$$E_{stay,h} = \sum_i \left[ d(h,m(i)) \times \left[ t_{in,i} \times r_{c/g}(k) + t_{out,i} \right] \right]$$

$$E_{move,h} = \sum_i \left[ \frac{d(h,m(i)) + d(h,m(i+1))}{2} \times t_{move,i} \right]$$

where the division number including the place, $i$ is $m(i)$, and the dose reduction factor correspond to the type of the building, $k$ is $r_{c/g}(k)$. Finally, the effective dose from March 12 to July 11, 2011, $E$, can be obtained with the following equation.

$$E = \sum_h (E_{stay,h} + E_{move,h})$$

Additionally, a body size correction was performed by Fukushima Medical University using age coefficients supplied by us, because the external effective dose depends on body size even in the same radiation field due to the self-shielding effect. The age coefficients, $C_{age}$, for the main radionuclides discharged from the Fukushima Daiichi NPP, could be obtained from the ratios

![Fig.3](image-url)  
*Fig.3* Ratios of ambient dose equivalent to effective dose conversion coefficients for each age group to adult (Age coefficients, $C_{age}$). The maximum values in the main radionuclides released from the Fukushima Daiichi NPP were adopted.
of ambient dose equivalent to effective dose conversion coefficients for children to adult calculated based on published data\textsuperscript{3} as shown in Fig.3. By adopting the maximum values among the radionuclides, age coefficient for infants was 1.36 and age coefficients in the age range from 1 to 15 years old could be expressed as the following linear function of age, $y$.

$$ C_{\text{age}} = -0.0144 \times y + 1.27 $$

Present statuses of the system and the survey

NIRS and Fukushima Medical University reached a work consignment agreement regarding the external dose estimation for Fukushima residents in April 2012, and since then our system has been used only for the Fukushima health management survey. Fukushima Medical University digitizes the questionnaire results on behavior of the resident, and the digitized outputs without personal identifiable information are sent to us. To date, we have completed effective dose estimations of about four hundred thousand residents, which represent all the data sent to us by Fukushima Medical University, with our system. The estimated results were provided to the Fukushima residents individually by Fukushima Medical University, and a summary was sequentially reported by the Commission on the Fukushima Health Management Survey.

Conclusion

We developed the NIRS external dose estimation system for Fukushima residents to estimate the external effective doses for the first four months after the Fukushima Daiichi NPP accident. This system has been adopted in the Fukushima Health Management Survey, and the estimated results were provided to the Fukushima residents, individually. The estimated results include various uncertainties such as the vagueness of the residents’ memories; however, our dose estimation can be very useful as the first approximation of the external effective doses to Fukushima residents by the accident.

References

The residents of Fukushima Prefecture have been suffering psychologically, economically and socially from the accident at TEPCO’s Fukushima Daiichi Nuclear Power Plant, which happened in 2011. Specifically, people who live in areas of high background levels of radiation feel uneasy about their health. Attention is, in particular, focused on unborn children and young children. With the current radiation protection system, it is assumed that the dose of low-dose-rate radiation accumulates, but with the reduction factor (dose and dose-rate effectiveness factor: DDREF) of 2. However, the following questions remain unresolved: 1) Is the dose-rate effect for children the same as that for adults? 2) Can the dose-rate effect be explained in part by the reduced accumulation of radiation-induced damage in stem (progenitor) cells or elimination of damaged stem cells? 3) Could the cancer risk after childhood exposure be reduced by subsequent control of diet?

The purpose of the project described here is to elucidate the effects of low-dose-rate radiation and its underlying mechanism, and then to provide possible measures to mitigate the risks based on findings using animal models. At first, the effects of the low-dose-rate radiation on life shortening and cancer induction are examined for juvenile exposure in comparison with adult exposure. Secondly, the accumulation of radiation effects in the stem cells of the skin and mammary glands is evaluated. Thirdly, inhibitory effects of calorie restriction and anti-oxidant food ingredients on radiation-induced cancer are investigated.

Long-term animal experiments have become considerably difficult to perform on a large-scale, because of financial and ethical reasons. Unfortunately, many local archives of the past animal experiments have been lost when investigators retired. In the 1990s, however, animal samples were collected into shared international archives for future re-examination of data using novel methods or hypothesis; re-examination now would facilitate the effective utilization of research resources in the U.S, Europe and Japan. Samples and the data provided by the present project will be incorporated into these international archives, and be available in collaborative investigation with domestic and foreign research organizations.

**Risk analysis for effects of low-dose-rate exposure**

Male and female B6C3F1 mice in the juvenile (1 week of age) and adult (7 and 15 weeks of age) stages were gamma-irradiated at low-dose-rate for 4 consecutive weeks, and life shortening and incidence of leukemia and solid cancers are being investigated. The dose rate was 0.026 mGy/min and 0.105 mGy/min (total exposure dose of 1 Gy and 4 Gy, respectively) (Fig.1). The effect on the induction of mammary tumors (SD rats) and brain tumors (Ptc1+/− mice) is also being examined. The dose-rate effectiveness factor (DREF) will be estimated in comparison with the data of single irradiation exposure. The survival of these animals is now being followed.

**Accumulation of radiation effects on tissue stem cells**

The present radiological protection system assumes full accumulation of the stochastic effect (especially, induction of carcino-
genesis) of ionizing radiation. Given that long-lived tissue stem or progenitor cells are the targets of radiation carcinogenesis, this model system seems reasonable. This means that continuous radiation exposure at low dose rate should impose small but significant health risks. However, epidemiologic studies do not necessarily support this idea. In addition, it was recently hypothesized that the radiation effects after chronic exposure do not accumulate in proportion to the cumulative dose when tissue turnover rate or radiation-induced change in self-renewal activity is taken into account.

1) Study on the damage response of hair follicle stem cells

Hair follicles are self-renewing structures that reconstitute themselves through three cycling stages: anagen (growing phase), catagen (regression phase) and telogen (resting phase). Differentiating keratinocytes constitute the hair matrix with mature melanocytes, pigment-producing cells. Recent findings indicate that keratinocyte and melanocyte stem cells reside in the bulge area of the hair follicle. It is expected that the effects of damage in keratinocyte and melanocyte stem cells in the telogen stage of the first hair growth cycle can be detected as the phenotype of descendant hair follicle structure in the anagen phase of the second hair growth cycle, since newly formed hair follicles are derived solely from keratinocyte and melanocyte stem cells in the telogen stage of the first hair growth cycle.

To study the accumulation of effects by irradiation, 22 to 24-day-old C57BL/10Jir (B10) mice were exposed to gamma-rays of $^{60}$Co, and the radiation effects were examined on 35 to 37-day-old B10 mice. The number of hair follicles and the pigment production in hair bulb are established as the criteria.

2) Study on the cell kinetics and modeling of mammary stem cells

Another focus of study is on the effects of radiation on mammary stem cells. The mammary gland is a highly susceptible organ to radiation induction of carcinogenesis and its stem cells are enriched in a culture of mammary epithelial cells on a non-adherent substrate (‘mammospheres’). It is hypothesized here that radiation exposure not only induces oncogenic mutations but also increases the probability of losing self-renewal activity or increases the chance of undergoing differentiation of stem cells, which may lead to a relative decrease in the chance of maintaining affected stem cells. The first goal is to provide a new model using the mammosphere system, which can evaluate the behavior of irradiated stem cells during continuous radiation exposure.

Mitigation of cancer risks from radiation exposure

Children are the most susceptible subpopulation to radiation carcinogenesis. After the TEPCO Fukushima Daiichi NPP accident, people became worried about the long-term health effects on children, especially children who live in areas affected by the release of large amounts of radioactive materials. Therefore, it is important to lay a special emphasis on finding a useful remedy to prevent carcinogenic effects of radiation on children.

Calorie restriction (CR) is known to extend the life span and prevent the major causes of morbidity and mortality including cancer. Thus, it may be one of the most potent interventions for decreasing deleterious effects of radiation. Then attention is given to investigating the cancer preventive effects of CR after early-life exposure. Male and female B6C3F1 mice were irradiated with X-rays of 3.8 Gy at one week of age. Then, calorie restrictions of 21% and 32% were started at 26 weeks of age, and will be continued for the natural life span. The life span, incidence and spectra of tumors will be clarified (Fig.2A).

Phytochemicals, a wide variety of compounds produced by plants, are known to prevent many health conditions, including cancer. Resveratrol, a phytochemical, has been demonstrated to have properties that mimic CR. The inhibitory action of resveratrol on early-life exposure to radiation-induced carcinogenesis is being investigated using the mouse model of familial adenomatous polyposis. Male and female C3B6F1 Apc<sup>Min</sup> mice were irradiated by X-rays of 2 Gy at 2 and 7 weeks of old, and administration of resveratrol was started 2 weeks after the irradiation. All mice will be autopsied at 30 weeks old, and the preventive effects of resveratrol will be evaluated (Fig.2B).