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Joint IES-ICRP Symposium on Environmental Protection within the ICRP System of Radiological Protection

Rokkasho, Aomori, Japan
Tuesday, October 4, 2016

Abstracts

Organised by the Institute for Environmental Sciences (IES)
and the International Commission on Radiological Protection (ICRP)
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Cover photo: autumn views of the Institute for Environmental Sciences (orange color building) and Mt. Fukkoshi (left side) from the Lake Obuchi in Rokkasho Village.
The photograph by Mr. Kazuaki Ichinohe (IES).

Background

Committee 5 is concerned with radiological protection of the environment. It aims to ensure that the development and application of approaches to environmental protection are compatible with those for radiological protection of man, and with those for protection of the environment from other potential hazards. The ICRP system for radiological protection is sound and robust and has contributed to the understanding of environmental impact in different contexts, e.g. in relation to the accident at the Fukushima Daiichi Nuclear Power Station, in relation to the London Convention and in relation to the impact of radioactive discharges into the North-East Atlantic Ocean. Committee 5 continues to develop protection of the environment within the system of radiological protection by broadening and consolidating the scientific basis that underpins the system, and by drawing on the experience gained in its application in the three exposure situations considered by ICRP.

Objectives

IES and ICRP welcome this opportunity to discuss current work on radiological protection of the environment, covering topics including:

- The concept and use of Reference Animals and Plants (RAPS), including a general introduction to environmental protection within the ICRP system of radiological protection: From *Publication 91* to TG99 and beyond.
- The “science base” underpinning environmental radiation protection: Transfer, dosimetry, RBE weighted absorbed dose, effects.
- Applying the ICRP system for environmental protection.

Symposium venue

Swany (1-8 Nozuki, Obuchi, Rokkasho-mura, Kamikita-gun, Aomori, Japan)
http://www.jomon.ne.jp/~pulaza97/index_en.html

Coffee break and lunch

Coffee will be served during the morning and afternoon breaks. ICRP members and invited speakers are able to eat a lunch box provided by the secretariat. Participants may also reserve a lunch box provided by the secretariat. However this must be ordered in advance. Otherwise participants can visit the restaurants and convenience store around the venue for lunch.

Language

English. Presentations will be given in English without interpretation.

Program

Opening Address

10:30–10:40	Opening Address	Prof. Higley, ICRP-C5	(Chair: Prof. Ono, IES)

Scientific Session (Chairs: Prof. Higley and Dr. Hisamatsu)

10:40–11:10	Brief overview of the role of ICRP and where C5 fits within this structure	Prof. Higley (ICRP-C5)
11:10–11:50	The concept of protection of the environment and C5 current approach	Prof. Copplestone (ICRP-C5)
11:50–13:00	*Lunch*	
13:00–15:00	Panel discussion to address issues, focused in the Japanese situation, related to:	
	i. Transfer of radionuclides	Prof. Strand (ICRP-C5))
	ii. Dosimetry	Dr. Ulanovsky (ICRP-C5)
	iii. Effects	Dr. Garnier-Laplace (ICRP-C5)
	iv. RBE weight absorbed dose	Dr. Real (ICRP-C5)
	v. System for radiation protection of the environment (i.e., existing, planned and emergency)	Prof. Copplestone (ICRP-C5)
	Discussion	
15:00–15:15	*Coffee break*	
15:15–16:45	Topics on dosimetry and radiation effects	
	i. Dosimetry of wild organisms and their natural dose	Dr. Ohtsuka (IES)
	ii. Radiation effects and dosimetry of large Japanese field mice in Fukushima	Dr. Miura (Hirosaki Univ.)
	iii. Morphological defects in native trees around the Fukushima Daiichi Nuclear Power Plant	Dr. Watanabe (QST, NIRS)
16:45–17:00	Summary of key points from presentations	Prof. Sakai (ICRP-C5)

Concluding Remarks

17:00–17:10	Concluding Remarks	Prof. Higley, ICRP-C5 and Dr. Hisamatsu, IES

An overview of the role of the International Commission on Radiological Protection's Committee 5 (Protection of the Environment)

K. Higley[a,b] on behalf of all members of Committee 5

[a] School of Nuclear Science and Engineering, Oregon State University, Corvallis, OR, USA; e-mail: kathryn.higley@oregonstate.edu
[b]Chair, ICRP Committee 5

Abstract–The International Commission on Radiological Protection (ICRP) was founded in 1928, and is a non-profit organisation which provides recommendations and guidance related to radiation protection. ICRP has developed a system of radiation protection which balances the scientific understanding of radiation effects with the ethical and societal implications of exposure. Following publication of a framework for assessing impact of ionising radiation on non-human species (ICRP, 2003), ICRP established its fifth committee, 'Protection of the Environment - Committee 5' in 2005. This newest ICRP committee was given the objective of developing a framework for environmental protection based on an evaluation of the ethical and philosophical basis established in ICRP *Publication 91*. Two years after C5 began its tenure, ICRP published recommendations for radiological protection (ICRP, 2007) that incorporated environmental protection as one of the integral elements of the overall radiological protection system. In 2008, ICRP published a document which outlined the concept and use of twelve Reference Animals and Plants (RAPs). The RAPs span terrestrial, freshwater and marine ecosystems through selection of as few organisms as necessary to enable collection and development of datasets on radiation effects and radionuclide transfers and associated dosimetry. The RAPs were also intended to serve as a basis for exploring characteristics of more site-specific representative organisms (RO) which might be necessary to examine exposure conditions in certain circumstances. In addition to defining the characteristics of the RAPs, ICRP *Publication 108* developed dose conversion factors and examined the current understanding of radiation effects on RAPS. This publication also proposed 'Derived Consideration Reference Levels' (DCRLs) and how these could be applied as points of reference within a system of radiological protection. In 2009, in *Publication 114* ICRP examined approaches used to model transfer of radionuclides in the environment and provided a tabulation of concentration ratios for the RAPs. The most recent publication from Committee 5, considered application of the system of environmental radiation protection in planned, emergency, and existing exposure situations (*Publication 124*). Publications in press or undergoing review include a compilation of improved dosimetry and an evaluation of relative biological effectiveness in the context of RAPs. C5 and its Task Groups continue to examine update databases related to RAPS in order to quantify their representativeness of Representative Organisms. There is also consideration of application of the system to environmental protection in relation to certain human activities of potential environmental concern (existing exposure situations).

References

ICRP, 2003. A framework for assessing the impact of ionising radiation on non-human species. ICRP Publication 91. Ann. ICRP 33(3).

ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37(2–4).

ICRP, 2008. Environmental protection: the concept and use of reference animals and plants. ICRP Publication 108. Ann. ICRP 38(4–6).

ICRP, 2009. Environmental protection: transfer parameters for reference animals and plants. ICRP Publication 114. Ann. ICRP 39(6).

ICRP, 2014. Protection of the environment under different exposure situations. ICRP Publication 124. Ann. ICRP 43(1).

The concept of protection of the environment and the Committee5 current approach

D. Copplestone[a,b] on behalf of all members of Committee 5

[a] *Biological and Environmental Sciences, Faculty of Natural Sciences, University of Stirling, Stirling, UK; e-mail: david.copplestone@stir.ac.uk;* [b]*Secretary, ICRP Committee 5*

Abstract–Protection of the environment is integral to the system of radiological protection as outlined in the 2007 Recommendations of the International Commission on Radiological Protection (ICRP) (ICRP, *Publication 103*). Committee 5 has been given the objective of developing a framework for environmental protection based on an evaluation of the ethical and philosophical basis established in ICRP *Publication 91*. This was first described in 2008, when ICRP published a document which outlined the concept and use of twelve Reference Animals and Plants (RAPs). The RAPs are intended to span terrestrial, freshwater and marine ecosystems through selection of as few organisms as necessary to enable collection and development of datasets on radiation effects and radionuclide transfers and associated dosimetry. Other ICRP reports and Task Group outputs have expanded on different aspects of the system of radiological protection which now incorporates the environment. Most recently, the way to apply the system of radiological protection to demonstrate environmental protection has been described in the ICRP's *Publication 124*. In this publication, the Commission's objectives for environmental protection and how the Derived Consideration Reference Levels (DCRLs) apply within different exposure situations (planned, existing and emergency) were laid out. The DCRLs are defined as the reference range of dose rates, above the natural background, within which deleterious effects of ionising radiation may occur in individuals of a given RAP type. This presentation will describe the ICRP approach to environmental protection and demonstrate how the system for radiological protection protects both humans and wildlife. It will highlight where there are differences between aspects of human and environmental radiological protection. For example, in the protection goal. Put simply, the environmental goal (to protect populations and biodiversity) differ from the goal of protecting individual humans. Furthermore, there are differences in the application of the system of radiological protection where for humans we have dose limits but for wildlife we do not. This is based on the fact that for there to be a limit there must be some benefit to the potential increased exposure which is being limited but for wildlife it is difficult to see how there may be such a benefit for a population of a potentially impacted wildlife population. However, the use of limits and constraints is not dissimilar to the intent behind DCRLs which are numeric benchmarks of importance in risk assessment. While the system has been established, there are still areas where further development/thinking is required and the presentation will discuss these.

References

ICRP, 2003. A framework for assessing the impact of ionising radiation on non-human species. ICRP Publication 91. Ann. ICRP 33(3).

ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37(2–4).

ICRP, 2008. Environmental protection: the concept and use of reference animals and plants. ICRP Publication 108. Ann. ICRP 38(4–6).

ICRP, 2014. Protection of the environment under different exposure situations. ICRP Publication 124. Ann. ICRP 43(1).

An overview of the transfer of radionuclides to the International Commission on Radiological Protection's Reference Animals and Plants

P. Strand[a] on behalf of all members of Committee 5

[a] *Norwegian Radiation Protection Authority, Grini naeringspark 13, N-1345 Osteras, Norway; e-mail: per.strand@nrpa.no*

Abstract–Equilibrium concentration ratios (CRs) are commonly used to model the transfer of radionuclides to wildlife and the data available in the literature were reviewed in ICRP *Publication 114* to provide CRs for the twelve Reference Animals and Plants (RAPs) outlined in *Publication 108*. A series of methods that could be used to derive CRs and summaries of statistical information from empirical data sets are now available. Emphasis has been placed on using CR data from field studies, although some data from laboratory experiments have been included for some RAPs. There are, inevitably, many data gaps for each RAP, and other data have been used to help fill these gaps. CRs specific to each RAP were extracted from a larger database, as described in ICRP *Publication 114* in terms of generic wildlife groups. In cases where data were lacking, values from taxonomically related organisms were used to derive suitable surrogate values. The full set of rules which have been applied for filling gaps in RAP-specific CRs is available and means that CR values for 39 elements and 12 RAP combinations are given. The data coverage, reliance on derived values, and applicability of the CR approach for each of the RAPs has also been discussed. More recently, new data specifically on species which belong to the RAPs have been made available and this includes, where possible, information on RAPs life stages. The data in *Publication 114* are being updated as part of ongoing work within Task Group 99 of ICRP.

References

ICRP, 2009. Environmental protection: transfer parameters for reference animals and plants. ICRP Publication 114. Ann. ICRP 39(6).

Improved dosimetry for animals and plants:
What does the new ICRP draft publication bring?

Alexander Ulanovsky [a,b] on behalf of the ICRP Task Group 74 and Committee 5

[a] *Institute of Radiation Protection, Helmholtz Zentrum München – German Research Center for Environmental Health, Ingolstädter Landstraße 1, D-85764, Neuherberg, GERMANY*
E-Mail: ulanovsky@helmholtz-muenchen.de

[b] *Member of ICRP Committee 5 and Chair of the ICRP Task Group 74 "More realistic dosimetry for non-human species"*

Abstract–The diversity of non-human biota is a specific challenge when developing and applying dosimetric models for assessing exposures of flora and fauna from radioactive sources in the environment. Dosimetric models, adopted in *Publication 108*, provide Dose Coefficients (DCs) for a group of reference entities called the ICRP's Reference Animals and Plants (RAPs). These entities are characterised pragmatically by assuming simple body shapes with uniform composition and density, homogeneous internal contamination, limited sets of idealised sources of external exposure to ionising radiation for aquatic and terrestrial animals and plants, and truncated radioactive decay chains. This pragmatic methodology has been further developed and systematically extended in the new draft of the oncoming ICRP publication[1]. Significant methodological changes since *Publication 108* include: implementation of a new approach for external exposure of terrestrial animals with an extended set of environmental radioactive sources in soil and in air, considering an extended range of organisms and locations in contaminated terrain, transition to the contemporary radionuclide database of *Publication 107*[2], assessment-specific consideration of radioactive progeny contribution to DC of parent radionuclides, and use of generalised allometric relationships in the estimation of biokinetic or metabolic parameter values. These methodological developments result in changes to previously published tables of DCs for RAPs, and the revised values will be provided in the new publication. The draft publication is also complemented by a new software tool, called BiotaDC, which enables calculation of DCs for internal and external exposures of organisms with user-defined masses, shapes, and locations in the environment and for all radionuclides in *Publication 107*. The software tool is a freely-assessed web-based application and its test version runs currently on the ICRP website[3].

References

1. Draft Report for Consultation: Dose Coefficients for Non-human Biota Environmentally Exposed to Radiation. http://www.icrp.org/page.asp?id=326
2. ICRP, 2008. Nuclear Decay Data for Dosimetric Calculations. ICRP Publication 107. Ann. ICRP 38(3).
3. BiotaDC. The test pre-release version is available on-line at http://biotadc.icrp.org/

Improving the robustness of Derived Consideration Reference Levels for Reference Animals and Plants (RAP) - Insights from current ICRP activities

J. Garnier-Laplace[a,b] on behalf of all members of Task Group 99 of Committee 5

[a] *Institute for Radioprotection and Nuclear Safety, France; e-mail: jacqueline.garnier-laplace@irsn.fr*
[b] *Task Group 99 Chair, ICRP Committee 5*

Abstract–Last year, ICRP launched a new Task Group of Committee 5, entirely dedicated to the update of RAP-related basic data and guidance for their best use and practices in support of the application of the system of radiological protection to protect the environment in planned, emergency and existing exposure situations[1]. In addition to the evaluation of the completeness of RAPs and associated data in a comprehensive manner with regard to ecology/biology, transfer, dosimetry and effects, a specific objective is pursued to improve the robustness of Derived Consideration Reference Levels (DCRLs). These ranges of dose rates were derived on the basis of a critical literature review published in ICRP *Publication 108*[2]. For application to any environmental exposure situations, DCRLs are part of the system of radiological protection to be used as reference levels to identify whether there is likely to be some chance of deleterious effects of exposure to ionising radiation on individuals of the same RAP-type[2,3]. Task Group 99 is improving the transparency of the derivation method used to obtain those DCRLs along with the quality and quantity of the underlying effect data sets describing the radiosensitivity of various endpoints and species. To reach this aim, two activities are on-going: (i) to develop an inference method for making use of acute radiotoxicity data in addition to chronic effect data, in order to establish a robust statistically-based extrapolation model representing the range of radiosensitivity within a RAP-type group of species; (ii) to analyse the discrepancy at the taxonomic level between laboratory effect data and field data coming out from radio-contaminated sites. For both (i) and (ii), post-Fukushima-Daiichi accident studies published in the literature, will be of great added value, as it was demonstrated for some of the studies performed in the Chernobyl Exclusion Zone[4].

References

[1] ICRP, 2015. Terms of Reference of Task Group 99, Committee 5: http://www.icrp.org/icrp_group.asp?id=92

[2] ICRP, 2008. Environmental Protection – the Concept and Use of Reference Animals and Plants. ICRP Publication 108, Ann. ICRP 38(4-6).

[3] ICRP, 2014. Protection of the Environment Under Different Exposure Situations, ICRP Publication 124, Ann. ICRP, 43(1).

[4] Garnier-Laplace, J., Geras'kin, S., Della-Vedova, C., et al., 2013. Are radiosensitivity data derived from natural field conditions consistent with data from controlled exposures? A case study of Chernobyl wildlife chronically exposed to low dose rates. J. Environ. Radioact. 121, 12–21.

RBE weighted absorbed dose in the context of the radiological protection of the environment

A. Real[a,b] on behalf of the members of Task Group 72 and Committee 5

[a] *Centre for Research in Energy, Technology and Environment, CIEMAT. Av. Complutense 40. Madrid 28040, SPAIN. e-mail:almudena.real@ciemat.es;* [b] *Vice-Chair of ICRP Committee 5*

Abstract–It has long been recognised that different radiation types have different effectiveness in producing biological effects in organisms. These differences are experimentally quantified as the "Relative Biological Effectiveness" (RBE) of specific radiation types. RBE values have been measured for a variety of end points in in-vitro (including human and animal cell lines) and in-vivo experiments (with animals)[1]. Such studies have shown that the RBE value for a specific radiation type depends on the dose and dose-rate, the dose fractionation scheme, the biological end-point, the species and the tissue or cell type used in the study. In radiological protection of humans, the RBE values for stochastic effects at low doses have been used, together with biophysical considerations and judgements, to determine the radiation weighting factors (w_R) used to define the equivalent dose[2]. In organisms other than humans, it is well documented that the RBE concept is relevant. In fact, different organizations have proposed values of radiation weighting factors (for alpha and low-energy beta particles) to be applied to estimate the doses received by non-human biota. Not applying the RBE weighting factors could lead to an underestimation of the potential effects on wildlife produced by alpha- and low energy beta-emitting nuclides present in the environment. In spite of the need for a formal accepted approach to provide RBE weighting factors to be applied in the context of radiological protection of the environment, nowadays such approach does not exist. Committee 5 created Task Group 72, whose final aim is to determine if the absorbed dose has to be multiplied by a RBE weighting factor in order to account for the quality of the radiation when assessing radiological impacts to non-human biota, and to provide recommendations on nominal values of RBE weighting factors for α radiation and low energy β particles. In a first step, the TG has reviewed the available information on experimental RBE data for α particles and low-energy β radiation in relation to the RAPs[3]. The protection of animals and plants from the effects of ionising radiation has largely focussed on endpoints which are relevant at the population level (early mortality, reproductive capacity, etc.). Therefore, the use of weighting factors derived from evaluations of stochastic effects, as in the system of protection for humans, appears inappropriate. TG72 has considered the challenges in differentiating stochastic from deterministic effects.

References

[1] ICRP, 1990. RBE for deterministic effects. ICRP Publication 58. Ann. ICRP 20(4).

[2] ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37(2-4).

[3] Higley, K.A., Kocher, D.C., Real, A., Chambers D.B., 2012. Relative biological effectiveness and radiation weighting factors in the context of animals and plants. Proceedings of the First ICRP Symposium on the International System of Radiological Protection. Ann. ICRP 41(3/4). Pp 233-245.

Environmental protection within the ICRP system for radiological protection (i.e. existing, planned and emergency exposure situations)

D. Copplestone[a,b] on behalf of all members of Committees 4 and 5

[a] *Biological and Environmental Sciences, Faculty of Natural Sciences, University of Stirling, Stirling, UK; e-mail: david.copplestone@stir.ac.uk;* [b]*Secretary, ICRP Committee 5*

Abstract–This presentation will expand upon the objectives of the Commission in relation to protection of the environment and how these can be met using the Reference Animals and Plants (RAPs) and their Derived Consideration Reference Levels (DCRLs) described in *Publication 108*[1]. DCRLs represent a band of dose-rates, above the natural background, within which deleterious effects can occur in individuals of a given type of RAP. For each of the three types of exposure situations defined by the Commission (planned, existing and emergency), the key principles that are relevant to the protection of the environment and how these apply will be described[2]. Some of the future work in this area will be highlighted for example, in relation to existing exposure situations. For existing exposure situations, we need to better understand the potential impacts on animals and plants especially in light of remediation options that may be applied. Consequently, understanding the radiological and non-radiological consequences is important. A new Task Group will soon take this aspect forward by making use of examples of how existing situations have been managed in the past and looking at the potential impacts on the environment while considering the potential benefits of humans to reduced exposure levels.

References

[1] ICRP, 2008. Environmental Protection - the Concept and Use of Reference Animals and Plants. ICRP Publication 108. Ann. ICRP 38(4-6).

[2] ICRP, 2014. Protection of the environment under different exposure situations. ICRP Publication 124. Ann. ICRP 43(1).

Dosimetry of wild organisms and their natural dose

Y. Ohtsuka[a], T. Iyogi[a], N. Okabe[a,b], Y. Takaku[a], S. Hisamatsu[a]

[a] *Department of radioecology, Institute For Environmental Sciences*

e-mail: ohtsuka@ies.or.jp

[b] *Tono Geoscience Center, Japan Atomic Energy Agency*

Abstract–To protect ecosystems from radiation, precise assessment of the radiation dose to wild organisms is important. However, the radiation dosimetry, which involves conversion of the radiation dose in air and the internal radionuclide inventory to the absorbed dose, has not yet been established for various wild organisms. In addition, though the background radiation dose rate in a contaminated environment is of fundamental importance for evaluating the effects of radiation on wild organisms living there, very few studies have evaluated it. Japan's first large-scale commercial nuclear fuel reprocessing plant, in Rokkasho Village, Aomori Prefecture, is now under safety assessment by Nuclear Regulation Authority; it is scheduled to start commercial operation in FY 2018. Although the discharge of radionuclides from the plant is strictly controlled, for public acceptance of the plant, it is important to assess the radiation dose to wild organisms living around the plant from both natural and artificial radiation sources. Some ecological changes around the plant may be due to causes other than radiation from the plant; therefore, it is necessary to compare the radiation dose originating from the plant with the background dose and to show that the radiation dose did not cause those ecological changes. In this study, a dosimetry method for terrestrial and aquatic organisms living around the reprocessing plant was developed, and then the background dose rates to representative organisms were evaluated. We selected four species of terrestrial animals and seven species of aquatic biota as target organisms. Mouse (*Apodemus argenteus*), shrew mole (*Urotrichus talpoides*), red fox (*Vulpes vulpes japonica*), and raccoon dog (*Nyctereutes procyonoides viverrinus*) were chosen as representative wild terrestrial organisms of the forest ecosystem surrounding the plant, and Japanese pond smelt (*Hypomesus nipponensis*), Pacific herring (*Clupea pallasii*), chum salmon (*Oncorhynchus keta*), starry flounder (*Platichthys stellatus*), Pacific oyster (*Crassostrea gigas*), blue mussel (*Mytilus galloprovincialis*), and common eelgrass (*Zostera marina*) were selected as representative aquatic organisms in Lake Obuchi, a brackish lake neighboring the reprocessing plant. Voxel phantoms, which have realistic body and organ forms, were constructed for each organism by several techniques, including magnetic resonance imaging and X-ray computed tomography. Concentrations of major stable elements and of radionuclides, including ^{210}Po, in each organ and integrated system, such as the viscera, of each organism were determined for the absorbed dose rate calculation. The radiation dose rates in the air and water of the organisms' habitats were also measured, along with the ^{222}Rn concentration in terrestrial habitats. Finally, the absorbed doses were estimated by the Monte Carlo method (EGS4, EGS5, and UCPIXEL code systems) from the external radiation dose and the internal radionuclide distribution. The developed phantoms and the natural radiation dose rate for each organism are presented at the meeting.

Acknowledgments

This study was performed under a contract with the Government of Aomori Prefecture, Japan.

Radiation effects and dosimetry of large Japanese field mice in Fukushima

T. Miura [a], A. Nakata[b], Y. Fujishima[a], R. Ujiie[a], K. Kasai[a], H. Tazoe[c], K. Ariyoshi[c], M. Saito[d], K. Suzuki[e], M. Yamada[c], M. A. Yoshida[c], M. Fukumoto[f]

[a] Hirosaki Univ. Graduate School of Health Sciences, [b] Hokkaido Pharmaceutical Univ.,[3] Hirosaki Univ. Institute of Radiation Emergency Medicine (IREM/HU), [4] Institute for Environmental Sciences, [e]Michinoku Fauna Research, and [f] Tohoku Univ. Institute of Development, Aging and Cancer
e-mail: tomisato@hirosaki-u.ac.jp

Abstract– After the Fukushima Daiichi nuclear power plant (F1-NPP) accident, the environment was contaminated with radionuclides around the F1-NPP. Even though radiation dose rate is decreasing, people are concerned with adverse effects on the organism in the future. It is, therefore, important to assess the effect of radioactive materials on animals. The objective of this study was to evaluate the effect of radioactive materials on the Japanese large field mouse, *Apodemus specious* by analyzing age distribution, growth and chromosome aberrations of mice. For the population study, mice were collected in the ex-evacuation area of F1-NPP and in the autumn of 2011 and spring of 2012. Mice in Aomori prefecture (350 km north of F1-NPP) were caught as negative control for exposure. The age of collected mice was estimated by tooth wear status or lens weight. Spleen cells obtained from mice were cultured and chromosomal aberrations, such as breaks, gaps, dicentrics and rings were analyzed. The external dose of mouse was measured using the small radiophotoluminescence glass dosimeter embedded in the back of mice. There was no significant difference in individual growth between the mice collected in Fukushima and Aomori. The ratio of mice number born before and after the F1-NPP accident was significantly low in the Fukushima population. However, our results showed that the population of mice in Fukushima has been recovered. There was no radiation-specific chromosomal abnormality in the mice examined. The external dose of mice in the evacuation area was avg. 1.2 (min.: 1.0, max.: 1.3) μGy/h in low air-dose rate area and avg. 12.4 (min.: 8.0, max.: 17.4) μGy/h in high air-dose rate area. Although the mice in the evacuation area were exposed chronically, the adverse genetic effects of radiation were not detected at present. Continuous investigation of wildlife is necessary to determine biological effects of radiation from the F1-NPP accident.

Morphological defects in native trees around the Fukushima Daiichi Nuclear Power Plant

Y. Watanabe, Y. Kubota, S. Fuma, K. Maruyama, I. Kawaguchi, S. Yoshida

National Institute of Radiological Sciences, National Institutes for Quantum and Radiological Science and Technology; e-mail: watanabe.yoshito@qst.go.jp

Abstract–After the accident at the Fukushima Daiichi Nuclear Power Plant (F1NPP) in March 2011, high contamination levels in the environment suggest possible effects of radiation on non-human biota. 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. Some biological studies have been reported so far to elucidate the influence of radiation derived from the F1NPP accident on non-human biota. However, further studies using radiation-responsive indicator organisms inhabiting the highly contaminated areas may help us to reach a consistent conclusion, whether radiological contamination from the F1NPP accident had a biological impact on the environment. Our project has been analyzing biological samples in heavily contaminated areas in the former “Restricted Area” and the present “Area 3” where it is expected that the residents have difficulties in returning for a long time (Ministry of Economy, Trade and Industry). We selected wild mouse, salamanders, medaka fish and coniferous trees as suitable indicator organisms, because these organisms have abundant biological data about the radiation (wild mouse and medaka fish) or/and known to have comparatively large genome size and consequently estimated to have radiosensitive characteristics (wild mouse, salamanders and coniferous trees). In addition, these organisms are easily associated to Reference Animals and Plants (RAPs) in the ICRP system of radiological protection. Among these indicator organisms, we especially focused on coniferous trees for the purpose of biomonitoring in the forest environment. We investigated the morphological changes in Japanese fir, a Japanese endemic native coniferous tree, because of the easiness of observation and the regular annual branching that make possible to identify the year the morphological changes occurred on the past. Japanese fir populations near the F1NPP showed a significantly increased number of morphological defects, involving deletions of leader shoots of the main axis, compared to a control population far from the F1NPP. The frequency of the defects corresponded to the radioactive contamination levels of the observation sites. A significant increase in deletions of the leader shoots became apparent in those that elongated after the spring of 2012, a year after the accident. These suggest possibility that the contamination by radionuclides after the accident contributed to the morphological defects in Japanese fir trees in the area near the F1NPP. To verify the causal relationship inferred from the field observation between ionizing radiation and morphological defects in Japanese fir trees, more investigations are necessary. We have started chronic irradiation experiments in gamma irradiation facilities, because there were no experimental data on long-term effects of irradiation on Japanese fir trees. We are also making attempt to develop a detailed model to estimate the dose rate in the growing points (apical meristem) of leader shoots in Japanese fir trees. The dose rate-response relationship obtained in the irradiation experiments and the dose rates estimated by the model calculation should enable assessment of radiation effects on the fir trees in the highly contaminated areas in Fukushima.

Summary of key points from presentations
Impacts of the Fukushima Daiichi NPP accident on the Non-Human Biota: Challenges to the Environmental Protection System

K. Sakai[a,b]

[a] *Tokyo Healthcare University; e-mail:k-sakai@thcu.ac.jp*
[b] *ICRP Committee 5*

Abstract–After the Fukushima Daiichi NPP accident, some "abnormalities" were reported in a number of environmental species, including both animals and plants. They drew much attention of media and the general public to claim that the radioactivity released by the accident gave biological impact on the environmental organisms. From the viewpoint of radiological protection, it should be critical to distinguish between the effects of radiation and those of other factors including the earthquake and tsunami and some biological factors. Proper comparison between "before" and "after", dose-effect relationship analysis, and comparison of field observation with results of laboratory experimental research should provide solutions to this problem. Dose estimation is another big challenge. The current dosimetry system assumed uniform distribution of radioactivity in biota and stable level of radioactivity concentration surrounding the organisms. After the accident, there was a rapid increase in environmental radioactivity. The radioactivity level reached a peak in a relatively short period of time, and then gradually decreased. In an affected area, after several months after the accident, the estimated dose-rate level exceeded the DCRL (derived consideration reference level) for some RAPs. The challenge posed by the accident should make the environmental protection system more useful and robust as partly discussed earlier in this workshop. The improved system of radiological protection of the environment, in turn, should contribute to better understanding of the situation in Fukushima.