The Fifth International Symposium on Radiation Education

第５回放射線教育に関する国際シンポジウム

Abstracts

要旨集

December 16-19, 2016
Koriyama Chamber of Commerce and Industry
Koriyama, Fukushima, Japan

Organized by
Organizing Committee of ISRE2016
NPO Radiation Education Forum

ISRE2016

ABSTRACTS
要 旨 集

The Fifth International Symposium on Radiation Education

December 16-19, 2016
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Koriyama, Fukushima, Japan

Organized by
NPO Radiation Education Forum

後援
福島県、福島県教育委員会
郡山市、郡山市教育委員会
郡山商工会議所、郡山コンベンションビューロー
福島民報社、福島民友新聞社

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Symposium Schedule

	Morning	Afternoon	
Friday, December 16, 2016	11:00- Registration	14:00-14:10 Opening Address 14:10-17:00 Keynote Lectures	17.00-17:10 Group Photo 17:10-18:10 Welcome Reception
Saturday, December 17, 2016	8:30-11:50 Plenary Session	13:00-15:50 Plenary Session	16:00-17:30 Poster Session
Sunday, December 18, 2016	9:00-12:40 Tour : Fukushima Environmental Creative Center	13:00-16:40 Public Session 13:00-14:20 Keynote Lecture 14:30-16:40 Plenary Session	17:00-19:00 Symposium Dinner 19:00-19:10 Closing Address
Monday, December 19, 2016	9:00-18:00 Excursion: Fukushima Daini Nuclear Power Plant		

Venue: Koriyama Chamber of Commerce and Industry (KCCI)

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K. Hasegawa	Chairperson
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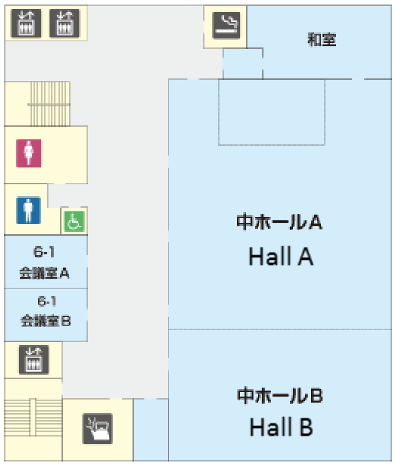
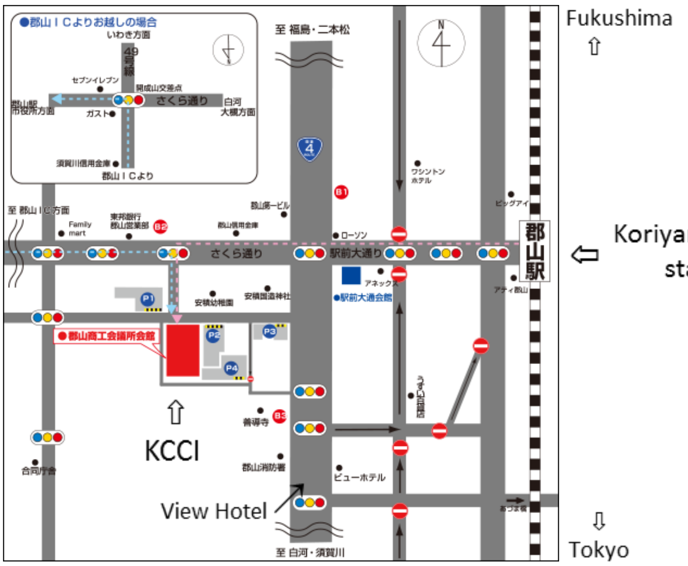
Koriyama Chamber of
Commerce and Industry (KCCI)

Hall A, 6th Floor





Map to KCCI

Symposium Program

Venue: Hall A, 6F
Koriyama Chamber of Commerce and Industry (KCCI)

Friday, December 16

14:00-14:10 Opening Address **K. Hasegawa**

Keynote Lectures

14:10-15:10 (S-1) **A. Arima** Chair: **K. Hasegawa**
Necessity of Education on Radiation and Radioactivity in Japan

15:10-15:20 Tea break

15:20-16:20 (S-2) **T. M. Nakanishi** Chair: **T. Nozaki**
Agricultural Effects by Fukushima Daiichi Nuclear Accident —The Findings by the Graduate School of Agricultural and Life Sciences, The University of Tokyo—

16:20-17:00 (S-3) **Keh-Shih Chuang** Chair: **C. Mori**
The Nuclear Energy Education in Taiwan

17:00-17:10 Group photo

17:10-18:10 Welcome reception

Saturday, December 17

Plenary Session

8:30-10:10 Radiation Therapy Chairs: **Nopporn Poolyarat**, **Y. Yoshizawa**

8:30- 8:50 (O-1) **Chun-Yi Wu**
Applications of Boron-containing Gold Nanoparticles to Boron Neutron Capture Therapy (BNCT)

8:50- 9:10 (O-2) **Feng-Huei Lin**
Preparation and Evaluation of Gadolinium Hexanedione Nanoparticles as MRI Imaging Enhancer for Stem Cell Tracker

9:10- 9:30 (O-3) **Yuan-Jen Chang**
Development of Polymer Gel Dosimetry and Optical-CT for Radiation Therapy in Taiwan

9:30- 9:50 (O-4) **Hsin-Hon Lin**
Patient-specific Time Activity Curve Estimation Using External Thermoluminescent Dosimeters (TLDs)

9:50-10:30 Natural Radioactivity Chairs: **Feng-Huei Lin**, **S. Shibata**

9:50-10:10 (O-5) **M. Shimo**
Risk of Natural Radiation of Japanese

10:10-10:30 (O-6) **K. Horiuchi**
Effects of Radioactive Spring

10:30-10:50 Tea break

10:50-11:50 Nowadays of Thailand Chairs: **Keh-Shih Chuang**, **K. Kondo**

10:50-11:20 (O-7) **Thanakit Lerdlu**
Nuclear Technology Education at the Secondary Level in Thailand
11:20-11:50 (O-8) **Nopporn Poolyarat**
Nuclear Radiation Education in Thai Universities

11:50-13:00 Lunch

13:00-13:30 Report from Taiwan Chair: **K. Hasegawa**
13:00-13:30 (O-9) **Chin-Wang Huang**
Radiation Education and Nuclear Power Plant in Taiwan

13:30-14:10 Radiation Education for pupils and general citizen
Chairs: **Chin-Wang Huang**, **M. Shimo**
13:30-13:50 (O-10) **H. Kudo**
An Example of Lectures on the Nature of Radiation for General Public
13:50-14:10 (O-11) **K. Ohno**
How Can Clinical Radiologists Mitigate the Public's Fear of Ionizing Radiation and Radioactive Materials?

14:10-14:30 Tea break

14:30-15:50 Radiation Education: Practice Chairs: **Chun-Hsu Yao**, **Y. Ogata**
14:30-14:50 (O-12) **C. Mori**
Radiation Education Experiments and Other Science Education Experiments with a Hand-made GM Counter
14:50-15:10 (O-13) **M. Akiyoshi**
Development of Radiation Educational Program Using the Peltier Cooling Type Highly Performance Cloud Chamber
15:10-15:50 (O-14) **T. Nozaki**
Use of ^{68}Ge/^{68}Ga Generator as Experimental Tool in Wide Fields of Education

Poster Session
16:00-17:30 Chair: **S. Shibata**
(P-1) **Chih-Chieh Chiang**
Detection of Spatial Distribution of Dual Photon Emitters Using TOF Coincidence Imaging Technique with Stochastic Origin Ensemble Approach
(P-2) **Chun-Hsu Yao**
A Study on Clinic Brachytherapy Using 3D Polymer Gel Dosimeter
(P-3) **M. Aratani**
Post-3.11 Literacy Promotion Activities for Urban Citizenry and High School Students, by Literature and Practice Covering Science and Disaster
(P-4) **C. Mori**
Mystery of Alpha Particle Track in Cloud Chamber!
(P-5) **C. Mori**
The Image of Alpha Emitter Distribution on the Surface of Environmental Material with CR-39
(P-6) **T. Kawano**
Radiation Sources Fabricated from the Zuiki Taro Plant and Educational Uses

(P-7) **T. Kawano**
Experiential Learning to Understand the Necessity of Radiation Device Calibrations at NSG Koriyama Calibration Center

(P-8) **N. Sakashita**
Analysis of the Consciousness of University Students in Okinawa about the Radiation

(P-9) **Y. Nakahodo**
Development of Teaching Materials for Radiation Education Using CR-39 Solid State Nuclear Track Detectors

(P-10) **S. Ohno**
The Road to a World of Elementary Particles, Quantum Mechanics, and Relativity Theory from the Radiation Education

(P-11) **Y. Ogata**
X-ray Imaging with Imaging Plate by Geissler Tube

(P-12) **S. Ohmori**
Instrumental neutron activation analysis of the hair - A study of the biological monitor in persons exposed by toxic metals -

(P-13) **A. Kishimoto**
Effects of the Thoron Spa or Bath on the Anaplastic Carcinoma of Thyroid

(P-14) **K. Ohnishi**
HATO Project / Practice of Radiation Education through Partnership of Teacher Education Universities

Sunday, December 18

9:00-12:40 Tour to Fukushima Environmental Creative Center
Lunch (on the Bus)

Public Session

13:00-13:05 Opening Address **K. Hasegawa**

Keynote Lecture Chair: **A. Ohtsuru**

13:05-14:20 (PS-1) **S. Yamashita**
How to Explain Radiation Health Risk to the General Public
— Lessons learned from Chernobyl and Fukushima Nuclear Power Plant Accidents —

14:20-14:30 Tea break

Plenary Session Chair: **R. Tanaka**

14:30-14:55 (PS-2) **H. Abe**
Radiation Education Initiatives in Fukushima Prefecture

14:55-15:20 (PS-3) **K. Sasaki**
Education for Radiation Awareness which Values a Relationship among Schools or People

15:20-15:45 (PS-4) **H. Hara**
Radiation Education in Fukushima High School

15:45-15:55 Tea break

Chair: **H. Kudo**

15:55-16:20 (PS-5) **R. Tanaka**

Recent Support Activities of Teaching Practice in Radiation Education Forum

16:20-16:40 (PS-6) **K. Kudo**

Support Activities of Nuclear and Radiation Education in Atomic Energy Society of Japan (AESJ)

17:00-19:00 Symposium dinner

19:00-19:10 ISRE2016 Closing Address **K. Hasegawa**

<u>Monday, December 19</u>

9:00-18:00 Excursion: Fukushima Daini Nuclear Power Plant

S-1

Necessity of Education on Radiation and Radioactivity in Japan

日本における放射線教育の必要性

Akito Arima

有馬朗人

President, Japan Radioisotope Association

日本アイソトープ協会会長

2011 年 3 月 11 日、東日本大震災・大津波によって東京電力福島第一原子力発電所の事故が発生した。津波によって外部電源も、非常用発電機も破壊され、原子炉の冷却が不可能になり、水素爆発が起きた。その結果福島第一原子力発電所より放射能物質が放出され、周辺の地帯が放射能に汚染され、多くの住民が疎開せざるを得なくなった。

この事故によって福島県を始め日本全般に放射能・放射線への恐怖心が高まった。また福島県の農産物や海産物への不買運動が発生した。その恐怖心の中には正しいものも勿論あるが、必要以上に恐れるという面もある。そのような事態の発生した原因の一つに、日本において放射能・放射線教育が充分に行われていなかったことがある。

ここで日本の過去の放射能・放射線教育の問題を検討し、その現状を分析し、望ましい姿についての私の見解を以下の３項目に分けて述べたい。

１、日本の小中高生の理科力と成人の科学知識

２、日本の初中教育における放射能・放射線教育

３、放射能・放射線教育で教えて欲しいこと

Ｓ－２

Agricultural Effects by Fukushima Daiichi Nuclear Accident —The Findings by the Graduate School of Agricultural and Life Sciences, The University of Tokyo—

福島原発事故による放射能汚染について農業面で判ってきたこと

－東大農学部の放射能汚染調査を中心に－

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Five years have passed since the accident of Fukushima nuclear accident. Immediately after the nuclear accident, 40 to 50 academic staffs of Agricultural Dept. of The University of Tokyo had started to study the movement of radioactive materials emitted from the nuclear reactor, since most of the contaminated area in Fukushima is related to agriculture. They are still continuing their research to find out the effects of the accident in the agricultural fields. Our Graduate School holds many research fields and there are many facilities attached to the School, such as meadows, experimental forests, farming fields, etc. Together with these facilities a lot of on site researches have been conducted in Fukushima. One of the most important findings was that the fallout was found at the surface of anything exposed to the air at the time of the accident. The main radioactive nuclides now are ^{137}Cs and ^{134}Cs. But the radioactive nuclides were hardly moved from the original point they touched. It is very difficult to understand form our estimation of chemical behavior of cesium. Since the carrier free Cs amount was so small, there was an obvious difference between the behavior of the fallout and that of the macroscopic Cs. During these 5 years, though the results of our work have been published in many reports and in three books already, this review summarized the information important from the point of analytical chemistry, together with the other interesting results we obtained.

福島原発事故から 5 年が経過し、農業においては農地にカリウム施肥を施すことにより、農作物へのセシウムの移行が格段に抑えられるようになった。まず、コメについてであるが、福島県で毎年生産される 1000 万袋以上にのぼるコメについて全袋調査を実施し、100 Bq/kg という基準値を超えた袋の数は、2012 年に 71 袋、2013 年に 28 袋だったのが 2014 年には 2 袋となり、2015 年以降には基準値を超えるコメの生産は 0 となった。他の農作物についても、出荷される全ての品種について放射能のモニタリング調査が行われており、市場には基準値を超えた農作物は出回っていない状況となっている。放射能汚染については航空機などによる上空からの調査測定が定期的に行われてきているものの、汚染地域の 8 割が森林も含め農業関連地であることから、まだ地上に降り注いだフォールアウトの動態についてはあまり解明されていないことが多い。

東京大学大学院農学生命科学研究科では、事故直後から、東京の弥生キャンパス内の研究室と、圃場・牧場・演習林などの附属施設に所属する教員 40-50 人ほどが協力してグループを作り、これまで馴染が薄かった異分野の研究者が共同で復興支援のための研究を開始した。フォールアウト動態の対象は環境そのものであり、ひとつの専門からだけでは議論できないことが多い。例えば農地についてでは、土壌、作物育種、水利など複数の専門家が集まって初めてフォールアウト動態の全体像が少しずつ判ってくるのである。研究科で取り組んでいる研究プロジェクトは、土壌・水・植物・魚類・野生生物・家畜など多岐に渡っており、福島県農業総合センターとの農作物についての共同研究を始めとして、地域の NPO などの組織や個別の農家の方たちとも一緒になった研究も進めている。そこで事故直後から今まで判ってきたことについて紹介したい。

S－3

The Nuclear Energy Education in Taiwan

Keh-Shih Chuang
Department of Biomedical Engineering and Environmental Sciences
National Tsing-Hua University, Taiwan

Tsing-Hua Open-pool Reactor (THOR), the first nuclear reactor built in Taiwan, reached its state of criticality in 1961. THOR is a reactor dedicated for research and education in Nuclear Energy. Since 1961, both the College of Nuclear Science (CNS), National Tsing-Hua University (NTHU) and Atomic Energy Council (AEC) assumed the responsibility in the Nuclear Energy Education in Taiwan. While CNS offers formal education and degree to the students in nuclear technology and science, AEC provides the general public information on atomic energy, nuclear power and radiation safety. Today, there are three commercial nuclear power plants commissioned: Chin-Shan Nuclear Power Plant (1978, 636 MWe), Kuo-Sheng Nuclear Power Plant (1981, 985 MWe), and Ma-An-Shan Nuclear Power Plant (1984, 951 MWe). The fourth nuclear power plant, Long-Men, was licensed to build in 1999 but was deferral in 2015. During these years, the public opinion on nuclear energy in Taiwan is similar to the riding of roller coaster. The society favored nuclear energy during the global energy crisis but turned to downside due to the nuclear accident and the problem in handling the nuclear waste. The Fukushima disaster in 2011 caused a significant impact on the nuclear energy policy in Taiwan. The new government proposes a nuclear-free homeland at 2025, i.e. to phase out all the nuclear power plants. The college of Nuclear Science also adjusts its structure to meet the rise and fall of the society favorite on nuclear energy. The original mission of AEC was to foster peaceful applications of atomic energy, and to coordinate international cooperation on nuclear energy. However, due to the non-nuclear policy AEC's goal also changed. In this talk, we will address the evolution of both the Atomic Energy Council and College of Nuclear Science, National Tsing-Hua University, Taiwan.

O－1

Applications of Boron-Containing Gold Nanoparticles to Boron Neutron Capture Therapy (BNCT)

Wen-Yi Chang[1], Jia-Jia Lin[2], Jou-An Chen[2], Bin-Xu Tsai[2], Chun-Yi Wu[2]*

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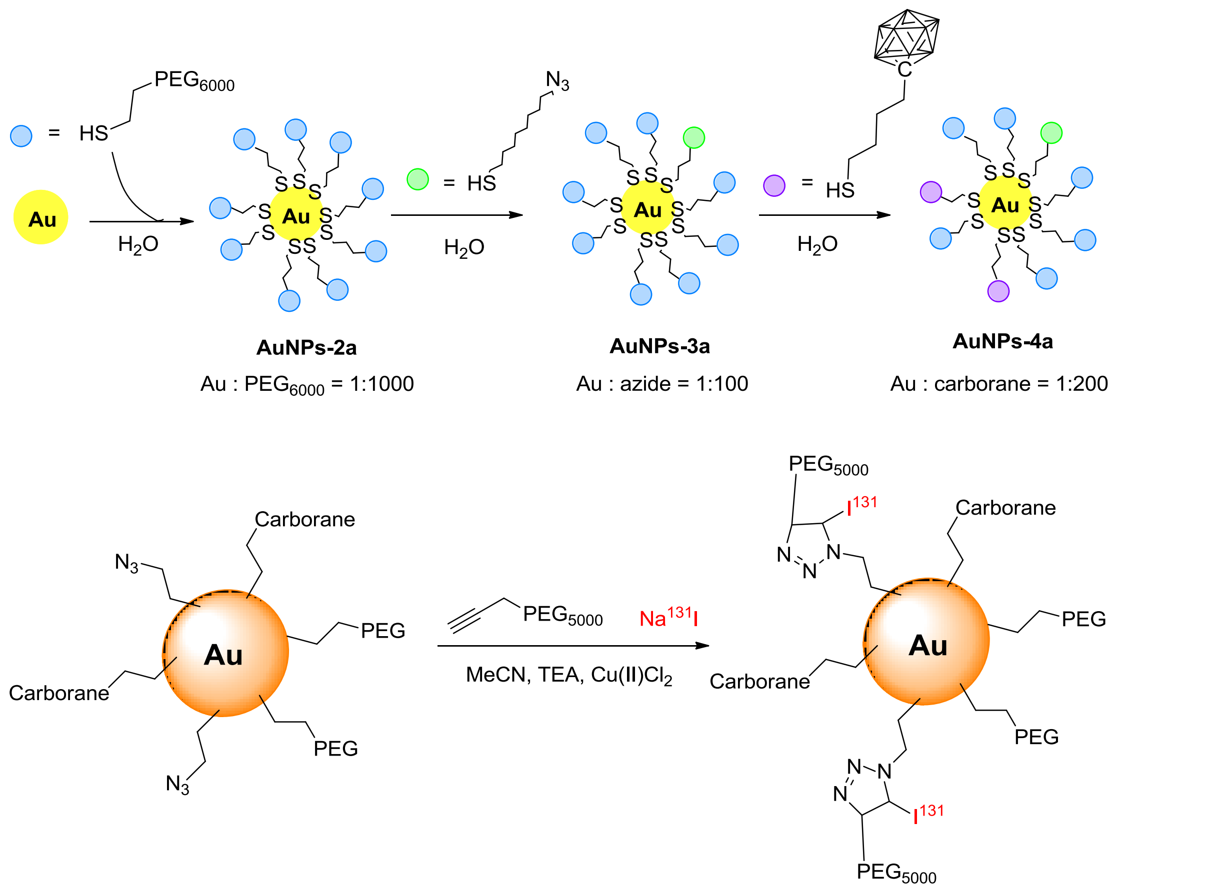
Boron neutron capture therapy (BNCT) is a binary treatment system. Nor neutron beam alone neither boron drug is able to cause tissue damage. However, when a boron atom specifically retains in tumor, it can captures a neutron and then undergoes fission reactions to produce Li-7 and high-energy alpha particles to destroy tumor rather than normal tissues. This study aims to develop a “theranostic” gold nanoparticle-carborane assemblies, which are labeled with radioiodine (^{125}I and ^{131}I) through “click” chemistry so that their distribution can be noninvasively monitored by using SPECT/CT imaging modalities. Gold nanoparticles with different sizes (20, 60 and 100 nm) have been functionalized with poly ethyl glycol (PEG), azidonudecanethiol, and boron cage. After surface modifications, radioiodine was introduced to gold nanoparticles using copper-based catalysts and free radioiodine was separated by centrifugation. The radiochemical yield of gold nanoparticles was around 90% with high radiochemical purity (>95%) for each sizes. The biodistribution studies and microSPECT/CT imaging of radiolabeled boron-containing gold nanoparticles have been performed in a SASV03 human tongue squamous carcinoma-bearing mouse model.



O－2

Preparation and Evaluation of Gadolinium Hexanedione Nanoparticles as MRI Imaging Enhancer for Stem Cell Tracker

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Stems cells are multipotent cells which are capable of self-renewing and differentiating into multipotent cell lineages. The therapeutic application of stem cells in many diseases has been widely studied in the past few years. However, the actual function and movement of stem cells after injection into human body remains unknown. In order to determine the function and movement of therapeutic stem cells, it is crucial to develop a technique to trace these therapeutic stem cells.

MRI is the most utilized modality for tracking stem cells in vivo because of its safety and 3-dimensional capabilities. Gadolinium is one of the most effective MRI contrast agent in clinical. The purpose of this study is to synthesize Gd nanoparticles, which can permeate cell membrane for labeling the cells as a cell tracker.

Gadolinium hexanedione (GdH), which was synthesized by complexion of Gd3+ with 3,4-hexanedione, was used as the nanoparticle matrix. By the combination of GdH matrix and emulsifying wax, GdH nanoparticles (GdH-NPs) were obtained from oil-in-water microemulsion technique. The stem cells were labeled by culture with hydrophobic GdH-NPs and detected by MRI.

From the result of this study, the size of synthesized particles was about 100 nm. GdH-NPs were biocompatible when the concentration was under 300μg/ml. Moreover, GdH-NPs had greater ability of image enhancement than the commercialized Gd-DTPA. The TEM image of labeled stem cells showed that GdH-NPs was accumulated in the cells by endocytic pathway. The accumulation behavior of GdH-NPs and Gd-DTPA were analyzed by ICP-MS and GdH-NPS showed a better labeling ability than Gd-DTPA. Labeled stem cells showed better signal in the result to cellular MRI. In order to evaluate possible adverse effect of GdH-NPs, we examined the immunophenotypes of labeled cells and the immunophenotypes of stem cells labeled with GdH-NPs showed no difference with control group.

In this study, GdH NPs are synthesized with a nano-scale size and show a good biocompatibility. In conclusion, GdH-NP has a great potential as a stem cell tracker in the near future.

Keywords: Gadolinium, nanoparticle, mesenchymal stem cell, MRI, cell tracker

O－3

Development of Polymer Gel Dosimetry and Optical-CT for Radiation Therapy in Taiwan

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In the past two decades, polymer gel dosimetry has attracted significant research attention because of its capability to record real three dimensional dose distribution as well as its high resolution and accuracy. However, complex process and oxygen-free environment are needed for gel preparation. It is not suitable for clinic use if the gel dosimeters cannot be manufactured easily and be provided with uniform quality. A new type of normoxic gel dosimeter MAGIC was proposed by Fong *et al.* in 2011, which can be fabricated easily on the benchtop in the laboratory. In addition, a less-toxic monomer is required in gel preparation to ensure user safety. Senden *et al.* (2006) proposed N-isopropyl acrylamide (NIPAM) polymer gel using less-toxic monomer. Hsieh and Chang have chosen NIPAM as the first polymer gel to develop in Taiwan since 2006, because NIPAM polymer gel has some advantages such as high sensitivity (greater than 0.995), high linearity (up to 0.0241 mm^{-1}) and long-term stability (post irradiation time up to 3 months). At the same time, the single beam optical computed tomography (CT-s1) was implemented by Chang (2010) in their study. Hsieh's research group also developed a new type of polymer gel, called DEMBIG, by using 2-(Dimethylamino) ethyl acrylate monomer. The DEMBIG showed very good linearity 0.995 for 1 to 25 Gy. But the disadvantage is that the fabrication process has to be under anaerobic environment inside a glove box. The three-dimensional characteristics of NIPAM gel dosimeter was further investigated by using a fast optical-CT laser scanner (OCTOPUS™, MGS Research, Inc., Madison, CT, USA). Chang *et al.* improved the holder adapter of gel phantom used in OCTOPUS™ to avoid the positioning errors when the gel was used during pre- and post-scan, thus higher accuracy can be achieved. To shorten the scanning time of OCTOPUS™, Chang *et al.* have developed a new type parallel-beam optical-CT scanner (CT-s2) in 2014. Combined with the pinhole, spatial filter and speckle reduction techniques, the same reconstruction images can be obtained but scanning time can be reduced to only 36 seconds, which was about one twentieth of the scanning time of OCTOPUS™ when they scanned the same size of gel phantom. Chang et al. investigated more clinic radiotherapy cases such as RapidArc, VMAT and brachytherapy by using NIPAM gel dosimeter and self-developed optical-CT. The results reveled good agreement between measured dose and treatment planning. Therefore, based on previous studies, the NIPAM gel dosimeter combined with parallel-beam optical-CT scanner have been considered as a potential three dimensional dose measurement tool for radiation therapy.

O－4

Patient-Specific Time Activity Curve Estimation Using External Thermoluminescent Dosimeters (TLDs)

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Aims: In this work, we proposed a novel method to estimate time activity curve in nuclear medicine examination using serial timely measurements of thermoluminescent dosimeters (TLDs). The approach is based on the combination of the measurement of surface dose using TLDs and Monte Carlo simulations to estimate the patient-specific time activity data.

Materials & Methods: Since the surface dose is connected to the cumulated activities of source organs through the radiation transport from the human body which can be pre-calculated with the Monte Carlo simulations by inputting the patient CT images, the organ cumulated activities can be estimated by solving the dose-activity equations. Therefore, the activity of each organ at the time of measurement can be simply the cumulative activity divided by the time span between measurements. Serial sets of TLDs to be read in a sequential manner were employed and each TLD set measured a fraction of cumulative activity in each organ. By connecting these timely fractional cumulative activities, the TAC can be constructed for each source organ. The usefulness of this method was investigated using a Monte Carlo simulations based on a multi-compartment phantom and an ORNL phantom with $^{18}F^{-}$FDG filled in several source organs.

Results: For multi-compartment phantom, the percent sum of squared error (PSSEs) under various activity distributions appeared to be stable and most were less than 3%, demonstrating the robustness of the method. Large errors occurred in the estimation of the background activity. For ORNL phantom, the time-activity curves (TACs) of all organs were successfully reconstructed. The PSSE between the simulated and calculated (decay-corrected) activities was 8.94%, 17.9%, 19.7%, 11.8%, 14.1%, 5.66%, 8.19%, and 5.93%, respectively, at the time of the TLD reading.

Conclusion: Preliminary results indicate that it is an effective, robust, and simple method to assess the TAC. The proposed method holds great potential for a range of applications in areas such as targeted radionuclide therapy, pharmaceutical research, or patient specific dose estimation.

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Risk of Natural Radiation of Japanese

日本人の自然放射線のリスク

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The cancer risk due to external and internal exposures by natural radiations was estimated using the nominal risk factor 5.5×10^{-2} Sv^{-1} adapted by ICRP.　Two hypotheses were taken in estimation. One is that the health effect by radiation was caused by dose accumulated with time, without reduction effect.　Another is adaption of LNT (linear no-threshold) model.　The accumulated dose is taken from mean accumulated dose of each 5-years layer.　The used data are the population visual statistics of Japan that released by the Ministry of Health, Labor, and Welfare, and the Japanese annual dose due to natural radiation of 2.1 mSv that was estimated by the Atomic Safety Research Association.　The results are as follows; the mean dose is 95.6 mSv from mean age of 45.5, the lifetime dose is 175 mSv from lifetime of 83.5、and age-weighted mean lifetime dose is 160 mSv.

When we assume that every cancer leads to death with no-effect of treatment, the death rate of cancer exposed by natural radiation is estimated to be 0.88%, the rate to all dead to be 0.29%, and the rate to population to be 0.0029% (risk was 2.9×10^{-5}), where Japan population, annual death of Japanese and cancer death are 120,000,000, 1,200,000, 400,000, respectively.

外部被ばく及び内部被ばくに係る自然放射線による発がんリスクを算定した。名目リスク係数は、ICRP2003 の名目リスク係数 5.5×10^{-2} Sv^{-1} を使用した。算定では、2 つの仮定を置いた。すなわち、①放射線の生体への影響は単純な経年累積線量で、逓減効果はないとし、②しきい値のない直線仮定の LNT モデルの採用である。累積線量は、年齢 5 年刻みの加重平均累積線量を採用した。データには、わが国の平成 25 年の人口動態（厚生労働省）を使用し、また、年間の放射線量は 2.1 mSv（原子力安全研究協会；新版生活環境放射線 2011）とした。わが国の平均年齢は 45.5 歳であるから、平均線量は 95.6 mSv となり、また、男女を平均した平均寿命は 83.5 歳であるから、生涯線量は 175 mSv となり、さらに、がん死亡者に限ると、年齢加重の平均生涯線量は 160 mSv となる。

仮に、放射線により発がんした人は、治癒がなくすべて死亡すると仮定すると、自然放射線による発がんによる死亡率は 0.88%、また死亡者に対する割合は 0.29%、全人口に対する割合は 0.0029%（リスク：2.9×10^{-5}）となる。ただし、概数として、日本の総人口 1.2 億人、年間の死亡者 120 万人、がん死亡者 40 万人としている。

O－6

Effects of Radioactive Spring
放射能泉の効用

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Radioactive spring is radon hot springs.

There are three kinds of radioactive radon gases in nature, even though the word radon (Rn) often means ^{222}Rn. The two others are thoron (^{220}Rn) and actinon (^{219}Rn) and all of the three are decay products of the natural radioactive chains of Uranium, Thorium and Actinium. Since the half-life of ^{219}Rn is too short (4.0 seconds) and there has been little study done on it.　And radon which belongs in the rare gases, is the main element of the radioactive spring.　As radon is chemically inert, it dose not make any complex with other chemical component present in hot and mineral spring water.

Radon research is presently being performed in environmental science, geochemical science, medical science, physics, biology and technology with many other applications.

The human body is made up of approximately 60 trillion cells, and the number of cells is known to decline with age. Recent research results show that radon bathing helps reactivate cellular function, thus helping ease symptoms of chronic illnesses and aging. But radon research is complex and has a distinct mechanism of action, not yet understood.

This time I would like to report about effects of radon and radioactive spring.

放射能泉はラドン温泉である。

自然界には 3 種類のラドンがあるが、通常は ^{222}Rn を意味している。他の二つはトロン(^{220}Rn)とアクチノン(^{219}Rn)で、三者はそれぞれ天然崩壊系列ウラニウム、トリウム、アクチニウム系列に属している。^{219}Rn は半減期が 4.0 秒と短く研究報告はほとんど無い。また、希ガスラドンは放射能泉の主要成分であり、化学的に不活性で、他の成分と化合物は作らない。

現在、ラドンは環境科学、地球科学、医学、物理学、生物学、工学その他多くの分野で研究されている。

人間の身体は 60 兆個の細胞からなり、細胞は年齢とともに減少する。最近の研究によりラドン温浴には慢性的な病気や老化を軽減し、細胞の再活性化に効果があることが示された。しかし、ラドン研究は複雑で、作用の明確なメカニズムはいまだ解明されていない,

今回ラドンと放射能泉の効用について報告する。

O－7

Nuclear Technology Education at the Secondary Level in Thailand

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The modern development of nuclear technology has both advantages and disadvantages. In Thailand, the electric nuclear factory will be operational since 2020. Therefore people should be informed about the positive and negative effects of nuclear technology. An authorized organization should pass this knowledge down to people. At the moment, there is no official science organization that incorporates nuclear technology into its curriculum. In accordance to this problem, the researchers of this article have discussed, surveyed and collected data about nuclear technology education at the secondary level in Thailand. This was done in order to present the various problems of nuclear education and identify how to reform this. This study will also be presented to the fifth international symposium on Radiation Education on 16-19 December, 2016 in Japan.

The result of this study shows that there was less informational resources for people or students to access. Additionally, it was found that people didn’t realize how important nuclear education is. This was further reflected in the abysmal level of nuclear technology education at the secondary level.

O－8

Nuclear Radiation Education in Thai Universities

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In this presentation, an overview of nuclear radiation education and nuclear power understanding in some Thai universities are presented. In Thailand, most major universities provide most basic nuclear knowledge in undergrad level. In some university, i.e. Chulalongkorn University, provide deeper knowledge into nuclear physics and technology. Moreover, it offers degree in nuclear engineering up to Ph.D. level. Additionally, nuclear engineering, nuclear physics and radiation science courses have been taught as electives for physics and engineering students in many universities in Thailand. Fields of study include medical and public health, agricultural, material and industrial, environmental and advanced technology like neutron scattering and nuclear fusion. Moreover, many academic activities have been conducted such the Thailand international conference and the ASEAN school on plasma and nuclear fusion. The nuclear fusion research and study have been one of targeted research in Thailand. Most of activities are under the Center for Plasma and Nuclear Fusion Technology (CPaF).

Ｏ－９

Radiation Education and Nuclear Power Plant in Taiwan

台湾における放射線教育と原子力発電所について

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Radiation education at school and the current state of the nuclear power plant in Taiwan are described. In compulsory education, radiation education and radioactivity education are not so much accomplished. The explanation of radioactive materials using a periodic law table is mentioned during "natural life and science technology" by science of a junior high school. Safety of radiation, division chain reaction and nuclear fusion reaction are mentioned about an X ray at a high school. A chapter of nuclear physics and nuclear chemistry is in the general physics and the chemistry texts of a university, but the majority teachers actually do not lecture.

There are four nuclear power plants and six nuclear power plants are working at present in Taiwan. A problem describes some facts to administrative correspondence of a government in a safety management side in a nuclear power plant.

台湾における学校での放射線教育と原子力発電所の現状について述べます。
義務教育では、放射線教育及び放射能教育はあまりなされていません。中学校の理科で、「自然の生活と科技」の中に周期律表を用いた放射性物質の説明が載っています。高校ではX線について放射線の安全性、核分裂連鎖反応及び核融合反応が記載されています。大学の一般物理と化学の中に、核物理と核化学の章がありますが、大部分の教員は講義していないのが現状です。

台湾には４つの原子力発電所があり、現在６基の原発が稼動しています。原発の安全管理面で、政府の行政的な対応に問題があることなど述べます。

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O－10

An Example of Lectures on the Nature of Radiation for General Public

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To make general public interested in and familiar to radiation, I have given lectures on the basic science of radiation for more than a decade. Because scientific literacy of general public is limited, it was sometimes hard to let people understand what radiation is and how does it interact with matter, within a limited time available for the lecture. After the FUKUSHIMA nuclear disaster in 2011, however, the situation has dramatically changed: a lot of Japanese people worried about health hazards of radiation, stirred up mainly by mass media that emphasized only risks of radiation even at the dose as low as 1 mSv. Variety of news put the society into confusion for a while. At present, more than 5 years since the nuclear disaster, the confusion has almost settled down and most of people fairly accept not only the risk, but also the benefit of radiation. I present here in this symposium an example of my lecture, by which the audience could understand the nature of radiation. To know fundamental features of radiation such as the origin and interactions with matter would help the audience to feel safe from danger of radiation in their daily life.

Ｏ－１１

How Can Clinical Radiologists Mitigate the Public's Fear of Ionizing Radiation and Radioactive Materials?

放射線や放射性物質に対する市民の恐れをどのように軽減するか？

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On March 11, 2011, a nuclear accident occurred at the Fukushima Daiichi Nuclear Power Station (FNP-1), operated by Tokyo Electric Power Company. Consequently, it provoked widespread skepticism and lasting anxiety about radiation, not only in Japan, but also in other countries that operate nuclear power plants. In addition to that, many patients in Fukushima prefecture and in the other part of Japan declined CT examinations despite a doctor's recommendation. Members of the radiological society shall continue efforts to dissolve irresponsible rumors about the effects of radiation that may hinder the beneficial uses of radiation in medicine. So, it is extremely important for clinical radiologists to encourage every medical staff to have a knowledge to correct prejudiced public understandings on the effects of ionizing radiation on human health, especially at low doses.
We had been taking many classes for medical staffs. Based on questions and answers in these classes, we have created simple booklets and an E-learning system on radiation for the education of medical staffs. We would like to inform these systems to our Asian colleagues.

O-12

Radiation Education Experiments and Other Science Education Experiments with a Hand-made GM Counter

手作り GM 管計数器による放射線教育実験と他の理科教育実験

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The seminar of radiation education experiment named “Radiation watching” has been held over many years by Chubu Atomic Conference for high school students and teachers. The participators fabricate GM counter and counting equipment by themselves. We recently developed air-filled GM counter with a darning needle as an anode. The counter is very easy to fabricate and the counting performance is stable. The usual radiation measurement experiments are possible. Moreover, since this counter can open the widow, an alpha-particle source is able to be put into the counter and alpha-particle absorption experiment is possible. When a small metal plate such as aluminum or zinc is put into the counter and irradiated with light, photoelectrons can be counted, and hence the experiment of metal surface oxidation is possible. When optical films are inserted between the light source and GM counter, the absorption of ultraviolet ray is evaluated. The air filled GM counter would be useful for science education experiments as well as for radiation education experiments at school teaching.

“放射線ウオッチング”と名付けた放射線教育実験を、中部原子力懇談会が中学・高校の生徒や先生を対象として長年開催してきた。受講者が GM 管や計数器を自ら組み立て、放射線実験をする。最近我々は、とじ針を陽極にした組立ての極めて簡単な空気 GM 管を開発した。通常の放射線実験は可能であるが、GM 管の窓を容易に開くことができるため、中にアルファ線源を入れたアルファ線の吸収実験、薄い金属板を入れて外から光を照射する光電子放出実験、紫外線吸収実験、金属表面の酸化やエキゾ電子放出などの放射線実験以外の実験ができるので、中学・高校の先生がこれらの実験に活用することができる。

O－13

Development of Radiation Educational Program Using the Peltier Cooling Type Highly Performance Cloud Chamber

ペルチェ冷却式高性能霧箱を用いた放射線教育プログラムの開発

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霧箱による放射線の観察は目で見て直感的に放射線の存在を知ることが出来るため、教育的効果が大きく、様々な教育者により改良されて来た。しかしながら、一般的なタイプの霧箱では直前にドライアイスの準備が必要であり、天候などにより飛跡が観察できないことも多かった。また、内容としても「α線の飛跡が見えた」に留まっていた。

そこで、発表者を中心としてペルチェ素子を使用した安価な普及型の高性能霧箱の開発を行っている（http://bigbird.riast.osakafu-u.ac.jp/~akiyoshi/Works/index.htm#CloudChamber）。最大の特徴は長時間安定してクリアな飛跡の観察が可能であるため、一般的な霧箱でのα線の飛跡の観察に加えてβ線の飛跡の観察も可能であり、さらにはγ線により放出された光電子なども観察可能なことである。これにより、放射線の種類による物質との相互作用の違いを直感的に学習することが出来るため、ただ単に飛んでいるのが見えた、に留まらない奥が深い放射線の世界を紹介することが可能である。さらに、放射線の種類により生体への影響がどう異なるのか（4000 Bq の K-40 と 20 Bq の Po-210 による実効線量の違い）を実習の結果を交えて説明できる。そのことからベクレルだけでは生体への影響（シーベルト）は評価できないこと、さらに、どういった核種がどのような放射線を出しているかという情報から、身の回りの放射線と福島の事故で放出された核種からの放射線について、同じ土俵で比較する力を付けることが出来るようなプログラムを作成した。

また、このペルチェ冷却霧箱には、ペルチェ素子による熱輸送、熱電対による温度測定、ヒートパイプや熱伝導グリースを含めた物質の熱伝導、蒸気圧と過飽和・核生成、電離とイオン化、電気工作などの要素に加えて、雑イオン除去のための静電気発生、高電圧発生装置による加速器の基礎など、極めて多様な工学的要素を含んでおり、放射線安全教育を中心とした、レベルの異なる教育現場での展示、解説を行うことが出来る教育プログラムが開発可能である。

大阪府立大学放射線研究センターでは、みんなの暮らしと放射線展をはじめとして非常に精力的な放射線教育活動を行っているが、2016 年 8 月 に福井県立若狭高校からの研修を受入れ、放射線基礎講義、施設見学、サーベイメーターを用いた実習と共にペルチェ冷却式高性能霧箱を使用した実習を行ったので報告する。さらに、2016 年 12 月には学部一年生向けの学生実験プログラムを作成している。発表時点では実施はしていないが、そのプログラムについて紹介する。

左図: 2016/10 時点での製品版のペルチェ冷却式高性能霧箱。
取扱は大阪ニュークリアサイエンス協会 onsa-ofc@nifty.com まで。

O－14

Use of $^{68}Ge/^{68}Ga$ Generator as Experimental Tool in Wide Fields of Education

小型 $^{68}Ge/^{68}Ga$ ジェネレーターを用いる種々の領域における教育実験

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Various characteristics of radioisotopes (RI) can be used effectively in experiments for education in various fields. As the source of RI, radioisotope generators, particularly small $^{68}Ge/^{68}Ga$ generators, are thought to be highly suitable. （^{68}Ge: 9 month half-life, EC decay; ^{68}Ga: 1.1 hour half-life, β^+ decay） Following experiments are ready for practice in education hours: (1) own-making of the generator, (2) milking of ^{68}Ga and measurement of its half-life, (3) observation of the approach to radiochemical equilibrium after the milking, (4) several tracer experiments by the use of the carrier-free ^{68}Ga, and (5) a few experiments related with positron annihilation. These experiments are clearly effective to provide to the attendants with deeper understanding of exponential and logarithmic functions, with intimacy on differential equations, and with some knowledge on the behavior of ultra-minute or ultra-dilute substances. In the decision of national policy on nuclear power, opinions should be appreciated of those who have experienced experiments using RI, been interested in it, and continued related studies.

ラジオアイソトープ (RI) の諸特性は、種々の分野における教育実習に活用可能と考えられる。その時の RI 供給源としてはアイソトープジェネレーター、なかでも小型の $^{68}Ge/^{68}Ga$ ジェネレーターが非常に優れている。(^{68}Ge;半減期 9 月, EC 壊変;^{68}Ge:半減期 1.1 時間, 陽電子壊変）次のような多数の実験題目が、(若干の法的問題が解決すれば）実行可能な状態にある:（1）ジェネレーターの自作 ; (2) ^{68}Ga のミルキングと半減期の測定 ; (3) ミルキング後のジェネレーター中での放射平衡生成過程の観察；(4) ミルキングで得た ^{68}Ga を用いる種々のトレーサー実験；(5) 陽電子消滅に関連の諸実験。これ等の諸実験は、指数/真数 /対数の関係を実感し、微分方程式に親しみを感じ、極微量物質・極低濃度物質の挙動を理解するのに大変有効なものを多く含んでいる。原子力発電の国家政策決定にも、RI 取扱いを経験して関連分野に関心を持って学習してきた市民たちの意見は大いに尊重されねばなるまい。

P－1

Detection of Spatial Distribution of Dual Photon Emitters Using TOF Coincidence Imaging Technique with Stochastic Origin Ensemble Approach

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Introduction: In this study, the time of flight (TOF) coincidence imaging technique is employed to obtain the spatial distribution of dual photon emitters. For each event, one hyperbolic response curve can be projected according to the time difference of the two arriving photons. ^{60}Co is a dual photon emitter (1.17 and 1.33 MeV) and plays an important role in the process of nuclear waste disposal. The proposed technique can be applied to Waste Inspection Tomography (WIT) system for nuclear waste drum characterization and activity measurement in the future.

Method: Dual photon emitters emit two directionally uncorrelated photons simultaneously. If both photons are detected in the same time, the possible location of decay could be determined by TOF information and the coordinates of detectors. A full-ring PET-like detection system was built to detect the dual-photon emitters (e.g. Co-60, Se-75, or In-111). By detecting the gamma rays with TOF information in coincidence, the hyperbolic response curve can be described on the space. Due to the complexity of the spatial distribution, the activity map was reconstructed by using stochastic origin ensemble (SOE) algorithm. An in-house developed GATE/MPHG Monte Carlo software was used for the simulation study of selenium-75. A point source and multi-rods phantom were used for assessment of the proposed system.

Results: Results show that the proposed system successfully reconstructs the source distribution. The SOE method works well with the imaging system. The spatial resolution in the central field-of-view achieves about 20 mm when coincidence resolving time (CRT) is under 100 ps. There is a strong relationship between spatial resolution and CRT.

Conclusion: The conclusion is drawn that TOF coincidence imaging system combined with SOE reconstruction technique is feasible and is suitable for the imaging of dual-photon emitters. It can be applied to existing multimodality WIT system to acquire the spatial distribution of nuclear waste inside the drum.

Key words: Time-of-flight, Stochastic origin ensemble, Waste inspection tomography.

P－2

A Study on Clinic Brachytherapy Using 3D Polymer Gel Dosimeter

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Brachytherapy is a treatment technique that put the radioactive source near the tumor target. However, it is difficult to measure the dose distribution because of the characteristic of high dose gradient and large variation of dose in clinically. Different from traditional dosimeter, TLD and radiochromic film which were one or two dimensional dose verification tool, polymer gel dosimeter is capable to record three dimensional (3D) does distribution and it is a high potential dose verification tool for new accelerator such as RapidArc, VMAT and proton therapy.

The aim of this study is to investigate the dosimetric characteristics of high dose rate (HDR) brachytherapy by using 3D NIPAM polymer gel dosimeter combined with self-developed parallel-beam optical-CT scanner. The gamma evaluation technique is used to compares the measured and TPS doses point by point. The criteria is set as 3% dose-difference and 3 mm dose-to-agreement.

In this study, a cylindrical PMMA phantom which is 10cm in diameter and 10cm in height is used. The plastic tube in phantom is use as a transfer tube for brachytherapy. NIPAM polymer gel comprise 5% gelatin, 5% NIPAM, 3% Bis, and 5mM THPC. After solidification, phantom is irradiated using Nucletron micro-Selectron with radiation source Ir-192. The target dose is 5 Gy at 2 cm from seed center.

The dose measured at 2 cm from seed center showed good agreement for HDR brachytherapy. The gamma pass rate was 84% to 99% at 2.0 cm from seed center. But the high dose rate and edge-enhancement effect does made influence on the dose distribution measured by gel dosimeter. Therefore, the measured dose distribution showed disagreement near the seed center. Other impact factors such as streak artifact occurred in image reconstruction needed to improve in the future.

Ｐ－３

Post-3.11 Literacy Promotion Activities for Urban Citizenry and High School Students, by Literature and Practice Covering Science and Disaster

都市圏市民から中高生まで対象とした 3・11 後の科学・災害リテラシーのための文書および実践活動

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Radiation literacy is essential for Rokkasho Village, the site of reprocessing facilities of spent nuclear fuel. Our reading circle (an affiliate of Rokkasho Cultural Assoc.) has steadily participated in various activities for, in cooperation with SJWS (Soc. of Japan Women Scientists), especially Tohoku branch (the then branch head: Dr. M. Suzuki). Once everything went so well as Tohoku branch of Radiation Education Forum was established (the then branch head: Ms. S. Tsushima).

After 3.11 disaster, however, nuclear power or radiation related literacy tended sluggish throughout Japan, being coupled with national policy of 'ex nuclear power' at that time. In taking those circumstances seriously, we published the first English version of our 'Bulletin' so as to send messages internationally: "Women's Messages from the Village of Rokkasho to the World" (2012).

Led by the view of former Representative (the late Ms. H. Nihon'yanagi): "it's now time to extend our activities over big cities, major power consuming areas", symposia were held successively in Tokyo, Sendai and Mutsu. We also took advantage of the Summer School of NWEC (National Women Education Center) for students (junior & senior high), with arrangements to foster their fundamental understanding of energy with global to cosmic vision.

使用済み核燃料再処理施設の立地村六ヶ所村では、文化協会傘下の読書愛好会が、発足時（1995）以来、日本女性科学者の会とくに東北支部（支部長：鈴木益子氏：当時）の指導のもと、自他共に対象とする放射線リテラシーの向上に努めてきた。ひと頃は、放射線教育フォーラム青森支部（支部長：津島園子氏：当時）が立ち上がる程の勢いであった。

3・11 カタストロフィー後は、脱原発という当時の政策もあり、全国的に原子力・放射線リテラシーが極めて低調であった。これを由々しく感じた会員たちは、それまで続けてきた文書活動を集大成、かつ国際的発信も兼ねて、"Women's Messages from the Village of Rokkasho to the World"（2012）を発行した。また「今はエネルギーの大消費地、東京・大阪級の大都市で活動すべき時」という代表（二本柳晴子氏*：当時）の考えのもと、東京・仙台・むつでシンポジウムを開催した。また、中高生に対しては国立女性教育会館「夏の学校」という場で宇宙の中の地球上の日本の国土をエネルギー的に基礎から理解するプログラムを 5 年間続行した。　（*2015 年 12 月 17 日逝去）

Ｐ－４

Mystery of Alpha Particle Track in Cloud Chamber!

霧箱におけるアルファ線の飛跡の謎

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The track length of alpha particle with 6 MeV in air with the atmospheric pressure is about 4.7 cm and the flight time is only 4.5 ns. Then ion pairs are produced almost simultaneously throughout the track and therefore the white track is supposed to appear simultaneously. However, the white track of alpha particle in a cloud chamber is clearly seen to extend from the alpha particle source to the end of the track. This is mystery! The specific energy loss of alpha particle along the track is expressed by the Bragg curve. The track is visible only when the liquid drops of alcohol have grown to about 3 μm in diameter and then Mie scattering of light has appeared. At the beginning of the track, two or three ion pairs per 1 μm are produced and they are able to grow to the liquid drops with 3 μm diameter by the diffusion of supersaturated vapor of alcohol through about 0.3 mm distance. However, near the end of the track, five or six ion pairs per 1 μm are produced and they need the alcohol vapor diffused through 0.5 mm distance to grow to the drops with 3 μm diameter. Therefore, the end of the track appears later than the beginning of the track. Beta ray track, on the contrary, appears simultaneously throughout the track length because of very low density of ion pairs per unit length.

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6 MeV のアルファ線の 1 気圧の空気中の飛程は 4.7 cm で飛行時間は 4.5 ns である。すなわち、全飛程にわたってほとんど同時にイオン対を作る。したがって飛程の全ての場所に白い飛跡（霧）が同時に現れると思われるが、飛跡は線源から遠方へと伸びて行く。これはまさに謎である。飛跡が白く見えるためには、霧滴は直径約 3 μm 程度に大きくなって Mie 散乱が生じなければならない。アルファ線のエネルギー損失はブラッグ曲線で表され、飛程の最初の位置では、飛跡の長さ 1 μm 当たりのイオン対の数は 2～3 個で、これらは、約 0.3 mm の離れた位置からの過飽和蒸気の拡散によって直径 3 μm に育つ。しかし飛程の最後の方では 5～6 個のイオン対ができ、これらが直径 3 μm に育つには、0.5 mm のより遠方の過飽和蒸気が拡散して来なければならない。従って飛跡の終わりの方は最初の方よりも遅く現れる。対照的に、ベータ線の飛跡は飛跡長さ全長にわたって同時に現れる。単位長さ当たりのイオン対の密度が非常に小さいからである。

Ｐ－５

The Image of Alpha Emitter Distribution on the Surface of Environmental Material with CR-39

身の回りの物品表面のアルファ放射体分布像を CR-39 で取得

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Some environmental materials, such as stone, brooch and ornament made of pottery, lead, solder, etc. contain Th-232 or U-238 and emit alpha-particles. The images of the distribution of alpha emitters on the surface of such materials are able to simply obtain using nuclear track detector CR-39 used for heavy particle radiations. The procedure to obtain the images is as follows;

① Purchasing CR-39 ($180 / 1 sheet (28 cm × 28 cm × 0.9 mm) , Nagase-landauer.co.jp)
② Cutting it into 15 pieces (Only $12 / 1 piece)　(Insensitive to beta- or gamma-rays)
③ Putting alpha emitter specimens on the CR-39 surface for 2-3 months.
④ Chemical etching for 5 hours in sodium hydroxide solution (7.5N, 80℃)
⑤ The image can be clearly seen by placing the CR-39 plate in a dark box and lightening through a side of the plate.
⑥ Taking the photograph and displaying on a personal computer; pseudo color display if you like.

Students of science clubs at senior or junior high schools would be interested in this method.

身の回りの物品、例えば岩石、陶器のブローチ、徽章、鉛、半田付け部品、などからは Th-232 や U-238 などの放射性壊変系列におけるアルファ線が放出されている。重粒子放射線の飛跡検出器である CR-39 で物品表面上のアルファ線放出核種の分布が簡単に取得できる。

① CR-39 板を購入する（28 cm × 28 cm × 0.9 mm　1 枚￥19,000－、長瀬ランダウア）
② 1 枚を 15 枚にカットする（1 枚￥1,300－）（ベータ線やガンマ線に不感）
③ 試料を CR-39 の上に乗せて 3 か月間放置する（遮蔽箱などは必要なし）
④ カセイソーダ液（7.5N，80℃）に 5 時間浸す（化学エッチング）
⑤ 黒い箱の中に入れ、横から光を当てて像を浮かび上がらせる
⑥ 写真に撮り、パソコンで処理する。安価で簡単に美しい画像が得られる。

中学校や高等学校の科学クラブの生徒たちに興味を持ってもらえると思う。

Ｐ－６

Radiation Sources Fabricated from the Zuiki Taro Plant and Educational Uses

ズイキで製作した放射線源と教育利用

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The Japanese name “Zuiki” means the edible stem of a kind of taro plant, which contains natural radioactive potassium-40. The several Zuiki stems were peeled, dried and micronized with a pulverizer; then the compression and formation method was applied to the Zuiki powder, making disk-shaped radiation sources. Thus, ten Zuiki radiation sources were obtained and measured as to their weight, thickness, diameter and radiation count rate including background radiation of each source. The radiation was counted for 1-minute using a GM-survey meter, mainly attributed to β-rays from ^{40}K. Then, the averages (SD's) of the weight, thickness, diameter, and radiation count rate were 15.1 (0.03) g, 9.98 (0.1) mm, 35.2 (0.01) mm and 163.4 (10.5) cpm, respectively. The usability of the sources for educational purposes was examined in three tests on the dependence of the radiation count versus time, distance, and shielding. Furthermore, the statistical fluctuation of the radiation counts was examined by making 50 measurements with the GM survey meter.

The time dependence test proved that an accumulate radiation count increased proportionally to the elapsed time (= accumulated time). The distance dependence test demonstrated that the relationship between distance and radiation count rate could be explained by the inverse-square law. The shielding dependence test showed that the radiation count rate decreased exponentially with shielding thickness. Ant it was found that the radiation counts were randomly fluctuated and the distribution of the count rates was statistically represented by Gaussian function.

It is concluded that the Zuiki radiation sources are useful aids to enable better comprehension of the three cardinal principles of radiation protection, and the randomness and statistical fluctuation of radiation counts. The experience-based radiation education using the Zuiki radiation sources will be conducted at all common places like school classrooms, community halls and even houses with children where legal radiation sources cannot be handled.

Ｐ－７

Experiential Learning to Understand the Necessity of Radiation Device Calibrations at NSG Koriyama Calibration Center

NSG 郡山校正センターにおける放射線測定器校正の必要性を理解するための体験学習

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After the nuclear accident at the Fukushima No. 1 nuclear power plant in March 2011, serious radioactive contamination occurred and environmental radiation levels suddenly went up in the Fukushima area. As a result, not only members of the authorities concerned but also members of the public sought for radiation measurement devices, like survey meters, and measured radiation doses in a variety of places, including their own houses and gardens as well as public places like parks and school grounds. Concurrently, various problems occurred when individual radiation doses were measured by using multiple survey meters. In a typical case, radiation doses measured with one survey meter were different from ones measured with other meters; leading to disagreements between users of the meters because they trusted the measurements of their own survey meters without any doubt. Although many problems resulting from the inaccurate measurement of radiation doses were largely caused by using uncalibrated devices, users were not aware of the importance of device calibration.

An experiential learning program for understanding the necessity for device calibration was established at the Koriyama Calibration Center in the Japan Shield Technical Research Co., Ltd (NSG). In this program, several weight scales and weight samples are used instead of radiation devices and radiation. Some weight scales work correctly but others do not because they are intentionally uncalibrated. Similarly, the weight samples are 250-ml bottles filled with river sand with some of the bottles containing a piece of lead and others a piece of styrofoam to change their weight. All the bottle samples look the same, but their weights are not necessarily the same. Participants measure the weight of the bottles using the weight scales, then compare and discuss the results with each other. Through this program, participants come to understand what calibration is and understand the importance of calibrating not only weight scales but also radiation measurement devices.

Ｐ－８

Analysis of the Consciousness of University Students in Okinawa about the Radiation

沖縄県の若者の放射線に対する意識分析

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By revising curriculum guidelines for junior high school in 2008, “radiation” was added to the third grade science. Most of the students who enrolled in the university in last year were the first student who learned a radiation at the age of a junior high school. In this study, we compared the awareness of radiation of undergraduate students who received the new curriculum (N=99) versus the old curriculum (N=224) by survey.

Compared with students from the old curriculum, students on the new curriculum showed an improvement for the knowledge about the type and properties of radiation. Though high radon concentration inside the houses had been observed in Okinawa, the recognition about a radon was very low with both groups. The investigation about the utilization of radiation, awareness of both the X-ray application and a radiation therapy were high. On the other hand, insect pest control using a radiation which brought much convenience for agriculture of Okinawa has been unknown. As described above, by the revision of curriculum guidelines, some knowledge of the radiation of students has been increased, but awareness of both radon and radiation applications have remained low.

平成 20 年の学習指導要領の改訂に伴い，中学校理科第三学年に放射線に関する内容が組み込まれ，昨年度，中学校で放射線を学んだ第一期生が大学に入学した。そこで本研究では，新課程の大学生（99 名）と旧課程の大学生（224 名）を対象に，放射線に対する知識やリスク認識に関するアンケート調査を実施し，分析を行った。

放射線の種類や性質に関する知識については，新課程の学生の方が旧課程の学生に比べ高い理解を示した。また，沖縄の住宅では高濃度のラドンが観測されているにもかかわらず，ラドンに対する認知度は，新課程，旧課程ともに低かった。放射線利用に関しても，エックス線利用やがん治療の認知度は高かったが，沖縄県の農業に多大な利益をもたらした害虫駆除に関する認知は低かった。このように，学習指導要領の改訂により，放射線に関する一部の知識は高まってはいるが，ラドンや放射線利用に関する意識は低いままであった。

Ｐ－９

Development of Teaching Materials for Radiation Education Using CR-39 Solid State Nuclear Track Detectors

固体飛跡検出器 CR-39 を用いた放射線教育教材の開発

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CR-39 solid state nuclear track detector suffers a microscopic defect when hit by an energetic particle. This defect can be enhanced into a visible track (etch pit) by chemical etching. If the students watch the defect caused by the radiation with eyes, they can understand easily that radiation has an energy. However, highly-concentrated solution is necessary for etching, the CR-39 has been difficult to use in elementary and junior high school. In this study, we investigated the visually effects of etch pits by different etching conditions for CR-39.

The etch pits in CR-39 were observed with an optical microscope, when it was etched in a low concentrated solution (5% NaOH) at 90℃ for 3 hours. As a more secure method, by chemical etching for 6 days in the room temperature, the small etch pits were observed. After 20 days, distinguished etch pits were observed. Furthermore, by pre-UV irradiating (254 nm, 6 W, 1h) on CR-39, the diameters of etch pit were enlarged. Thus, it can be safely utilized CR-39 in the school by combining several conditions.

エネルギーを持った粒子が固体飛跡検出器 CR-39 に衝突すると微小な欠陥が形成される。これに化学エッチングを施すことで，損傷は拡大され可視化できる。このような損傷を生徒が肉眼で観察することができれば，放射線がエネルギーを有することを容易に理解することができる。しかしながら，放射線損傷をエッチピットとして可視化するためには，高濃度のエッチング溶液が必要であるため，CR-39 を小学校や中学校で使用することは難しかった。そこで, 本研究ではCR-39 を様々な条件でエッチングし，エッチピットの見え方について検討した。

低濃度の水酸化ナトリウム水溶液（5%）をエッチング溶液として使用した。液温を 90℃に設定し，3 時間のエッチングを行うことで, エッチピットの観察が可能となった。さらに, より安全な手法として，室温でエッチングを行ったところ，6 日目から小さなエッチピットが確認でき，20 日目では明瞭なエッチピットを確認することができた。また，CR-39 に 254 nm の紫外線（6 W）を 1 時間照射した後に 3 時間エッチングすると，より大きなエッチピットを観察することができた。このような幾つかの条件を組み合わせることで，教育現場での CR-39 の安全な利用が可能となる。

Ｐ－１０

The Road to a World of Elementary Particles, Quantum Mechanics, and Relativity Theory from the Radiation Education

放射線教育から素粒子、量子力学、相対論の世界へ進む方法

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Some important scientific ideas have been born since the discovery of radiation at the end of 19th century. Atomic structure based on the idea of nucleus and electrons, quantum mechanics which describes motion of particles, energy transfer between colliding particles, and the theory of special relativity necessary to understand energy concept of moving particles having mass, all these ideas were developed experimentally and theoretically by use of the radiations. We propose a new radiation education in which people and students become interested in basic sciences through learning fundamental properties of radiations.

19 世紀末に発見された放射線を用いて、陽子、中性子と電子から成る原子構造が明らかにされ、現在ではクォーク、電子、ニュートリノがあらゆる物質の構成要素であり、粒子間のエネルギー移動も理解されている。これらの素粒子の性質は量子論と相対論によって始めて理解される。放射線教育では身近な実験道具で放射線の性質を理解・確認できるので、そこから重要な興味深い現代科学に興味を抱いて入門できる人材を育成することが期待できよう。その具体的な方法の例をいくつか提案し、議論したい。

P－11

X-ray Imaging with Imaging Plate by Geissler Tube

ガイスラー管とイメージングプレートを利用した X線透過像撮影

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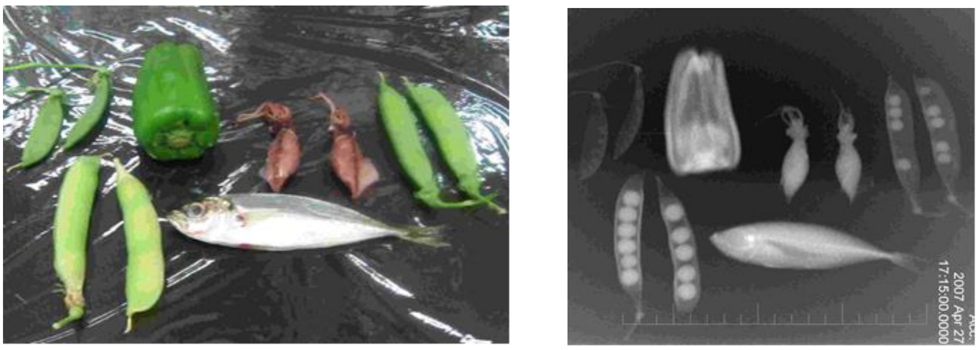
ガイスラー管は両端に電極を有し、高電圧を印加して放電させる単純な放電管で、真空度に応じて放電の態様が異なるため、真空度の目安を知るのに用いられる。真空度が 1 パスカル程度以下になるとX線が発生することが知られている。イメージングプレート（IP）は、高感度の 2 次元放射線検出プレートである。本稿ではガイスラー管からのX線と IP を使えば、身の回りの小物のX線写真を簡単に撮ることができるということについて述べる。この実験は、放射線の性質について、比較的容易に実験的に理解してもらうのに役立つと思われる。

当実験で使用したガイスラー管は、ガラス管の両端に直径 18 mm、厚さ 1.3 mm の円形のアルミニウム電極が 9 cm 離れて対向している。被写体試料として、花や葉、文房具などのX線を透過しやすい試料を並べた。実験の前に、電離箱式サーベイメータで周辺の線量率を測定し、安全に実験ができることを確認した。X 線は、ガイスラー管の両端の電極で発生する。そのまま撮影すると焦点が 2 カ所となり、像が 2 重になるため、片方の電極を 1 mm 厚の鉛板で覆った。図に野菜や魚を撮影した例を示す。グリーンピースやピーマン、小アジ内部構造が写し出されているのが分かる。手近にある簡単な装置を利用することにより、X 線写真の撮影を小・中学生や一般の方々にデモンストレーション的に見せることは、放射線の性質と利用について、容易に理解してもらうことに役立つと思われる。



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P－12

Instrumental Neutron Activation Analysis of the Hair

—A Study of the Biological Monitor in Persons Exposed by Toxic Metals—

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〔OBJECTS〕 It is assumed that not only individual metals but also the interactions multiple metals, such as assertive action, synergism and antagonism, may cause health hazard to persons. And it is assumed that mineral balance shows the condition of a disease. To examine the effects of human health on metals of hard metal factories and by manganese of persons living near manganese smelter, instrumental neutron activation analysis was carried out on their hairs. And also the conditions of disease on Cr poisoning patient absorbed into the system through the skin of Cr (VI+) were examined by activation analysis of the hair.

〔METHODS〕 Samples: Hairs were collected through the hard metal factories, manganese smelter area and a hospital. Irradiation: Instrumental neutron activation analysis of their hairs was carried out in KUR. Gamma ray spectrometry of short- middle- and long- lived nuclides was carried out with 4096 channel pulse height analyzer equipped with pure Ge detector.

〔RESULTS〕 Interesting results were recognized.

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Effects of the Thoron Spa or Bath on the Anaplastic Carcinoma of Thyroid

トロン温浴水の甲状腺未分化癌患者に対する効果

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It is well known that the low dose irradiation is effective for the improvement of the condition of the lifestyle diseases such as cancers and diabetes. In this meeting, we will report about the effects of the Thoron spa or bath on the anaplastic carcinoma of thyroid.

The thoron hot water was prepared using our devices based on the weak acid leaching method. The cancer patient took a bath in the thoron hot water from six to eight times a day for each ten minutes every day. We judged the evaluation from a blood test and so on.

The patient, who was diagnosed as the anaplastic carcinoma of thyroid in June 2014, received taxol treatment (130 mg/body/ times) after surgery. The myelosuppression is a side effect of the taxol treatment. The bone marrow activity recovered after the thoron hot bath, and the taxol schedule of 11 times of once a week could be performed. In addition, the peripheral nerve disorder as a serious side effect of taxol was minimal. On the other hand, four times of recurrences of the cancer were caused by June 2016. However, their progression was very slow unlike the normal anaplastic carcinoma of thyroid. Thus, the recurrent cancers were able to be eliminated by the surgical operations.

The mechanism of the Thoron spa or bath's effectiveness was still unknown, but it would be suggested of the good results for the improvement of the cancer.

低線量の放射線（α 線）は癌や糖尿病をはじめとする生活習慣病の症状改善に有効であると考えられている。弊社メディカルスパトロンはトロン人工温浴施設であり、様々な病気の改善を目的の一つとしている。今回は弊社温浴施設に訪れた甲状腺未分化癌患者の事例について紹介する。

トロン温浴水は、畑晋博士が開発した有機酸を用いる装置に改良を加え調製した。トロン温浴のスケジュールは、1 日 6 回から 8 回、各 10 分間毎日とし、その評価は血液検査等を総合して行った。

2014 年 6 月に甲状腺未分化癌と診断され、外科手術後、タキソール治療（130 mg/body/回）を受けている甲状腺未分化癌患者に関して、トロン温浴以前では骨髄抑制が現れたが、実施後では骨髄抑制は認められず、1 週間に 1 回、合計 11 回のタキソール連続投与が可能であった。また、タキソールの重大な副作用として認められている抹消神経障害も軽微なものであった。一方、2016 年 6 月までに甲状腺未分化癌の再発が 4 回起こったが、通常の甲状腺未分化癌と異なり進行が遅いことなどもあり、3 回までは切除手術のみで対応可能であった。4 回目の再発の際にはレンビマ治療を行った。

トロン温浴の有効性のメカニズムは未だ解明されていないが、癌症状の改善に対して効果的な作用を持つ可能性が示唆された。

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HATO Project / Practice of Radiation Education through Partnership of Teacher Education Universities
HATO プロジェクト/ 大学間連携による放射線教育の実践

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In Japan, curriculum guideline (Course of Study), for junior high school science was revised in 2008, and radiation education was added in the guideline of school science. After Fukushima Daiichi nuclear power plant accident of 2011, scientific literacy on radiation/radioactivity is socially demanded.

Under the circumstance described above, teacher training to produce junior high school science teachers who can teach radiation/radioactivity based on scientific perspective has become an urgent task in Japan. Since 2012, four Teacher Education Universities (**H**okkaido University of Education, **A**ichi University of Education, **T**okyo Gakugei University（TGU）, **O**saka Kyoiku University) have been engaged in the "HATO-Project". Under this big project, Tokyo Gakugei University has managed a sub-project; “HATO Radiation Education Project” whose objective is pre-service teacher training of radiation education for junior high school science. In this project we started two new subjects “Radiation Education I” and “Radiation Education II” in TGU from 2014. The former one is for the students of the four universities, and is made of lectures and educational experiments. The latter one (Radiation Education II) is for the students of TGU, and is made of lectures and practical work such as practice teaching at junior high school. In addition, we have developed teaching materials of radiation education (Video contents and “Teaching Materials Package for teachers”). Details will be reported at the conference.

日本では、平成20年度(2008年)に中学校の学習指導要領の改定が行われた。そこで、放射線教育が学習指導要領に加わった。また、2011年の東京電力福島第一原子力発電所の事故により、放射線や放射能に対する科学的リテラシーが一般にも求められるようになった。このような状況下で、日本では、科学的視点に立った放射線教育を指導できる中学校理科教員の養成が急務となった。

2012年から、4つの教員養成系大学（北海道教育大学、愛知教育大学、東京学芸大学（TGU）、大阪教育大学）が連携する「HATOプロジェクト」が立ち上がった。このプロジェクトの中の1つに、東京学芸大学が主催する「放射線教育プロジェクト」がある。このプロジェクトは、科学的視点に立った放射線教育を指導できる中学校理科教員の養成が目的である。このプロジェクトで、東京学芸大学では「放射線教育Ｉ」「放射線教育Ⅱ」の２つの授業を開設した。前者「放射線教育Ｉ」はHATO連携4大学の学生が参加し、放射線に関する講義と実験を受講する。後者「放射線教育Ⅱ」は、東京学芸大学の学生が、放射線を教える授業計画を立てる講義と、中学校での教育実習に参画する。また、我々は放射線教育の教材開発（ビデオコンテンツ、授業パッケージ）も行った。詳細については、カンファレンスにて報告を行う。

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本研究は、文部科学省国立大学改革強化推進補助金「大学間連携による教員養成の高度化支援システムの構築―教員養成ルネッサンス・HATO プロジェクト―」の助成を受けて行ったものです。
HATO Project　http://hato-project.jp/index.html (December 2016)

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How to Explain Radiation Health Risk to the General Public
— Lessons learned from Chernobyl and Fukushima Nuclear Power Plant Accidents —

放射線健康リスクを一般公衆にどのように説明するのか
— チェルノブイリと福島の原発事故から学んだ教訓 —

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I have passed through many difficulties and had a chance to actually realize the significance of responsibilities from the nuclear power plant accidents of Chernobyl and Fukushima on accurate evaluation of radiation risk and radiation health effects when communicating with the public. The public has already exposed similar negative feelings about terror, tragedy of the atomic bombings and nuclear accidents, frustration about the widely spreading illusion of nuclear safety before the accidents; we thus have many difficulties for a long time when we challenge to perform crisis and post-crisis radiation risk communications.

At first we should realize that there are two types of radiation health effects: an acute radiation syndrome, the so-called deterministic effect (tissue reaction) due to a massive radiation exposure, and chronic radiation damages and genetic effect, which underlie the stochastic effects caused by the lower doses or low dose-rate radiation exposure. It is important to understand that health effects of radiation may be very different depending on the level of the dose received. Clearly, we naturally are surrounded by radiation exposures and radiological materials, even from inside our body. Therefore, we should learn comprehensively the effects of low dose and low dose-rate radiation exposure at the standpoint of daily life and considering other health risk factors.

I was one of the medical experts and the advisors of radiation health risk management to command the emergency radiation medicine in Fukushima just after the accident. At first we tried to mitigate and block the radiation health risk to the general population in Fukushima, especially in order to calm down exaggerated anxiety and mental stress, and then, at present, are facing more challenges at the frontline of the individual risk management. When we see people’s feelings and difficulties of the daily lives of evacuation, we surely understand their deep damages and all negative consequences. If people could admit that “It is no use crying over spilt milk“, it would be possible to forward positively radiation risk communication. However, many still suffer from post-traumatic stresses, social stigma such as discrimination and inequality, even from disruption of local communities and dramatic changes of daily life-style; they sometimes could not avoid escaping from individual self-stigmatization. We should keep in mind when we implement a sound radiation education that the negative delayed impact of radiation exposure always influences not only physical, but also affects psychosocial recovery and resilience.

In this presentation, on a basis of our knowledge and own experience of Chernobyl+30 and Fukushima+5, an accurate and well-balanced way of education in radiation health risk will be mainly introduced.

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3. Ohtsuru A, Tanigawa K, Kumagai A et al: Nuclear disasters and health: lessons learned, challenges, and proposals. ***Lancet*** 386(9992): 489-497, 2015

チェルノブイリと福島の原発事故から多くの困難を経験し、放射線リスクを正しく評価すると同時に、その健康影響を人々に説明する事の難しさを痛感して来ました。特に、放射線の健康影響を考える場合、すでに人々の心には、原爆や原発事故の恐怖や悲惨さが前提としてあるため、事故前の原発安全神話の喧伝と相まって、事故後のクライシスコミュニュニケーションとその後の長きにわたる復興に向けたポストクライ時の放射線リスクコミュニュニケーションの現場では、多くの困難な課題を抱えることになりました。はじめに、放射線の健康影響には、急性放射線障害、すなわち大量被ばくによる確定的影響（組織反応）と、晩発性放射線障害、すなわち低線量、低線量率被ばくによる発がんリスクや遺伝的影響と呼ばれる確率的影響があります。まず放射線の影響はその被ばく線量によって異なる事を理解する必要があり、自然界にも、また私たちの体内にも放射能は存在し、すべからく放射線を被ばくしている日常生活や他のリスクとの関係から、この低線量の被ばくの影響を総合的に考える事が重要となります。

原発事故に遭遇し、福島の現場で指揮をとった医療人の一人として、はじめに集団健康

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リスクの低減、阻止と、特に、その過剰な不安や精神的ストレスの軽減に奔走し、その後個人リスクへの対峙を余儀なくされてきました。避難と言う困難な生活を余儀なくされている多くの被災者の心情と生活の困難さを考えると、原発事故の現場における深い傷跡が明確です。このような状況を、「覆水盆に返らず」と前向きに考えられる場合には、放射線リスクコミュニュニュケーションも前に進みます。しかし、どうしても事故のトラウマに苛まれ続けると、社会の心ない反応による差別や偏見、そして地域コミュニュティーの分断と大きな生活習慣の変化など、個人のスティグマを遅発性に生み出す恐れが大きいのです。この放射線のもう一つの側面が、身体に留まらず、精神心理的、そして社会的な影響を及ぼすと言うことを念頭に、正確かつ良く熟考された放射線教育を推進する事が肝要となります。

本講演では、チェルノブイリ原発事故から 30 年、そして福島原発事故から 5 年の知識と教訓から、健全で正しい放射線健康リスク教育のあり方を中心に紹介します。

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Radiation Education Initiatives in Fukushima Prefecture
福島県における放射線教育の取り組み

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平成 23 年 3 月の東日本大震災では、地震や津波により本県でも多くの学校、児童生徒等に甚大な被害・犠牲が生じています。被害の状況等については、防災教育指導資料第 1 版～第 3 版を参照していただきたい。

本県では、地震の翌日の 12 日以降の、福島第一原子力発電所の事故により、地震や津波の後処理や、行方不明者の捜索も不十分な状況の中で、多くの住民が避難生活をおくることとなりました。学校等においても、児童生徒の安否確認や教育活動再開等に向けて、未だかつて経験のない道を歩み始めることになりました。

原発事故以来、本県では、子どもたちの健康や生活に対する放射線の影響を、現在及び将来において最小限に食い止めることが極めて重要な課題となっています。これまでの義務教育では、放射線に関する教育が十分に実施されていませんでした。このため本県も例外ではなく、教育関係者でもほとんど知識を持たない状態からのスタートでした。各学校では、校舎内や校庭等の空間線量率の測定や、それらに基づいて子どもたちの屋外活動の制限などを手探りで進めていました。

そのような中、喫緊の重要な課題解決に向けて、指導の拠り所となる指導資料の早期の作成や、それらを元にした教員研修の実施に向けての取組がスタートしています。「放射線等に関する指導資料」は、平成 23 年 11 月発行の第 1 版から、平成 28 年 3 月発行の第 5 版までが既に作成されており、県内の各学校に配付され、各校の実践の参考としていただいております。

平成 25 年度～28 年度は、「放射線教育推進支援事業」の事業として本県の放射線教育の推進に努めてきました。その主な内容は、下記のア～エの内容です。

ア　実践協力校による授業実践例の開発

イ　研修会の開催

- 指導者養成の研修会［本年度はコーディネーター養成講座］
- 地区別の研修会（各学校から担当者が参加、教育事務所毎に年 1 回開催）

ウ　運営協議会の開催（年 6 回開催）

エ　研修会や授業実践で使用する教材等の整備

本県では、原子力発電所の廃炉作業等に今後長期間かかることが予定されています。そこで行われている国や民間の総力をあげた体制で進められている作業に注視し、子どもたちの新たな希望や夢の実現のため、福島発の放射線教育を創造していければと考えています。また、福島県が建設して、本年 7 月にオープンした環境創造センターの活用、県民健康調査における福島県立医科大学等との関連施策との連携など、福島県ならではの放射線教育の推進について紹介をしていきたいと考えています。

PS－3

Education for Radiation Awareness which Values a Relationship among Schools or People
学校と学校とのつながり、人と人とのつながりを大切にした放射線教育

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1.「学校と学校とのつながり」を大切にした放射線教育

－「放射線教育推進委員会」の発足と探究的な放射線授業の公開 －

2011 年東京電力福島第一原子力発電所事故の年、福島県内小・中・高等学校では、校舎修復や除染活動など、正常な授業再開に向け、県民一丸となって力を尽くしてきました。

次の年の 2012 年、自主研究団体である中学校教育研究会が再開され、放射線の学習が約 30 年間取り扱われなかったこともあり、理科における放射線教育の実践が喫緊の重要課題でした。そこで、福島県中学校教育研究会郡山支部理科部会では、全国を先がけて「**放射線教育推進委員会**」を発足させ、次のような活動を行ってきました。

① 4月総会 → 放射線学習指導案やワークシート等の資料提供・運営予算承認
② 5月から放射線教育推進委員会 → 放射線量計の貸し出し
③ 7月第一次研究協議会 → 放射線授業の実践発表・活用資料の紹介
④ 10 月第二次研究協議会 → 放射線授業研究公開・事後研究会の実施
⑤ 1月放射線教育推進委員会 → 学習指導案・ワークシート・PowerPoint 教材 CD 作成
⑥ 2月放射線教育推進委員会 → 「放射線授業の玉手箱」CD を会員全員に配布

このように会員同士が手を取り合うことで、学校間で放射線授業の具体的な情報が共有できるようになり、実験を取り入れた探究的な放射線授業が展開されるようになりました。そして、放射線被ばくを受けた福島県の実情に即した深まりのある授業が実施され、福島県教育委員会発行の「放射線等に関する指導資料」にも授業実践が紹介されています。

2.「人と人とのつながり」を大切にした放射線教育

－ 福島第一原子力発電所**廃炉従業員**をお迎えしての授業 －

2013 年には、放射線を教える授業から、放射線で科学的に探究する力を育む授業に

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チャレンジし、放射線の知識に触れるの理科授業から、探究活動の過程を取り入れた理科授業にレベルアップしました。しかし、自信を持って**福島の復興**をめざし，自ら考え，判断し，行動する福島県民を育てる放射線授業とは言えませんでした。4 年目の 2014 年、初めて福島第一原子力発電所を視察しました。その時、授業の中で、最前線で廃炉作業に従事している方々から直に話を聞くことによって、福島第一原子力発電所の「今」を知り、**福島の復興**への熱い使命感を燃やし続ける子ども達が育てられると感じ、次のような学習を行いました。なお、2015 年には時間を 2 倍とって、丁寧に放射線授業を進めました。

① 福島第一原子力発電所事故を振り返り福島県の空間線量率の年変化を調べる。
② 福島第一原子力発電所視察の資料を基に福島第一原子力発電所の「今」を知る。
③ 東京電力発電所員から立体模型を使って福島第一原子力発電所の「今」を学ぶ。
④ 福島第一原子力発電所の廃炉従業員の話を直に聞き、感想を述べ合う。
⑤ 福島第一原子力発電所で働く方々への応援メッセージを書く。

その他養護教諭と Team Teaching 授業を行って内部被ばくから放射線防護を考えたり、JAEA（日本原子力研究開発機構）の協力で数名の専門家を迎え生徒の質問に応える放射線シンポジウムを開催して放射線に関する疑問を解明したりしました。

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Radiation Education in Fukushima High School
福島高校での放射線教育の取り組み

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福島県立福島高等学校

１　授業の背景と目的

福島高校は福島第一原子力発電所から，北西約 62 km に位置する。事故から 5 年半経過したが、「私は子どもを産めますか」という生徒の質問をいまだに受ける。生徒の放射線に対する不安は消えていない。原子力発電所に近い浜通り地区では，健康への不安がさらに強いという調査結果もある。不安の解消のために福島の安全を学ぶ授業が必要と考え，実施している。

２　方法

日本の学校教育では小学校，中学校，高校で「総合的学習の時間」が設けられ，生徒が教科横断的，探求的に学ぶ時間を設定している。この時間を利用して，科学的事実だけではなく，住民全体で放射線について学び対策を積み重ねてきた地域の活動など，社会的な取り組みついても学ぶ内容を盛り込んでいる。高校 2 年生を対象に合計 9 時間実施した。概要は表の通りである。

回	月日	タイトル	内　　容
第1回 1時間	4/21	学びたいこと 線量計の使い方	・心配なこと，学びたいことについて （アンケート）
第2回 2時間	5/2	放射線の基礎 自宅線量調査説明	・放射線の基礎と福島の状況 ・自宅線量調査の方法説明
第3回 2時間	6/22	宿題の発表 末続地区の５年間	・自宅線量調査の結果（発表） ・暮らしの範囲を測る（外部講師）
第4回 2時間	7/7	福島県相双地区住民の健康について	・被ばくに関する不安や知識の程度 ・慢性疾患の推移について（外部講師）
第5回 2時間	8/22	まとめ	・風評への考え方（討論） ・学んだことの整理，次年度内容の提案

３　結果と考察

生徒の自宅の空間線量と生徒の個人線量を，同型機で同時期に調査し，その結果を互いに情報共有することは，線量の相場観を形成し，福島の生活に対する不安を和らげるのに特に有効であった。同じ授業時間の後半に，住民が互いに連帯して地域全体の線量を調べ情報共有し地域の生活を守ってきた活動について学ぶことで，自ら線量測定し情報を共有しあうことの重要性を深く捉えることができた。

４　文献

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Recent Support Activities of Teaching Practice in Radiation Education Forum

放射線教育フォーラムにおける近年の授業実践支援活動

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In Japan the learning guidance for radiation in the junior high school science was resumed 5 years ago for the first time in 30 years. In addition, it has been strengthened based on lessons learned from the nuclear disaster in Fukushima. However, if you look over the whole of Japan, as a matter of fact, many of the teachers are actually in such situation that they hesitate or do not know what to do in the practice of radiation lesson. On the other hands, there are teachers and regions who are practicing with enthusiasm on pioneering teaching practices on radiation classes.

Radiation Education Forum is working on the activities to support science teachers to disseminate radiation education nationwide in junior high schools, through planning and holding pubic panel discussions where constructive opinions have been exchanged on the practice of radiation classes, between experts and the teachers with leading experiences, or between the teachers. In junior high school science textbooks that was began to be used this fiscal year, enrichment of learning contents of radiation is making support for radiation class important. A growing importance of tuition assistance by learning the contents of the radiation has been substantial. For this reason, we are spreading and deepening the discussion on the teaching practice, for the purpose of collecting and providing such practice examples of radiation class, and developed "Teacher's Plaza" set up on the homepage and are promoting utilization for teaching practice support.

中学校理科において放射線に関する学習が 30 年ぶりに 5 年前から指導されるようになったことに加えて、福島での原子力災害を踏まえて放射線学習の指導が強化されている。しかし、全国的に見れば、多くの教員は放射線授業の実践に戸惑いやためらいを感じておられるのが実態である。その一方で、放射線の授業実践を意欲的に取り組んでいる教員や地域も見られる。

放射線教育フォーラムは、そうした先導的な授業経験をもつ教員と専門家・支援者の意見交流及び先生方同士の交流の輪をパネル討論、勉強会などにより、全国的に広げる活動に取り組んでいる。これらによって学校における放射線に関わる授業実践を支援し、放射線教育の全国的な普及を目指している。

2016 年度から使われている中学校理科教科書では、放射線の学習内容が充実したことによって授業支援の重要性が高まっている。このため、授業実践に関わる議論を促進するとともに、放射線授業の実践例の収集・提供などを目的として、ホームページ上に設けた「先生の広場」の整備・活用を進めている。

こうした NPO 活動に関わるさまざまな情報は、すでに 55 号を数える放射線教育フォーラムニュースレターや定期刊行誌「放射線教育」誌などを通して発信に努めている。

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Support Activities of Nuclear and Radiation Education in Atomic Energy Society of Japan (AESJ)

日本原子力学会における原子力・放射線教育の支援活動

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1. Nuclear and Radiation Education in Elementary, Junior High and High Schools

The concept of energy and electric power generation (Water Power, Thermal Power, Nuclear Power, Renewable Energy) are introduced in elementary schools.

Nuclear power plant and radiations are described in the junior high school science textbooks. Damages by Great East Japan Earthquake, the evacuation of peoples and the environmental pollution caused by Fukushima Daiichi Nuclear Power Accidents are mentioned in the textbooks.

The structure of nucleus and mechanism of nuclear fission are explained in the high school physics. But, less than 20% of high school students study physics. So the knowledge about the nuclear power and radiations stays at the level of junior high school for the majority of high school students. Energy resources, the advantages and disadvantages of nuclear power, status of renewable energies and the influences by the Fukushima Daiichi Nuclear Power accident etc. are written in the civics history and geography textbooks.

2. Support Activities of the Nuclear and Radiation Education in Atomic Energy Society of Japan (AESJ)

2.1 Activity of AESJ Educational Committee

The sub-committee about elementary and secondary education in AESJ Educational Committee researched and reported about the descriptions of energy, nuclear power and radiations in the textbooks for last twenty years. Incomplete or inadequate descriptions about the effects of radiation exposure, safety of radioactive waste are picked up in the report. The report has been submitted to the Ministry of education and textbook companies.

2.2 Meeting and Dialogue with Students by Senior Network Members

Senior Network (SNW) of AESJ is established in 2005. SNW members talk with university and college students about nuclear power to encourage and foster their dreams in the dialogue meeting. Two or three SNW members talk with 5 to 7 students in a meeting for sufficient exchange of opinions.

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_2.3_ Cooperation with Japan Network of Human Resources Development (JN-HRD.Net)

JN-HRD.Net was established 2011 for the cooperation of nuclear-related organizations. ASEJ has been a member from the start. JN-HRD will help member organization to cooperate each other and to help activities. One of major objectives of JN-HRD is support activities of elementary and secondary education. The JN-HRD sub–committee offers teaching materials, model class plans about nuclear and radiation education.

１．初等中等教育段階での原子力･放射線教育の状況

日本では、小学校ではエネルギーの概念や発電電力の種類（水力、火力、原子力、再生可能エネルギー）の紹介がある。

中学校の理科では簡単な原子力発電のしくみおよび放射線に関する説明がある。また、社会系の教科書では東日本大震災による大きい被害とともに、福島第一原子力発電所事故によって周辺住民の避難、環境汚染などが起きたことが記載されている。

高等学校では物理において原子核の構造や核分裂のしくみが述べられる。しかし、高校生の理科の選択科目のうち、物理の履修者は 20%以下といわれており、多くの生徒の原子力･放射線に関する知識レベルは中学校で学習したレベルに留まっているのが実情である。社会系の歴史、地理、公民科目では、エネルギー資源、原子力発電の長･短所、再生可能エネルギーの状況および福島第一原子力発電所事故の社会的影響などが取り上げられている。

２．日本原子力学会の原子力･放射線教育の支援活動

２．１　原子力学会教育委員会の活動

原子力学会には常置の教育委員会があり、その中の初等中等教育小委員会では約 20 年にわたって初等中等教科書におけるエネルギー、原子力、放射線に関する記述を調査して、報告書をまとめている。教科書はほぼ正確に記述されているが、中には放射線の人体への影響、放射性廃棄物の安全性などについて、やや不十分な個所も見られた。これらは報告書に記載して、教科書を検定する文部科学省や教科書会社等に提出し、原子力学会でも公表している。

２．２　シニアネットワークの学生との対話活動

原子力学会のシニアネットワーク連絡会は、2005 年に設置された。企業や研究機関などで活躍してきたシニア世代が、次世代を担う若者との対話活動を行っている。毎年全国各地の大学、高専の約 10 個所で学生との集会（基調講演と小人数のグループに分かれてシニアとの対話）を開き、学生の原子力･放射線への理解・関心を高める対話や、キャリア支援へのアドバイスなどを行なっている。

２．３ 原子力人材育成ネットワークとの連携

原子力関係機関が協議して2011 年に｢原子力人材育成ネットワーク(JN-HRD)｣を設立し、原子力人材育成活動・事業等を推進してきた。この活動の一部に、初等中等教育および高等教育の支援活動を行う分科会が置かれている。中学校における原子力･放射線教育の充実のため、教諭の教材、授業モデルの紹介などを行っている。

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