HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 75–98

REM
Radiat Environ Med

# Presentation Abstracts of "The 6th Bilateral Workshop on Radiation Research and Its Related Issues 2023"

December 5–6, 2023
The Office of Atoms for Peace (OAP) of Thailand

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 76

REM
Radiat Environ Med

# The Project on Indoor Radon Measurement in Kazakhstan. What Do We Need to Clarify?

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**Abstract:**
Exposure to radon is the second leading factor causing lung cancer incidence. According to several epidemiological studies, relative risk of lung cancer was positively correlated with indoor radon concentration higher than 100 Bq $m^{-3}$ at statistically significant level and increase rate was 16% per 100 Bq $m^{-3}$. Statistical estimate implied that radon-attributable lung cancer deaths for 66 countries totaled 226,057 in 2012 and represent a median of 3.0% of total cancer deaths. The World Health Organizations and the International Commission on Radiological Protection recommend a reference level of indoor concentration as 100-300 Bq $m^{-3}$ for member states. Radon (Rn-222) has a radioisotope of thoron (Rn-220). Both of these radionuclides coexist in the living environment and show similar behavior each other except for different half-lives (3.8 d for radon vs. 56 s for thoron). Thus, thoron becomes an interfering factor on radon measurements using detectors without appropriate discrimination functions. In 2000s, passive-type radon-thoron discriminative detectors and thoron calibration chambers were developed, and studies using such equipment and instruments revealed that detectors conventionally used in epidemiological studies overestimated radon concentration due to contribution of exposure to thoron. This finding raises the question that the reported relationship between lung cancer incidence and exposure to radon may include the effect of exposure to thoron and the risk of radon is higher than that expected. The present authors launched the project on indoor radon measurements in northern Kazakhstan in 2023 to estimate risk of radon inhalation to lung cancer incidence. In northern Kazakhstan, uranium is actively mined and highest lung cancer incidence is reported. Preliminary survey performed by the authors revealed that 3-mo average residential radon concentrations are remarkably high, showing 130 to more than 2000 Bq $m^{-3}$. Thoron concentrations were lower than radon by one to two orders of magnitude, which indicates that dose received from exposure to thoron is negligible compared to exposure to radon. The authors plan to expand the scale of surveys to establish the quantitative relationship between exposure to radon and lung cancer incidence.

**Key words:**
Radon, lung cancer, Kazakhstan, uranium mine

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https://doi.org/10.51083/radiatenvironmed.13.2_76

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Radiation Environment and Medicine 2024 Vol.13, No.2 77

REM
Radiat Environ Med

# Dose Estimation for Industrial Radiography Worker in Accidental Radiation Exposure

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**Abstract:**
Radiography is one of the most effective tools and widely used for non-destructive testing (NDT) to inspect and evaluate structures or any damages without destroying objects. Radiography is usually using radioactive material or x-rays generator to produce radiation. So, safety operation procedures and recommendations are implemented to prevent harmful exposure to workers, public and environment. However, radiation accidents can take place. This study presents the dose estimation of 2 radiographers who were exposed radiation from Ir-192 source stuck in the guide tube during working; Worker 1 who may have received a high dose and injured the left index finger from this unintentional exposure and Worker 2 who volunteered to secure the source back to the shielding. Several working scenarios were performed contributing to the possibilities of radiation exposure. Optically stimulated luminescence dosimeter (OSLD); InLight and NanoDot models with RANDO and rod phantoms were used to estimate whole body, eye lens and finger doses. The result from the scenario shows that Worker 1 was exposed to averaged doses of 171.8, 102.3 and 1773.9 mSv for the whole body, eye lens and finger respectively which exceeds the annual dose limit. Worker 2 received a dose under the annual dose limit at dose of 3.3, 1.2 and 12.5 mSv for the whole body, eye lens and finger respectively as he recovered the radioactive source with radiation protection rules. Both workers are suggested to be regularly checked up at the hospital even one of them received a dose lower than the annual dose limit. The uncertainty of measurement is reported at 33.0% at k=2 which came from the dosimeter and readout system. This value can be much larger than expected as several factors may be different between real situations and scenarios. Monte Carlo simulation can be a good model to predict the possibility and confirm the result. This study shows the feasibility of scenario-based measurement to estimate a dose delivery in radiation accidents when a dosimeter is absent.

**Key words:**
dose estimation, OSL, radiography, radiation accident, Ir-192

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Radiation Environment and Medicine 2024 Vol.13, No.2 78

REM
Radiat Environ Med

# Biodosimetry in Radiation Emergency Medicine: Current Insights and Its Impact in Asia

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**Abstract:**
Radiation emergency medicine relies on accurate dose estimation through biodosimetry, assessing biological responses to radiation exposure. This presentation will explore the significance of biodosimetry in Asia, considering the specific needs of the region. Key criteria for an effective endpoint in dose assessment are specificity, stability, and dose-dependency, with the dicentric chromosome assay considered as the gold standard due to its fulfillment of these criteria. The presentation will also encompass cell cycle progression and cytogenetic biodosimetry, summarizing cytogenetic aberration assays best suited to various exposure scenarios, including partial or prior exposure to ionizing radiation. To improve biodosimetry strategies across Asia, efficiency, high throughput, and cost-effectiveness are needed. Challenges in biodosimetry, such as incubation time, chromosome aberration scoring throughput, and addressing large-scale nuclear disasters and terrorism, are globally acknowledged. The development of young human resources for biodosimetry is also an important issue. IREM publishes the Biodosimetry series in journals as user-friendly educational materials (Nakayama *et al*., 2022; Anderson *et al*., 2023). The Asian biodosimetry network includes the Institute of Radiation Emergency Medicine (IREM) at Hirosaki University. IREM is working to streamline assays for different radiation scenarios, including shortened blood cultures for triage scoring (Goh *et al*., 2023) and enriching metaphase cells in whole blood cultures. Additionally, IREM is conducting epidemiological studies like chromosome aberration analysis in Graves' disease patients, emphasizing the importance of local and international biodosimetry networks. While acknowledging the critical need for funding in research and development, staff training, and laboratory maintenance, it is important to note that biodosimetry budgets are often insufficient. Moreover, the evolving trends in biodosimetry will be influenced by new events and local government priorities. In closing, it is evident that Asian countries may need distinct biodosimetry strategies compared to Europe and North America, reflecting the unique challenges and requirements of the region.

**Key words:**
Cytogenetic biodosimetry, human resource development, Asian strategy

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https://doi.org/10.51083/radiatenvironmed.13.2_78

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Radiation Environment and Medicine 2024 Vol.13, No.2 79

REM
Radiat Environ Med

# Biodosimetry for High-Dose Radiation

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**Abstract:**
Addressing the response to high-dose radiation accidents is a global concern, given past incidents like the Chernobyl nuclear power plant accident, the Goiania accident in Brazil, the Tokai village JCO criticality accident in Japan, and the Shanxi Taiyuan radiation accident in China. In addition, the ongoing threat of nuclear terrorism and conflicts demands preparedness for handling individuals exposed to high radiation doses. This exposure causes significant damage to hematopoietic and gastrointestinal organs and the cranial nervous system, resulting in a variety of symptoms. Early stem cell transplantation and cytokine therapy are needed to improve the prognosis of these patients (IAEA, 2011). Accurate dose estimation through biodosimetry is necessary for their treatment decisions. While the dicentric chromosome assay is the gold standard for radiation biodosimetry, the PCC-ring assay should be used for high doses above 5 Gy (Nakayama *et al*., 2022). In regions with limited biodosimetry facilities, the chemically-induced PCC method offers an economical and straightforward solution, notably in Asian countries. In our pursuit of more efficient approaches, we've optimized this method, reducing culture time by 8 hours. Caffeine supplementation (Pujol *et al*., 2012), known to bypass cell cycle arrest, led to a 1.4-fold increase in analyzable cells for the PCC assay. Improvements in cell fixation and staining further streamlined the process. As a result, the time required for dose estimation by the chemically-induced PCC assay was reduced from 55 hours as in the JCO model case to 43 hours (11 hours total). This method can estimate the dose using the same analysis as the conventional method. There has been much discussion about how to deal with biodosimetry for such high-dose exposure accidents, and the technology is advancing every day. With the recent development of AI and other technologies related to automation, more efficient methods than those of today will be developed.

**Key words:**
Biodosimetry, High dose radiation accident, PCC-ring assay

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HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 80

REM
Radiat Environ Med

# A New Method to Improve Accuracy of Dose Estimation in Biodosimetry

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**Abstract:**
The dicentric chromosome assay (DCA) remains the "gold standard" in biological dosimetry, undergoing continuous refinement and validation since the mid-1960s. Using the DCA, it is theoretically possible to estimate an unknown dose to an individual by establishing a correlation between the number of induced dicentrics following irradiation and the dose applied to generate such damage. However, the frequency of dicentrics is influenced by factors like the type of irradiation source and dose rate (Anderson *et al*. 2023). Additionally, there are inherent scoring variations in dicentrics per radiation dose (Gy) among scorers due to the qualitative nature of metaphase selection (Ainsbury *et al*., 2009) and the challenge of detecting specific dicentric chromosomes in solid-stained slides, especially those formed by two acrocentric chromosomes. In this study, we developed an innovative staining method that combines conventional solid chromosome staining with a specialized technique targeting and marking the centromeric region, henceforth called "cTAG". The cTAG technique streamlines the identification of dicentrics in complete metaphases by emphasizing centromeres in 1.5 hours. Preliminary results showed that it significantly reduced disparities in dicentric yield measurements among experienced scorers, decreasing the coefficient of variation from 12% with conventional Giemsa staining to 1.2% with the new technique. Furthermore, the cTAG technique can be applied to de-stained Giemsa slides, facilitating image preparation for DCA training and development. In the future we will conduct inter-laboratory comparisons using the cTAG technique in DCA to see if scoring variations still occur across laboratories or if disparities are reduced.

**Key words:**
Biodosimetry, c-banding, dicentric, absorbed dose

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Radiation Environment and Medicine 2024 Vol.13, No.2 81

REM
Radiat Environ Med

# Annual Effective Dose Due to External Exposure at Hamadori District in Fukushima Prefecture

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**Abstract:**
Ever since the accident at TEPCO's Fukushima Dai-ichi Nuclear Power Plant (FDNPP) has passed for 12 years, a part of residents is still concerned about radiation exposure to radionuclides from the environment. In this study, we carried out measurement of the absorbed dose rate in air and assessment of annual effective dose at Kawauchi Village, Tomioka Town, and Okuma Town in Fukushima Prefecture, which are in Hamadori District, to clarify the external exposure dose to the public from artificial radionuclides based on natural radionuclides for use in risk communication with residents. The measurement point was selected in a 2 km × 2 km mesh, and spot measurement and a car-borne survey were conducted using a 3 in × 3 in cylindrical NaI (Tl) scintillation spectrometer. The measurement points were shared using the Global Positioning System. The ambient dose rates in the air from natural radionuclides, artificial radionuclides by spot measurement, and artificial radionuclides by car-borne survey were 0.022-0.069, 0.018-2.394, and 0.001-1.610 μSv $h^{-1}$, respectively. The areas with high dose rates contain mountainous areas and areas where decontamination has not yet implemented. The annual effective doses from natural radionuclides at Kawauchi, Tomioka, and Okuma were 0.17-0.35, 0.13-0.28, and 0.15-0.28 mSv, respectively. The annual effective doses from artificial radionuclides in the residential zones at Kawauchi, Tomioka, and Okuma were 0.04-0.29, 0.16-0.70, and 0.31-0.73 mSv, respectively. All the measurement points in the residential zone were below the reference level of 1 mSv in the existing exposure situation reported by the ICRP. This data can be used as background data and the comparison between the past and the present, natural and artificial. It is also useful for the residents and those who are considering returning. This work was supported by the Research Project on the Health Effects of Radiation organized by the Ministry of the Environment, Japan.

**Key words:**
Fukushima, external exposure, dose assessment

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Radiation Environment and Medicine 2024 Vol.13, No.2 82

REM
Radiat Environ Med

# Dose Assessments Due to Inhalation of Radon and Thoron at 70 Dwellings in the Coastal Area of Fukushima

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**Abstract:**
We are conducting a research project on dose assessment for residents in the coastal area of Fukushima Prefecture. This project estimates annual effective doses from inhalation, ingestion and external exposure. These dose estimates cover both artificial radionuclides, such as radiocesium, and natural radionuclides. The doses from both sources will be compared to enable the local population to assess the influence of the FDNPP accident on the total dose. We have selected three coastal communities: Kawauchi Village, Tomioka Town and Okuma Town. In this presentation, we would like to show the results of indoor and outdoor radon and thoron progeny concentrations, as well as atmospheric $^{137}$Cs concentrations. Indoor radon concentrations are measured in 70 dwellings (every 30 dwellings in Kawauchi Village and Tomioka Town and 10 dwellings in Okuma Town) using radon-thoron discriminative monitors (RADUET, Radosys, Hungary). In addition, passive radon and thoron progeny monitors (progeny monitor) are installed in each house along with the RADUETs. These monitors will be replaced every three months for one year in order to assess the annual effective dose, taking into account the seasonal variation of each concentration. We have selected the two locations in each municipality for outdoor radon measurements using RADUETs. Airborne dust is collected using a high-volume sampler at 500 L/min for 24 hours, and then $^{137}$Cs concentrations are measured using a HPGe detector. The annual means of indoor radon concentrations in Kawauchi Village, Tomioka Town and Okuma Village were evaluated to be 20 ± 10, 18 ± 12 and 19 ± 16 Bq/m$^3$, respectively. In addition, the annual means of EETC in each municipality were evaluated to be 1.1 ± 1.1, 0.4 ± 0.3 and 0.8 ± 0.8 Bq/m$^3$, respectively. On the other hand, the concentrations of radon and $^{137}$Cs in the atmosphere at six measurement sites were estimated to be 7 ± 4 Bq/m$^3$ and 44 ± 54 μBq/m$^3$, respectively. The annual effective doses due to inhalation of natural (radon and thoron) and artificial ($^{137}$Cs) radionuclides were estimated to be 0.81 mSv and 1.1 nSv, respectively. Thus, the contribution of annual effective doses due to airborne artificial radionuclides are quite small compared to the natural sources. We will summarise the comprehensive doses from natural and artificial components to enable better radiation risk communication to residents. This work is supported by Research Project on the Health Effects of Radiation organized by Ministry of the Environment, Japan.

**Key words:**
Fukushima, coastalarea, inhalationdose, radon, EETC, passivemonitor

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https://doi.org/10.51083/radiatenvironmed.13.2_82

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 83

REM
Radiat Environ Med

# The Effective Dose from Inhalation of Radon and Thoron in the Dwelling around the Tin Mine and Smelter Area in Bangka, Indonesia

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**Abstract:**
Inhalation of radon ($^{222}$Rn) and thoron ($^{220}$Rn) gases is considered to be the largest contributor to the radiation dose received from natural radiation due to the abundance of $^{238}$U and $^{232}$Th in the environment. Bangka Island in Indonesia is one of the largest tin mining areas in the world, with the source of the tin being the granite formation which also contains relatively high levels of naturally occurring radioactive material. Therefore, there is reasonable concern about the possibility of elevated levels of radon and thoron in the area. In this study, the daily variation of radon and thoron was investigated using an electrostatic collection-type monitor, RAD7. The seasonal variation of radon and thoron progeny was measured using a passive radon-thoron discriminative monitor called RADUET and a deposition rate-based thoron progeny monitor. The passive monitors were installed in 135 dwellings for a period of one year, including the dry and rainy seasons. The annual effective dose was then estimated from the annual indoor radon concentration and equilibrium equivalent thoron concentration (EETC). The result shows that the radon concentration peaks at 41 Bq m$^{-3}$ at midnight when the ventilation of the dwelling was closed, while the thoron concentration peaks at 172 Bq m$^{-3}$ at midday. The result also shows that on Bangka Island, radon concentrations did not indicate significant seasonal variation, possibly due to a minimal change in ventilation rate. Meanwhile, the thoron progeny was higher in the dry season, possibly due to the lower ambient aerosol concentration in the rainy season. The estimated annual effective dose from the inhalation of radon and thoron on Bangka Island ranges from 1.1 to 10.2 mSv, with an arithmetic mean and standard deviation of 4.0 ± 2.1 mSv. From the total inhalation dose, the dose from thoron was the largest contributor with an arithmetic mean of 3.1 ± 2.0 mSv. The study highlights the importance of the effective dose from thoron inhalation.

**Key words:**
Bangka, Indonesia, Tin mining, Radon, Thoron, Progeny

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https://doi.org/10.51083/radiatenvironmed.13.2_83

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 84

REM
Radiat Environ Med

# Statistical-Based Modeling Strategy for Entrance Skin Dose Estimation in Patient Undergoing Body Interventional Radiology

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**Abstract:**
Nowadays, interventional radiology (IR) plays an important role in a wide range of invasive diagnostic imaging and minimally invasive imaging-guided therapeutic procedures. However, the radiological risk associated with unwanted side effects in patients is a concern. Radiation-induced erythema, skin burns, and epilation have been reported in the literature. For safety reasons, risk assessment in IR patients is quantified with the entrance skin dose (ESD) exceeding 2 Gy is unacceptable. However, direct dose measurement for each patient is labor-intensive and impractical because the detector probe may cause perturbation on the X-ray image during a fluoroscopy-guided procedure. The purpose of this study is to develop a statistical-based model for ESD estimation in the body-IR procedures by using simple quantities derived from the DICOMRDSR data. As a result, a simplified ESD calculation model is introduced without complicated parameters generally used in conventional calculation methods, such as a backscatter factor and a mass-energy absorption coefficient. This user-friendly ESD calculation method makes it easy for patients and medical staff to calculate the dose they received by themselves after ending each IR examination. The models are classified into two groups of body-IR procedures: 1) the vascular procedure includes TACE and TAE, and 2) the non-vascular procedure includes PTBD and PCD. The study provides that the simplified regression models are sufficient to estimate the patient entrance skin dose for both groups of body-IR procedures, accounting for a 95% confidence interval.

**Key words:**
Body interventional radiology, entrance skin dose assessment, radiological hazard

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https://doi.org/10.51083/radiatenvironmed.13.2_84

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Radiation Environment and Medicine 2024 Vol.13, No.2 85

REM
Radiat Environ Med

# Morphological Characteristics of Respiratory Tract on Inhalation Dose Assessments for Japanese Populations

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**Abstract:**
The Human Respiratory Tract Model (HRTM) proposed by the ICRP is used to assess internal doses due to inhalation of radioactive aerosols[1)]. The morphological information on the respiratory tract in the HRTM was based on a few cases of Caucasians. In this study, we evaluated the morphological characteristics of the respiratory tract for Japanese using computed tomography to examine whether the HRTM could be adapted to other racial groups. Patients without disease affecting the analysis were selected and the diameter, length, and subcarinal angle to trachea axis were measured using software (Thoracic VCAR software, GE Healthcare Japan). As a result, we analyzed 100 males and 109 females. The diameter of the bronchi was slightly different from that in the HRTM because it was created from a cast replica and this study was implemented based on images taken during inspiration. Although the HRTM defines a bronchial structure as the symmetrical shape, differences in bronchial length were observed between the left and right lungs even if the bronchial generation was the same. The similar morphological characteristics have been reported in Chinese and Koreans[2, 3)]. In the ICRP publication 66, tracheal and bronchial dimensions are correlated with patient's height, but no correlation was found in the present study. From an anatomical point of view, it is difficult to conclude that the HRTM reproduces the actual respiratory airway. How the differences affect particle deposition in the respiratory tract should be examined. This work was partially supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI Grant No. JP20H00556.

**Key words:**
X-ray Computed Tomography, Human Respiratory Tract Model, Trachea, Radioactive Aerosol

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https://doi.org/10.51083/radiatenvironmed.13.2_85

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 86

REM
Radiat Environ Med

# Development of Electrically Conductive Carbon Fiber Reinforced Plastic Composite for Airplane with Lightning Strike Protection Property

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**Abstract:**
Carbon fiber reinforced plastics (CFRP) composites, having high mechanical strength and light weight, have been already utilized in not only sports goods, such as running shoes, bicycle etc. but also airplane. It is known the half of B787 is made of CFRP, instead of metals. CFRP, consisting of thermosetting epoxy resin matrix and carbon fiber reinforcement, has no electrically conductivity toward thickness direction, because the epoxy resin matrix is not electrically conductive. The lightning strike protection is one of the most critical requirement for the safe flight. The conventional airplane itself, made of all metals, has the lightning strike protection property, however, CFRP needs the electrically conductive metal mesh surface layer for the protection, which causes the additional complex manufacturing process. Therefore, the development of electorally conductive CFRP, without using the metal mesh, has been awaited using electrically conductive matrix. For the development, we have been closely collaborating with Japan Aerospace Exploration Agency (JAXA) and The Universiy of Tokyo. The present presentation provides the novel matrix material design for the electrically conductive thermosetting resins, the lightning strike protection performance using artificial lighting strike test, and the development current status.

**Key words:**
Carbon fiber reinforced plastic, lightning strike protection, airplane, electrically conductive

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https://doi.org/10.51083/radiatenvironmed.13.2_86

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 87

REM
Radiat Environ Med

# Introduction of Coupled Map Lattice and Its Application to Simulate the Complex Mechanism of Change from Fresh Cream to Butter via Whipped Cream

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**Abstract:**
Coupled map lattice (CML) is a powerful simulation approach that reproduces well complex and diverse patterns and motions in dynamical phenomena with spatial degrees of freedom (Kaneko and Tsuda, 2001). Indeed, CML has simulated various phenomena such as full range boiling (Yanagita, 1992), convection with turbulence transition (Yanagita and Kaneko, 1993), cloud formation predicting 'guerrilla rainstorms' (Yanagita and Kaneko, 1997), and astronomical formation of grand-design spirals (Nozawa, 2020, 2030). We proposed a CML for simulating phase inversion processes (Fujita, 2006) from fresh cream to butter via whipped cream. It is one of complex systems approaches to the pattern formation and self-organization of diverse food textures appearing in the phase inversion processes. The proposed CML has three field variables, surface energy, cohesive energy, and velocity of the emulsion defined on a two-dimensional square lattice, and is constructed by the three simple procedures, whipping, coalescence, and flocculation, acting on the field variables. In the simulations, we have observed two different phase inversion processes at high and low whipping temperatures (WTs). The overrun and viscosity changes in these processes are consistent with those in experiments. The two processes give rise to distinctive spatial patterns of overrun (surface energy) and viscosity (cohesive energy), and are characterized on the viscosity-overrun plane which is one of the state diagrams, as the viscosity-dominant process at high WT and the overrun-dominant process at low WT, respectively. The butters obtained in the two processes were of low overrun and viscosity and of high overrun and viscosity, respectively in the butter region, and had, so to say, *soft & creamy* and *hard & fluffy* texture patterns. In the presentation, we will design a new texture (*fluffy & creamy with moderate firmness*) by controlling the cooking parameters of the CML procedures based on the above texture difference.

**Key words:**
coupled map lattice, dairy products, phase inversion, overrun, viscosity, food texture

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HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 88

REM
Radiat Environ Med

# Preparation of Barium Sulfate Polymer Composites Using Tapioca-Starch and Its X-Ray Shielding Properties

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**Abstract:**
Lead (Pb) have often been used as radiation shielding materials in various fields, including the aerospace and medical fields together with nuclear power plants. However, lead has several disadvantages. As the replacement, the composites, consisting of barium or bismuth having high atomic number and rubber or resin as the matrix, have been reported. In this research, we prepared the composites using barium sulfate and biodegradable polymer, consisting of glycerol and tapioca starch. The mechanical properties, such as softness and strength, controlled by optimizing the three-component materials, which will be presented together with X-ray shielding properties. In our previous study[1)], the effect of the inorganic filler surface modification on the mechanical property was shown. Here, we proposed a biodegradable additive, Tannic Acid (TA), as a new approach for the surface modification and its effect will be presented. Barium sulfate ($BaSO_4$), having the particle diameter of 10μm, was used. Glycerol is a liquid component to make thermal processability for Tapioca-starch. In addition, Tannic acid (TA) was used for surface modification between matrix and $BaSO_4$. Samples was produced using bath-type melt mixing at 120℃and 30rpm for 10min. The mechanical properties of the biodegradable composites, consisting of glycerol and tapioca-starch, suggested that the composites are very soft due to low tensile strength, modulus and high strain. By the addition of $BaSO_4$ 30vol%, the mechanical property of the composites was dramatically improved. On the other hand, TA coated $BaSO_4$ made the elongation at break larger, which can be interpreted by the effect of hydrogen bond between the matrix and surface. The present finding demonstrated that this proposed approach using TA as the surface modification will be one of the most effective and attractive approaches to enhance the flexibility of radiation shielding composite materials including large amount of inorganic filler particles.

**Key words:**
X-ray shielding, Composites, Biodegradable, Barium sulfate

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HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 89

REM
Radiat Environ Med

# An Appropriate Concrete Mixtures to Improve for Nuclear and Radiation Facilities in Thailand

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**Abstract:**
The main aim of this paper is looking for suitable local minerals to conduct high density concrete by analysis context factors. Radiation shielding by high density concrete are used in nuclear and radiation facilities. Especially, in cases of new construction or improvement the previous site by changed applications such as wall or ceiling and limited areas should be considered. High density concrete or heavy weigh concrete is designed by using heavy weight aggregates such as ilmenite, barite, magnetite, limonite or hematite etc. The basic definition of high density concrete or heavy weigh concrete should have density greater than 2600 kg/m$^3$ while mix concrete for general construction about 1700 kg/m$^3$. It's well known that, more density of concrete is more ability of materials to protect high energy ray and electromagnetic wave such as gamma ray or X-ray. The comparison by linear attenuation coefficient ($\mu$) and density of materials ($\rho$) are used for verification. However, the context for each country is different situations and resources. The factors for consideration are depended on policy of facilities, radiation safety, finance and physical characteristic besides strength and bearing capacity. The analysis for several dimensions to choose operational options are needed. The result of this paper is an option to improve shielding for radiation safety purpose in Thailand.

**Key words:**
high density concrete, heavy weigh concrete, radiation shielding, radiation protection

**References:**

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https://doi.org/10.51083/radiatenvironmed.13.2_89

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 90

REM
Radiat Environ Med

# Muncipal Inspection Services for Radioactivity in Food For Self-Consumption in Fukushima and Utilizaition of State-Of-The-Art Equipment for Testing

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**Abstract:**
Since the accident at the Fukushima Daiichi NPS, food inspection for radioactivity in home-grown products and wild foods collected by residents for their own consumption has been conducted in Fukushima. To inspect these foods, 300 temporary inspection stations were set up in public halls or assembly halls in municipalities. Due to a decrease in the number of inspections required, some laboratories have been consolidated or closed, but inspections are still ongoing. The conventional gamma-ray spectrometry technique using a NaI (Tl) scintillation spectrometer was utilized for the testing. Since the scintillation detector is inferior to the Ge detector in energy resolution, a screening method was applied for the inspection. For conventional radioactivity measurement in foods, however, sample preparation procedures, such as cutting and machining techniques, are required to homogenize radioactivity. Therefore, it is difficult to use measured cut samples for self-consumption even if radioactivy are not detected. Under such situations, municipal laboratories were strongly requested by residents to return the measured samples for their own consumption. In response to such a demand, state-of-the-art device named "non-destructive radioactivity measurement device" was launched to measure radioactive cesium in whole samples contained in a plastic bag so that all products can be inspected without any sample preparation procedures (Ishii, 2015). The device was installed in municipal food inspection stations in 2015. A total of 83835 samples were tested in 2015, of which 68 % were measured with the non-destructive radioactivity measuring devices. Although the number of tests decreased year by year down to about 18000 samples in 2022, 84 % of all samples were tested with non-destructive devices. The test pass rate (<50 Bq $kg^{-1}$) for about 350000 samples since 2015 has exceeded 90%, indicating that efficient screening tests have helped the residents. In case of using such non-destructive measurement devices, it would be important to determine the approximate detection efficiency for samples of various sizes and shapes, within acceptable uncertainty, only from the information on mass and type of the sample. The performance evaluation of such devices had been conducted by Yamada *et al*. (2023). Furthermore another approach using artificial radioactive samples was adapted.to determine possible uncertainties arising from variation of sample shapes. As a preliminary result, 10 % or less standard uncertainty due to variation of sample shapes were observed.

**Key words:**
Radioactivity, Food inspection, Gamma spectrometry

**References:**

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https://doi.org/10.51083/radiatenvironmed.13.2_90

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 91

REM
Radiat Environ Med

# Neutron Shielding and Mechanical Properties of Recycled High-Density Polyethylene (r-HDPE) Composites

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**Abstract:**
Utilization of effective and improved neutron-shielding materials is one of the main radiation safety principles that aim to reduce risks from excessive neutron exposure. Despite their great benefits, exposure to high neutrons could cause acute health effects such as skin burns and chronic radiation syndromes, which can increase the risk of longer-term effects such as cancer and death. In order to reduce risks from exposure, this research aimed to develop eco-friendly neutron-shielding materials based on the addition of 0–20%wt of gadolinium oxide ($Gd_2O_3$) in recycled high-density polyethylene (r-HDPE) composites. The results indicated that the abilities to attenuate thermal neutrons were noticeably enhanced with the increase of $Gd_2O_3$ contents. Furthermore, the addition of $Gd_2O_3$ particles to the r-HDPE composites generally led to higher values of tensile modulus and surface hardness (Shore D). The results also revealed that the composites with 5-%wt. $Gd_2O_3$ exhibited higher tensile strength, elongation at break, and crystallinity than those from other filler contents. In addition, the results on the effects of 70-kGy gamma irradiation on the properties of the r-HDPE composites suggested that gamma aging decreased neutron shielding properties but did not noticeably change mechanical properties of the composites. By comparing the shielding performances from this work with those from commercial 5%-borated PE composites, the developed r-HDPE composites exhibited higher overall radiation shielding and mechanical properties, implying the potential of utilizing r-HDPE composites as eco-friendly materials that surpassed stringent requirements in radiation safety.

**Key words:**
r-HDPE, $Gd_2O_3$, Neutron shielding, Mechanical properties

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HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 92

REM
Radiat Environ Med

# Research Activity of The Department of Radiochemistry and Radioecology, and Study on Internal Exposure Dose Assessment by Beverages

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**Abstract:**
The Department of Radiochemistry and Radioecology is part of the Institute of Radiation Emergency Medicine at Hirosaki University which carries out chemical approaches to evaluate radiation exposure and the course on radiochemical technique training. The current research themes are as follows; the study of internal radiation dose through bioassay, tritium in environmental and biological samples, radioecology in the Fukushima area, and isotope geochemistry. Our department focuses on tritium monitoring since it is also released into the environment by nuclear facilities. Tritium released into the atmosphere on an annual basis from nuclear power plants around the world was estimated to be equivalent to approximately 15-20% of the yearly rate at which cosmic rays produce tritium. Recently the issue of tritium has also raised public concern since the Japanese government decided to discharge the ALPS-treated water into the ocean. Therefore, continuing tritium monitoring also holds significant value for the public. Additionally, the study on radionuclides content and their annual effective dose in beverages is also one of the related topics. Radionuclides emitted into the environment can end up in the atmosphere, surface water, or groundwater. Ingestion is the primary mechanism responsible for the internal exposure of the human body to ionizing radiation. It is crucial to examine how radionuclides migrate and accumulate throughout the food chain. Humans and beverages are intimately associated since humans consume beverages to quench their thirst, stay hydrated, and enjoy a variety of flavors and nutritional benefits. Given that they make up a large portion of the diet and can have varied effects on health, beverages are considered an important issue. Additionally, some literature highlights the need for precise data in food monitoring at the initial levels in order to improve effect estimates of radionuclide contamination. Thus, the goal of this study is to evaluate radionuclides in beverages in order to create a preliminary database for more accurate evaluation in the future (Pintilie-Nicolov *et al*., 2021).

**Key words:**
radionuclides, tritium monitoring, internal dose, beverages

**Reference:**
Pintilie-Nicolov V, Georgesou PL, Iticescu C, Moraru DI, Pintilie AG. The assessment of the annual effective dose due to ingestion of radionuclides from drinking water consumption: calculation methods. J Radioanal Nucl Chem, 327(1). https://doi.org/10.1007/s10967-020-07438-5

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HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 93

REM
Radiat Environ Med

# Evaluation of Radioactive I-131 in Wastewater from Nuclear Medicine

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**Abstract:**
Iodine-131 is a radioactive substance widely used in nuclear medicine, particularly in the treatment of hyperthyroidism and thyroid cancer. To treat patients with hyperthyroidism, a low activity dosage of approximately 100 - 1000 MBq (2.7 - 27 mCi) is administered. For the treatment of thyroid cancer, a high activity dosage of 3.7 – 11.1 GBq (100 - 300 mCi) is required, necessitating the patient's hospitalization to isolate them from others. It takes approximately 2 - 3 days in order to decrease the radiation dose rate to a safe level (50 micro sievert per hour at 1 meter), before the patient returns home. The wastewater generated by patients during treatment is contaminated with radioactive waste (Iodine-131). Therefore, a specialized decay tank is necessary to store I-131 until its activity level is within the legal limit before discharge to the public. This level must not exceed 1x10^9 becquerels per year, as required by Ministerial regulations on the release of radioactive waste (B.E 2018).

**Key words:**
wastewater, nuclear medicine, decay tank

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https://doi.org/10.51083/radiatenvironmed.13.2_93

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 94

REM
Radiat Environ Med

# Water Quality Analysis for Comprehensive Evaluation of Combined Exposure from Heavy Metals and Radionuclides

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**Abstract:**
Ever since the accident at TEPCO's Fukushima Dai-ichi Nuclear Power Plant (FDNPP) has passed for 12 years, a part of residents is still concerned about radiation exposure to radionuclides from the environment. Our study employed a method that compares the effects of anthropogenic and natural radionuclides, evaluating the dose exposures to ambient radiation, inhalation of atmospheric aerosols, and ingestion of drinking water on three municipalities in the Hamadori region of Fukushima Prefecture, near the FDNPP. This presentation focuses on the analysis of water samples used as drinking water. Particularly in Kawauchi, well water is the primary source for drinking, distinguishing it from the other areas. All water sources for drinking undergo regular analysis for water quality and radionuclide concentrations by the local government, being lower the guidance level of drinking water in Japan. Drinking water samples were collected from tap water or well water used in residents' homes at Kawauchi, Tomioka and Okuma from March 2022 to March 2023. In addition to $^{222}$Rn and $^{137}$Cs concentrations analysis, concentrations of major ions and trace elements including Cd, As, Cr, Pb, Cs (stable) and $^{238}$U were determined by ion-chromagraphy and ICP-MS. $^{222}$Rn concentrations obtained at Kawauchi, Tomioka, and Okuma ranged from 17–399 Bq L$^{-1}$, <55 Bq L$^{-1}$, and <12 Bq L$^{-1}$, respectively. Notably, the $^{222}$Rn concentrations in six out of ten houses at Kawauchi exceeded 100 Bq L$^{-1}$ as a reference level reported by the EU. Abukuma granite belt, characterized by elevated $^{238}$U concentrations, is widely distributed as bedrock in Fukushima Prefecture including Kawauchi. High concentration of $^{238}$U were observed in water samples collected from Kawauchi and Okuma, with maximum of 0.039 Bq L$^{-1}$. This observation suggests that ground water played a significant role in interacting with granite bedrock and transporting $^{238}$U. This work was supported by the Research Project on the Health Effects of Radiation organized by the Ministry of the Environment, Japan.

**Key words:**
Fukushima, water quality, radionuclide, heavy metal

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HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 95

REM
Radiat Environ Med

# Comparison of Gamma-Ray Dose Rate Map Using Car-Borne Survey and Man-Borne Survey

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**Abstract:**
Hirosaki University mainly uses the car-borne and man-borne methods to measure gamma rays with the Global Positioning System (GPS). The car-borne method is capable of measuring large areas in a short time, while the man-borne method is capable of investigating details of places inaccessible by car. However, the values associated with these methods have not been compared. Recently, a man-borne survey was conducted in Hirosaki City in September 2022; this survey produced a gamma dose rate map by Worawat *et al*., 2023. However, this study aims to compare the dose rate profile using both methods of a car-borne survey and a man-borne survey with the previous results. The car-borne survey method was employed in Hirosaki City, Japan, using a 3 × 3 NaI(Tl) scintillation spectrometer with a GPS receiver, which were used to count the number of gamma-rays with latitude and longitude. The meter was installed in the car during the measurement process. In addition, the shielding factor of the car-body was determined by the count rate ratio of the car interior and exterior. Subsequently, the absorbed dose rate in air was also calculated using the response matrix method from the gamma-ray pulse height distribution obtained during the fixed-point measurement; this method established a relationship between the absorbed dose rate in air and the total counts of the gamma-ray pulse height distribution. Finaly, the absorbed dose rate in air was evaluated from the ongoing count rate; a dose rate map was then created. The average absorbed dose rate in air was estimated to be 23 ± 10 nGy $h^{-1}$ (19-29 nGy $h^{-1}$) in Hirosaki City by the car-borne survey method. Conversely, the average absorbed dose rate in air was estimated to be 32 ± 15 nGy $h^{-1}$ (7-146 nGy $h^{-1}$) by the man-borne survey method reported by Worawat *et al*. (2023). Thus, the car-borne survey results in this study had a lower value and a smaller range of the average absorbed dose rate in air than the man-borne survey. Thus, it could be seen that the locations that showed a relatively high degree of human-borne behavior were locations near sidewalks covered in stone materials. In the case of car-borne survey, the car was traveled on the road covered with asphalt, and it may far from the sources, so it had shown a lower value than the man-borne survey. Nevertheless, there was a good agreement between both methods when they were conducted on asphalt areas.

**Key words:**
Car-borne survey, Man-borne survey, Absorbed dose rate in air

**Reference:**
Poltabtim W, Musokawan S, Thumwong A, Omori Y, Kranrod C, Hosoda M, *et al*. Estimation of Ambient Dose Equivalent Rate Distribution Map Using Walking Survey Technique in Hirosaki City, Aomori, Japan. Int J Environ Res Public Health. 2023;20(3):2657.

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https://doi.org/10.51083/radiatenvironmed.13.2_95

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 96

REM
Radiat Environ Med

# Development of Machine Learning Based Computer Software for Alpha Track counting on CR-39 Using YOLOv8 Instance Segmentation Model

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**Abstract:**
$^{222}$Rn, or radon, is a radioactive element with an atomic number of 86 and exists in the form of a scentless gas that can be found in nature's surroundings or underground material. The effects of radon and its progeny on humans and the environment are highly concerning, which makes radon analysis and detection important. In radon concentration measurement, it's difficult to count an enormous amount of track using bare eyes, which is why the most frequently used method to count alpha track on a passive detector is ImageJ. But there is a huge flaw in this method that causes an error in tracking measurements. This study aims to create ML-based software capable of effectively separating tracks from contamination stains. The results show that ML-based software is capable of counting alpha tracks more efficiently and precisely, but there are some limitations in image resolution and the low number of data points used, causing some errors that should be improved.

**Key words:**
Alpha track, CR-39, Image Segmentation, $^{222}$Rn, Radon, Ultralytics YOLOv8

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https://doi.org/10.51083/radiatenvironmed.13.2_96

HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2024 Vol.13, No.2 97

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Radiat Environ Med

# Investigation for Adaptation of Tritium Analysis in Fish Samples Using a New Combustion System

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**Abstract:**
The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident resulted in a large amount of contamination, and decommissioning was required to remove the damaged reactors and decontaminate the surrounding areas has been underway. The contaminated water in FDNPP is treated by the Advanced Liquid Processing System (ALPS), but tritium in the water cannot be removed by the system. The Japanese government then decided to release that water into the ocean, which was carried out by Tokyo Electric Power Company in August 2023. Therefore, it is crucial to understand the environmental impact of tritium and its behavior, as there are concerns about internal exposure to tritium and harmful rumors. To study the effects of tritium on the environment, it is important to determine the concentration of tritium in environmental samples. However, organically bound tritium (OBT) which is bound to the carbon skeleton of organic materials analysis requires several pre-treatments and time. In particular, the combustion process is difficult due to sudden ignition depending on the samples. The recovery of combustion water therefore requires skilled techniques. For this reason, data on OBT in environmental samples is limited. In this study, a semi-automatic combustion system was developed to enable the combustion of water easily, safely, and with reproducibility in the combustion process. Combustion tests were carried out on four different fish samples. To achieve combustion without ignition, combustion conditions were investigated by adjusting the temperature increase program and gas flow rate. In addition, the validity of this method was then verified by evaluating the volume of combustion water recovered. Furthermore, to verify the validity of this method, an analysis was performed on a standard fish sample, and a comparative test was performed with other analytical methods. The results of this test confirmed that the four types of fish were able to complete the combustion operation without sudden ignition. Combustion water recovery rates exceeded 80%. However, sudden ignition was often observed in black rockfish and trout. Therefore, it was possible to prevent sudden ignition by adjusting the sample volume and gas flow rate. Comparative tests of fish standard samples showed similar values of 2.01 ± 0.54 Bq/L for this method and 2.11 ± 0.17, 1.72 ± 0.09 Bq/L for the mass spectrometer method. Therefore, it was confirmed that this combustion device is effective for the analysis of OBT. The method is expected to make obtaining OBT data easier and safer, as well as contribute to a better understanding of tritium environmental impact and behavior.

**Key words:**
Organically bound tritium analysis, semi-automatically combustion system, tritium analysis

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https://doi.org/10.51083/radiatenvironmed.13.2_97

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Radiation Environment and Medicine 2024 Vol.13, No.2 98

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# Radiological Emergency Due to Cs-137 in Prachinburi, Thailand: Challenge for Thailand in Radiological Emergency Preparedness and Response

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**Abstract:**
In March 2023, there were two radiological incidents in Prachinburi province, Thailand which were interested to public as well as both national and international medias. The first emergency was a missing radioactive source of caesium-137 (Cs-137) contained in a metal cylindrical shielding from a radiation facility, and the second was the detection of metal ash contaminated caesium-137 at a metal foundry. It has not been confirmed whether those two emergency situations are linked to each other. The situations caused people confusing and concern about radiation health effects and the release of caesium-137 into the environment, which need to be considered in radiation measurements both people and the environment around the affected areas. Local and international medias were also interested to those radiological emergencies from which relevant organizations responded on press conference, media interview, public communications during the situations. There are challenges on emergency preparedness and response that need to be considered as lesson learns from the emergencies in Prachinburi for improving Thailand's systems and capabilities in preparedness and response in the case of radiological emergencies efficiently. This study presents scientific information on the radiological emergencies in Prachinburi and responding details of relevant organizations as the lesson learns and challenges for further improvement of radiological emergency preparedness and response in Thailand.

**Key words:**
Radiological emergency, Cs-137, Radioactive source

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https://doi.org/10.51083/radiatenvironmed.13.2_98