福島大学環境放射能研究所

第10回

成果報告会

The 10th Annual Symposium of the IER,
Fukushima University

要旨集
Abstracts

日時
Date
2024年 2月 28日 (水) ～ 29日 (木)
From Wed, February 28 to Thu, February 29, 2024

会場
Vanue
コラッセふくしま
CORASSE Fukushima

主催 国立大学法人 福島大学 Fukushima University　環境放射能研究所 INSTITUTE OF ENVIRONMENTAL RADIOACTIVITY

後援 福島県　筑波大学　広島大学　長崎大学　東京海洋大学
公立大学法人福島県立医科大学
国立研究開発法人量子科学技術研究開発機構

はじめに

　今回の成果報告会のテーマは「福島の森と海はどうなっているか」です。原発事故から10年以上を経て長期的なフェーズの研究対象として、福島大学環境放射能研究所では福島の森と海について重点的に取り組んできました。大部分の森林は除染が行われず、原発事故で放出された放射性物質がこの先も継続して存在し続ける可能性があります。帰還困難区域の避難指示解除が進んでいますが、森林と隣接する地域の避難指示解除も進むでしょう。里の豊かさを支えてきた森林からの恩恵の享受を回復できるかが大きな課題だと考えています。そのためには森林内での放射能の分布が時間経過とともにどのように変化してきたのかについて、従来からの研究を継続するとともに、将来的な変化についての仮説を視野に入れながら、研究を通じて見極めることが重要です。

　もう一方の海については、2023年夏から開始された処理水放出により、関心が集まりました。ヒトや生態系への安全性には問題のない放出を行う計画ですが、中国への水産物輸出が滞るという問題が発生しています。東日本大震災からの復興の歩みを妨げることのないよう、科学的研究の観点からも新たな知見や情報の開示を進めていかねばなりません。処理水には除去ができないトリチウムが含まれていることから、トリチウムについての安全性や生態系内での挙動等についても関心が高まっています。トリチウムは宇宙線により生成され、天然にも存在しています。福島での人工的な放出の影響を評価するためには天然トリチウムの環境動態も継続的に観測し、バックグラウンドを把握する必要があります。

　さて、森林と海とが河川を通じて栄養塩や有機物を輸送することなど、生物地球化学的な観点でさまざまなことが語られています。森林生態系では土壌生成や窒素固定によって生物が利用可能な栄養が生成されています。これらの一部が河川を通じて森林の外に運ばれ、下流地域や海洋にも恩恵をもたらします。約5億年前、原始の海から陸地に進出したカビと植物の連携が現在の豊かな大地のもととなっており、そしてそれらパイオニアの活動が今もなお続いているようです。放射性セシウムの動きを理解することは重要ですが、反対に放射能の動きから推定されるそもそもの自然のプロセスを理解することが今後一層重要性を増すと考えられます。例えば、トリチウム濃度は地下水の年代推定にも用いられ、地下水資源量の推定にも役立つ水文学的解析のツールとしても活用されています。これは、放射能が自然のプロセス理解に用いられる一つの例です。

　成果報告会第10回の節目にこれまでの研究を振り返りながら、自然の理解や損傷した原子炉の廃炉など長期的課題を視野に今後の方向性についてご意見を賜りたいと思います。

<div style="text-align: right">

福島大学環境放射能研究所

所長　難波　謙二

</div>

FOREWORD

The theme of this 10th Annual Symposium is "Forest and Marine Environments in Fukushima now." After more than 10 years since the incident, the Institute of Environmental Radioactivity, Fukushima University (IER) has been focusing on the forests and oceans of Fukushima as subjects of long-term phase research. Most of the forests have not undergone decontamination, and there is a possibility that radioactive materials released by the nuclear accident may continue to persist in the future. Evacuation orders are being lifted in the difficult-to-return zones, and it is likely that evacuation orders in areas adjacent to forests will also be lifted. We believe that recovering the benefits from the forests that have supported the richness of the villages is a significant challenge. Therefore, it is important to continue our existing research on how the distribution of radioactivity in the forests has changed over time, and to determine this through research while considering hypotheses about future changes.

Regarding the marine environment, there has been a growing concern due to the release of treated water initiated in the summer of 2023. The plan is to release treated water with no safety issues for human health and ecosystems; however, an issue has arisen concerning disruptions in the export of marine products to China. To ensure the progress of reconstruction after the Great East Japan Earthquake is not hindered, it is necessary to continue to advance new findings and disclose information from a scientific research perspective. The treated water contains tritium, which cannot be removed, leading to increased interest in the safety of tritium and its behavior in the ecosystem. Tritium is naturally produced by cosmic rays and exists in the environment. To detect the impact of artificial tritium releases in Fukushima, it is necessary to regularly monitor the environmental dynamics of natural tritium and understand the background.

Now, various aspects are discussed from a biogeochemical perspective, such as the transportation of nutrients and organic matter between forests and the ocean through rivers. In forest ecosystems, nutrients available to organisms are generated through processes like soil formation and nitrogen fixation. Some of these nutrients are transported beyond the forests through rivers, benefiting downstream areas and the ocean. Approximately 500 million years ago, the collaboration between fungi and plants that advanced from the primordial sea to the land laid the foundation for the current fertile land, and the activities of these pioneers seem to persist to this day. While it is important to understand the movement of radiocesium, it is also considered increasingly important to comprehend the fundamental natural processes inferred from the movement of radioactivity. For instance, tritium concentration is utilized in estimating the age of groundwater and serves as a hydrological analysis tool contributing to the estimation of groundwater resources. This is one example that illustrates how radioactivity is employed as a tool to understand natural processes.

At the 10th anniversary of the annual symposium, we would like to look back on our research to date and ask for your opinions on future directions with a view to long-term issues such as understanding nature and decommissioning damaged nuclear reactors.

NANBA Kenji

Director, Institute of Environmental Radioactivity, Fukushima University

Working Group for
The 10th Annual Symposium of the IER, Fukushima University

Aleksei KONOPLEV　　　　　　　　（Project Professor）
Ismail Md. Mofizur RAHMAN　　　　（Associate Professor）
WADA Toshihiro　　　　　　　　　（Associate Professor）
TAKATA Hyoe　　　　　　　　　　（Associate Professor）
Maksym GUSYEV　　　　　　　　　（Project Associate Professor）
ISHINIWA Hiroko　　　　　　　　　（Project Lecturer）
IGARASHI Yasunori　　　　　　　　（Project Lecturer）
KIMURA Airu　　　　　　　　　　　（Staff of the Support Unit）
NAGATA Hiroko　　　　　　　　　　（Research Associate/Coordinator for International Affairs）
MIZUNO Shinobu　　　　　　　　　（Coordinator for International Affairs）
ITO Osamu　　　　　　　　　　　　（Research Coordinator）
CHIBA Mariko　　　　　　　　　　（Research Coordinator）

Institute of Environmental Radioactivity, Fukushima University
1 Kanayagawa, Fukushima City, Fukushima 960-1296, JAPAN
Phone　+81-24-504-2114　Fax　+81-24-503-2921
E-mail　ier@adb.fukushima-u.ac.jp
https://www.ier.fukushima-u.ac.jp/en/

第10回成果報告会　ワーキンググループ

アレクセイ　コノプリョフ　　　　　　　特任教授
イスマイル　モハマド　モフィズル　ラハマン　　准教授
和田　敏裕　　　　　　　　　　　　　　准教授
高田　兵衛　　　　　　　　　　　　　　准教授
マキシム　グシエフ　　　　　　　　　　特任准教授
石庭　寛子　　　　　　　　　　　　　　特任講師
五十嵐康記　　　　　　　　　　　　　　特任講師
木村　会瑠　　　　　　　　　　　　　　主事
永田　広子　　　　　　　　　　　　　　研究員/国際コーディネーター
水野　　忍　　　　　　　　　　　　　　国際コーディネーター
伊藤　　修　　　　　　　　　　　　　　研究コーディネーター
千葉真理子　　　　　　　　　　　　　　研究コーディネーター

福島大学環境放射能研究所
〒960-1296 福島県福島市金谷川 1 番地
電話　024-504-2114　Fax　024-503-2921
E-mail　ier@adb.fukushima-u.ac.jp
https://www.ier.fukushima-u.ac.jp

Venue Guide Map / 会場案内

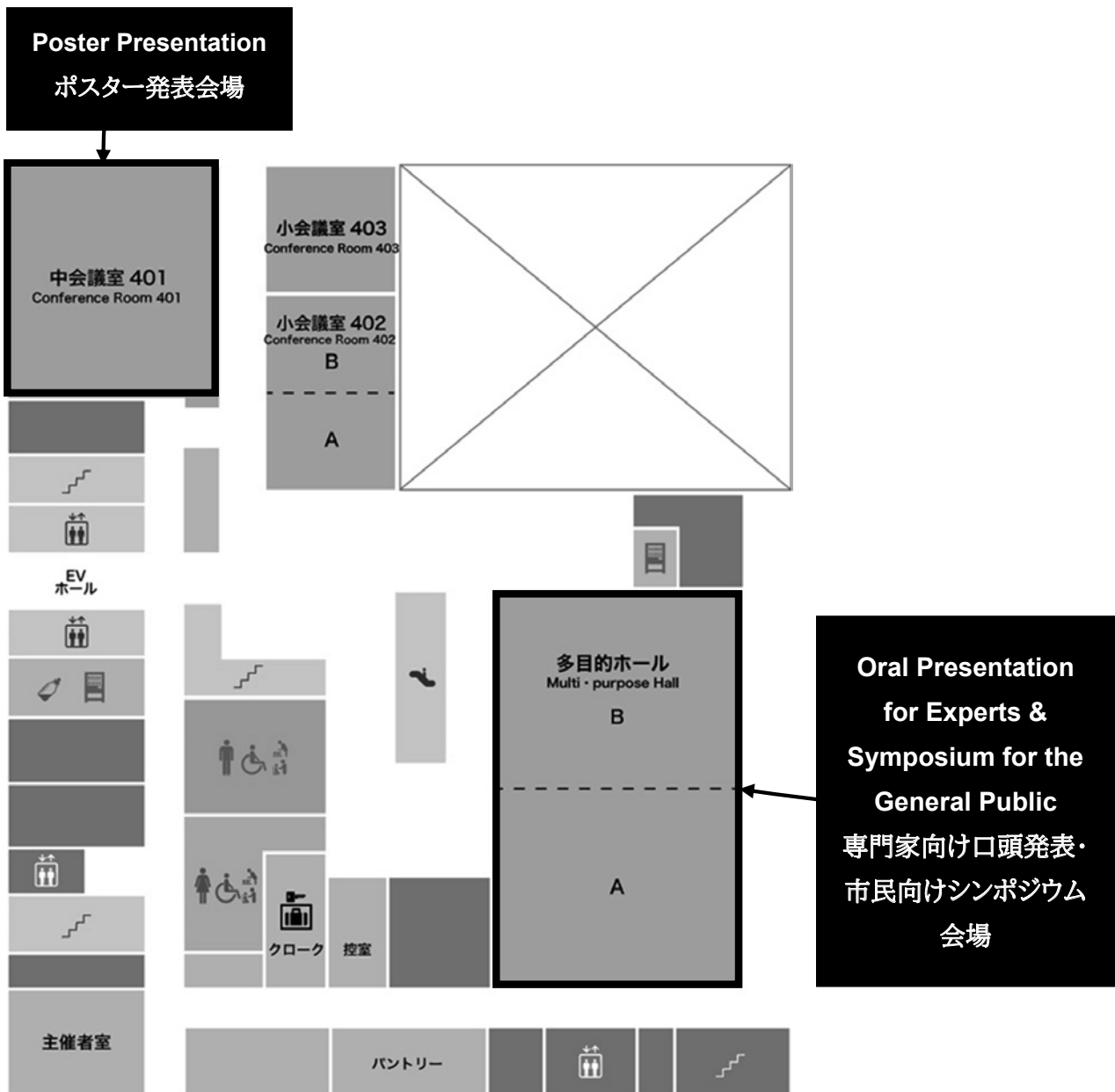## CORASSE Fukushima

1-20 Mikawaminamimachi, Fukushima City,
Fukushima Prefecture, Japan

コラッセふくしま

福島県福島市三河南町 1 番20号

Floor Guide / フロアガイド

Poster Presentation
ポスター発表会場

中会議室 401
Conference Room 401

小会議室 403
Conference Room 403

小会議室 402
Conference Room 402
B

A

EV
ホール

多目的ホール
Multi · purpose Hall
B

A

Oral Presentation
for Experts &
Symposium for the
General Public
専門家向け口頭発表・
市民向けシンポジウム
会場

クローク　控室

主催者室

パントリー

4th Floor / 4 階

2 月29日 February 29, 2024

市民向けシンポジウム／Symposium for the General Public

13：00　**開会挨拶**／**Opening Remarks**
福島大学　学長　三浦浩喜／MIURA Hiroki, President, Fukushima University

13：05　**趣旨説明**／**Overview**
福島大学環境放射能研究所 所長　難波謙二
NANBA Kenji, Director, Institute of Environmental Radioactivity, Fukushima University

13：10　**S-01**　**ALPS処理水放出前後の海のトリチウム**
高田兵衛、佐藤俊、三浦輝、西野圭佑、大槻哲、和田敏裕
Tritium in the marine environment before and after the ALPS treated water discharge
TAKATA Hyoe, SATOH Shun, MIURA Hikaru, NISHINO Keisuke, OHTSUKI Satoru, WADA Toshihiro ………………………………………………………………………… 11

13：35　**S-02**　**森林生態系における放射性核種循環の理解に向けて**
ヴァシル・ヨシェンコ、難波謙二
Toward understanding radionuclide cycling in forest ecosystems
Vasyl YOSCHENKO, NANBA Kenji …………………………………………………… 12

14：00　**休憩**／**Break**

14：10　**S-03**　**自然ベースの福島の農業と林業の「再生」**
金子信博
Nature-based regeneration of agriculture and forestry in Fukushima
KANEKO Nobuhiro ………………………………………………………………………… 13

14：35　**S-04**　**魚類の移動生態の解明と福島県の漁業復興**
和田敏裕
Elucidation of fish migration ecology and fisheries restoration in Fukushima Prefecture
WADA Toshihiro ………………………………………………………………………… 14

15：00　**休憩**／**Break**

15：10　**S-05**　**小動物に蓄積したわずかな量の放射性ストロンチウムを追いかける**
高貝慶隆
Small amounts of radioactive strontium accumulated in small animals
TAKAGAI Yoshitaka ……………………………………………………………………… 15

15：35　**S-06**　**人為起源および天然トリチウム放射性核種による陸水滞留時間の数値モデリング**
マキシム・グシエフ、アレクサンドル・コクゥン、五十嵐康記、高田兵衛、平尾茂一、赤田尚史、柴崎直明
Anthropogenic and natural tritium radionuclide for numerical modeling of terrestrial water transit times
Maksym GUSYEV, Alexandre CAUQUOIN, IGARASHI Yasunori, TAKATA Hyoe, HIRAO Shigekazu, AKATA Naofumi, SHIBASAKI Naoaki ………………………… 16

16：00　**総合討論**／**Discussion**

16：25　**閉会挨拶**／**Closing Remarks**
福島大学環境放射能研究所 副所長/長崎大学 教授　高村昇
TAKAMURA Noboru, Vice Director, Institute of Environmental Radioactivity, Fukushima University／Professor, Nagasaki University

2 月28日 Feburary 28, 2024

Oral Presentation for Experts / 専門家向け口頭発表

Poster Presentation for Experts / 専門家向けポスター発表

Ocean / 海洋

Rivers and Lakes/河川・湖沼

Ecosystem and Effects/生態系・影響

市民向けシンポジウム
Symposium for the General Public

S-01

Tritium in the marine environment before and after the ALPS treated water discharge

TAKATA Hyoe*[1], SATOH Shun[2], MIURA Hikaru[3], NISHINO Keisuke[3], OHTSUKI Satoru[2], WADA Toshihiro[1]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [3]Sustainable System Research Laboratory, Central Research Institute of Electric Power Industry
*Corresponding author：h.takata@ier.fukushima-u.ac.jp

This presentation focuses on spatiotemporal distributions of tritium（H-3）in coastal seawater and marine organisms collected near the Fukushima Daiichi Nuclear Power Plant（FDNPP）from 2021. Activities of H-3 in coastal seawater were about 0.1 Bq/L from 2021 to the early 2023 just before the discharge of ALPS treated water, with no significant change over time. Distribution of H-3 in marine organisms was similar to that in corresponding seawater. Relatively high values were observed within 5 km radius from the outlet on 5 September 2023 during the first discharge（24 August to 11 September）. However, it was not similar on 11 October during the second discharge（5 October to 23 October）. Distribution of tritium in coastal region around the FDNPP could be affected by the coastal currents. We will also present the data after the second discharge.

Keywords：coastal region, tritium level, seawater, marine organism

ALPS処理水放出前後の海のトリチウム

高田兵衛*[1]、佐藤俊[2]、三浦輝[3]、西野圭佑[3]、大槻哲[2]、和田敏裕[1]

[1]福島大学環境放射能研究所、[2]福島大学大学院共生システム理工学研究科、[3]電力中央研究所サステナブルシステム研究本部
*責任者者：h.takata@ier.fukushima-u.ac.jp

本成果報告会では、福島第一原子力発電所（FDNPP）近傍の沿岸海域において2021年から採取された沿岸海水および海洋生物中のトリチウム（H-3）の時空間分布について速報する。沿岸海水中のH-3濃度は、2021年からALPS処理水放出直前の2023年初頭まで約0.1 Bq/Lであり大きな変化は見られなかった。海洋生物中のH-3も同様であった。2023年の夏に最初のALPS処理水が放出され、放出期間中（8月24日〜9月11日）の2023年9月5日に採取した結果、放出口から半径5km以内において、比較的高いトリチウムが観測された。一方、2回目の放出期間中（10月5日〜10月23日）の10月11日に採取した結果は必ずしも1回目と同様の分布ではなかった。FDNPP周辺の沿岸域におけるトリチウムの分布は、主に沿岸の海流などに依存していることが示唆される。本報告会では、2回目以降に得られた結果も加えつつ発表する。

キーワード：沿岸海域、トリチウムレベル、海水、海産生物

S-02

Toward understanding radionuclide cycling in forest ecosystems

Vasyl YOSCHENKO[*1], NANBA Kenji[1]

[1]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：r705@ipc.fukushima-u.ac.jp

The forest ecosystems contaminated by the Fukushima accident are and will remain the largest depot of radiocesium in the terrestrial environment in the long term. Due to the high levels of radioactive contamination, forests in the evacuation areas have been excluded from economic use. The possibility of resuming commercial forestry in severe contaminated areas will depend on the compliance of radiocesium concentrations in forest products, primarily in wood, with the relevant national standards. Accordingly, assessment of the perspectives of forestry revitalization and development of the adequate forestry strategies require knowledge of radiocesium dynamics in forest ecosystems. In this review, we analyze the principal dynamics trends observed in the early and later stages after the deposition in Fukushima forests and in the late stage in Chornobyl forests. We investigate local factors that may be associated with the observed trends, identify knowledge gaps, and discuss perspective researches aimed at improving the understanding of biogeochemical cycles of radionuclides and elements in forest ecosystems.

Keywords：forest ecosystems, radiocesium, radionuclide cycling, Fukushima, Chornobyl

S-03

Nature-based regeneration of agriculture and forestry in Fukushima

KANEKO Nobuhiro[*1]

[1]Faculty of Food and Agricultural Sciences, Fukushima University
*Corresponding author：kaneko-nobuhirro@agri.fukushima-u.ac.jp

Considering farmland and forests as part of the ecosystem, we would like to consider the revitalization of agriculture and forestry in Fukushima on a natural basis. Twelve years after the earthquake, only 38% of the farmers in the formerly evacuated areas have resumed farming. This has not been addressed by facility development, smart farming, and larger-scale management alone. No-tillage cultivation is a basic technology for regenerative agriculture, which improves soil physicochemical properties by ensuring biodiversity in the soil ecosystem. It can keep farmland soil healthy while saving costs, fix carbon dioxide in the soil as a climate change countermeasure, and increase the resilience of agriculture to extreme weather conditions. In forests, the Fukushima Reforestation Project was implemented mainly in planted forests to maintain forestry production, and the Satoyama Reforestation Project in natural forests. However, as with agriculture, there is a lack of supporters and a high degree of dependence on subsidies. Instead of focusing on the limited use of coniferous timber and shiitake mushroom logs, the multifaceted function of forests should be utilized. In mid-mountainous areas, it is effective to cut down and utilize forests around agricultural lands that are obstructing sunlight. Forest can be regenerated at low cost by renewing the forests through sprouting and renewal, and by using the heat as small-scale distributed bioenergy, it can become a self-sufficient resource that can replace fossil fuels. In addition to securing sunlight, the forests can be expected to have a multifaceted effect in preventing animal damage and creating employment. The use of these nature-based resources is important for the reconstruction of Fukushima.

Keywords：soil ecology, regenerative agriculture, coppice forest

自然ベースの福島の農業と林業の「再生」

金子信博[*1]

[1]福島大学食農学類
*責任著者：kaneko-nobuhirro@agri.fukushima-u.ac.jp

農地と森林を生態系の一部と考え、自然ベースでの福島の農林業再生について考えてみたい。震災から12年がたったが、旧避難地域では38％程度しか営農再開されていない。施設整備やスマート農業、そして経営の大型化だけでは対処できていない。不耕起草生栽培は、環境再生型農業の基礎技術であり、土壌生態系の生物多様性を確保することで土壌の理化学性を向上させ，省コストながら農地土壌を健康に保ち、気候変動対策としての土壌への二酸化炭素の固定や、異常気象への栽培のレジリエンスを高めることができる。森林では人工林を中心にふくしま森林再生事業が行われ、天然生林では里山再生事業が行われた。しかし、農業と同様担い手不足であり、補助金への依存度が高い。針葉樹の用材利用としいたけ原木という限られた利用にこだわることなく、森林の多面的機能を活かすべきである。中山間地では、日照を阻害している農地周りの旧薪炭林の森林の伐採利用が有効である。萌芽更新により省コストで森林の再生利用が可能であり、小規模分散型のバイオエネルギーとして熱利用を行うことで、化石燃料を代替できる自給資源となる。日照確保だけでなく、獣害対策、そして雇用の創出といった多面的な効果が期待できる。これら自然ベースの資源利用が福島の復興にとって重要である。

キーワード：土壌生態学、環境再生型農業、萌芽再生林

S-04

Elucidation of fish migration ecology and fisheries restoration in Fukushima Prefecture

WADA Toshihiro*[1]

[1]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：t-wada@ipc.fukushima-u.ac.jp

Approximately 13 years after the Fukushima Daiichi Nuclear Power Plant（FDNPP）accident, radiocesium（^{134}Cs and ^{137}Cs, hereafter Cs）contamination of marine products has almost been settled. However, some fish in the FDNPP port still exceeded the Japanese regulatory limit of 100 Bq/kg, raising a concern about the potential risk of their migration to fishing grounds（outside the 10 km radius from the FDNPP）. Black rockfish *Sebastes schlegelii*, for which shipment restrictions have been implemented by the government, is considered as an example. In recent years, the proportion of individuals exceeding the regulatory limit has tended to increase within the FDNPP port, indicating the necessity to elucidate the contamination mechanism and migration ecology of fish with higher Cs concentrations. In this presentation, first, the relationship between Cs concentrations and the distribution and/or migration of fish observed after the FDNPP accident will be presented based on some examples to show that Cs can be used as a tracer of fish migration. Then, based on the recent bio-logging research using electronic tags（water temperature and depth loggers）attached to fish, the potential applicability of the research to assess the risk of migration of fish from the FDNPP port and its contribution to the fisheries restoration in Fukushima Prefecture will be introduced. The species introduced will be spotted halibut, a high-priced rare flatfish, and tiger puffer fish, the catch of which has been increasing remarkably in Fukushima. Where and how do Fukushima's tiger puffer fish migrate to? I will introduce a part of the mystery.

Keywords：fisheries restoration, radioactive contamination, bio-logging, spotted halibut, tigger puffer fish

魚類の移動生態の解明と福島県の漁業復興

和田敏裕*[1]

[1]福島大学環境放射能研究所
*責任著者：t-wada@ipc.fukushima-u.ac.jp

原発事故からおよそ13年が経過し、海産物の放射性セシウム（^{134}Cs及び^{137}Cs、以下Cs）汚染は収束しつつある。ただし、依然として福島第一原発港内の一部の魚類で基準値100 Bq/kgを超過しており、それらの漁場（原発から10km圏外）への移動が潜在的なリスクとして懸念されている。現在、国の出荷制限措置が取られているクロソイは、原発港内からの移動によるリスクが顕在化した例と考えられている。近年、原発港内では、基準値を超過する個体の割合が増加する傾向にあり、Cs濃度の高い魚類の出現メカニズムや移動生態の解明が強く求められる。本講演では、まず、原発事故以降に認められた魚類の分布や移動とCs濃度の関係性について、特徴的な事例をもとに示し、Csが魚類の移動のトレーサーとして有効であることを示す。また、魚体に装着する電子タグ（水温・深度ロガー）を用いた最新の研究（バイオロギング調査）をもとに、魚類の移動生態研究が、原発港内等からの移動のリスク評価だけでなく、福島県の漁業復興にも寄与する可能性について紹介する。紹介する魚種は幻の高級魚ホシガレイと漁獲量の増加が著しいトラフグである。福島のトラフグはどこにどのように移動するのか？謎の一端を紹介する。

キーワード：漁業復興、放射能汚染、バイオロギング、ホシガレイ、トラフグ

S-05

Small amounts of radioactive strontium accumulated in small animals

TAKAGAI Yoshitaka* [1]

[1] Fukushima University
*Corresponding author：s015@ipc.fukushima-u.ac.jp

Radioactive strontium 90 (^{90}Sr) is one of the most difficult radioactive materials to measure. As far, it has been still challenging to measure extremely small amounts of ^{90}Sr in samples that can be collected in only small quantities (e.g., teeth, bones of small animals, etc.). In 2023, Fukushima University first reported in the world to be able to measure extremely small levels of ^{90}Sr contained in a small amount of sample using thermal ionization mass spectrometry (TIMS). While conventional analysis requires the preparation of gram-level samples (1 to 100 g), this technique requires only 1 milligram (mg) of sample and can accurately measure radioactive strontium levels (0.98 ag (5.0 µBq)) that have never been measured before in the world. This technique enables precise measurement of amount of ^{90}Sr accumulation in the teeth and bones in small animals and fish, which has been unknown until now. In this presentation, I would like to introduce a piece of hot results from this research.

Keywords：strontium 90, ^{90}Sr, thermal ionization mass-spectrometry, small animal, teeth, bone

小動物に蓄積したわずかな量の放射性ストロンチウムを追いかける

高貝慶隆*[1]

[1] 福島大学
*責任著者：s015@ipc.fukushima-u.ac.jp

放射性ストロンチウム90(^{90}Sr)は、放射性物質の中でも特に分析することが難しいものの一つである。現在まで、サンプル量が現実的に少量しか採取できないもの(例えば、歯、小動物の骨など)については、極微量な^{90}Srを測定することすらできなかった。2023年、福島大学は、表面電離型質量分析によって、世界で初めてわずかな量の試料に含まれる^{90}Srを測定できることを報告した。

従来、分析する際はグラムレベル(1～100g)の試料を準備する必要があったが、この技術は1ミリグラム(mg)程度の試料で測定でき、世界で誰もなし遂げたことのないレベルの放射性ストロンチウム量(0.98 ag (5.0 µBq))を正確に測ることができる[ag：アトグラム＝10^{-18} g]。この技術によって、これまで未解明であった小動物や魚類の歯や骨への放射性ストロンチウムの蓄積を正確に測定できるようになる。今回はその研究成果の一端を紹介する。

キーワード：ストロンチウム90、^{90}Sr、表面電離型質量分析、小動物、歯牙、骨

S‒06

Anthropogenic and natural tritium radionuclide for numerical modeling of terrestrial water transit times

Maksym GUSYEV*[1], Alexandre CAUQUOIN[2], IGARASHI Yasunori[1], TAKATA Hyoe[1],

HIRAO Shigekazu[1], AKATA Naofumi[3], SHIBASAKI Naoaki[1,4]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Institute of Industrial Science, The University of Tokyo, [3]Institute of Radiation Emergency Medicine, Hirosaki University, [4]Faculty of Symbiotic Systems Science, Fukushima University
*Corresponding author：r891@ipc.fukushima-u.ac.jp; maksymgusyev@gmail.com

Tritium（^{3}H）radioisotope with a half-life of 12.32 years has been generated due to anthropogenic activities of thermonuclear atmospheric testing in 1960s and nuclear facilities worldwide while ^{3}H is naturally generated in the upper atmosphere by cosmic rays entering the water cycle in the troposphere as the water molecule（HTO）. In 2011, the atmospheric release of the Fukushima Daiichi Nuclear Power Plant（FDNPP）accident contributed anthropogenic ^{3}H to the water cycle, especially for coastal groundwater systems nearby the FDNPP, and the recent international attention has been focused on the Advanced Liquid Processing System（ALPS）treated water discharge from the FDNPP site to the Pacific Ocean. From 1960 to present, ^{3}H measurements in precipitation have been conducted by the Global Network of Isotopes in Precipitation（GNIP）of the International Atomic Energy Agency（IAEA）and World Meteorological Organization（WMO）worldwide and by the Government and Universities across Japan. In Fukushima Prefecture, ^{3}H measurements in monthly precipitation are available at several sites such as Fukushima city, Namie Town, and Institute of Environmental Radioactivity and many surface and coastal water sites have been sampled twice per year accumulating a decade-long record of ^{3}H measurements. For Fukushima surface water sites, measured ^{3}H concentrations indicate low ^{3}H levels and could be utilized to estimate terrestrial water cycle transit times. To utilize ^{3}H-tracer in Fukushima, we combine simulated anthropogenic ^{3}H released by the FDNPP in 2011 with the long-term time-series of ^{3}H in precipitation from 1950 to present in the Tokyo area, which was scaled to Fukushima area between 1.30 and 1.61. In addition, we estimated ^{3}H-tracer mean transit time and subsurface water storage volume after the ALPS-treated water discharge at several headwater catchments near Fukushima city as well as ^{3}H contribution of the ALPS-treated water discharge to the Pacific Ocean. Therefore, we demonstrate that environmental ^{3}H radioisotope is a useful tracer with developed ^{3}H time-series in precipitation and surface water measurements to evaluate terrestrial water cycle in Fukushima Prefecture.

Keywords：tritium radioisotope, numerical modeling, stream water, mean transit times

Oral Presentation for Experts
専門家向け口頭発表

O-01

Tritium in the marine environment before and after the ALPS treated water discharge

TAKATA Hyoe*[1], SATOH Shun[2], MIURA Hikaru[3], NISHINO Keisuke[3], OHTSUKI Satoru[2],
WADA Toshihiro[1]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [3]Sustainable System Research Laboratory, Central Research Institute of Electric Power Industry
*Corresponding author：h.takata@ier.fukushima-u.ac.jp

This presentation focuses on spatiotemporal distributions of tritium（H-3）in coastal seawater and marine organisms collected near the Fukushima Daiichi Nuclear Power Plant（FDNPP）from 2021. Activities of H-3 in coastal seawater were about 0.1 Bq/L from 2021 to the early 2023 just before the discharge of ALPS treated water, with no significant change over time. Distribution of H-3 in marine organisms was similar to that in corresponding seawater. Relatively high values were observed within 5 km radius from the outlet on 5 September 2023 during the first discharge（24 August to 11 September）. However, it was not similar on 11 October during the second discharge（5 October to 23 October）. Distribution of tritium in coastal region around the FDNPP could be affected by the coastal currents. We will also present the data after the second discharge.

Keywords：coastal region, tritium level, seawater, marine organism

ALPS処理水放出前後の海のトリチウム

高田兵衛*[1]、佐藤俊[2]、三浦輝[3]、西野圭佑[3]、大槻哲[2]、和田敏裕[1]

[1]福島大学環境放射能研究所、[2]福島大学大学院共生システム理工学研究科、[3]電力中央研究所サステナブルシステム研究本部
*責任著者：h.takata@ier.fukushima-u.ac.jp

本成果報告会では、福島第一原子力発電所（FDNPP）近傍の沿岸海域において2021年から採取された沿岸海水および海洋生物中のトリチウム（H-3）の時空間分布について速報する。沿岸海水中のH-3濃度は、2021年からALPS処理水放出直前の2023年初頭まで約0.1 Bq/Lであり大きな変化は見られなかった。海洋生物中のH-3も同様であった。2023年の夏に最初のALPS処理水が放出され、放出期間中（8月24日～9月11日）の2023年9月5日に採取した結果、放出口から半径5km以内において、比較的高いトリチウムが観測された。一方、2回目の放出期間中（10月5日～10月23日）の10月11日に採取した結果は必ずしも1回目と同様の分布ではなかった。FDNPP周辺の沿岸域におけるトリチウムの分布は、主に沿岸の海流などに依存していることが示唆される。本報告会では、2回目以降に得られた結果も加えつつ発表する。

キーワード：沿岸海域、トリチウムレベル、海水、海産生物

O-02

Evaluating terrestrial water cycle using numerical modeling with tritium radioisotope in Fukushima, Japan

Maksym GUSYEV[*1], Alexandre CAUQUOIN[2], IGARASHI Yasunori[1], TAKATA Hyoe[1],
HIRAO Shigekazu[1], AKATA Naofumi[3]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Institute of Industrial Science, The University of Tokyo, [3]Institute of Radiation Emergency Medicine, Hirosaki University
[*]Corresponding author：r891@ipc.fukushima-u.ac.jp; maksymgusyev@gmail.com

Environmental tritium（^{3}H）radioisotope with a half-life of 12.32 years is naturally generated in the upper atmosphere by cosmic rays and enters the water cycle in the troposphere as the water molecule（HTO） to become a useful terrestrial water cycle tracer. In 2011, anthropogenic ^{3}H entered the terrestrial water cycle due to the Fukushima Daiichi Nuclear Power Plant（FDNPP）atmospheric release and discharged in Advanced Liquid Processing System（ALPS）treated water from the FDNPP site to the Pacific Ocean in 2023 raising concerns internationally. In Japan, ^{3}H measurements in monthly precipitation have been conducted by the Government and Universities while many surface water sites were sampled twice per year across Fukushima Prefecture accumulating a decade-long record of ^{3}H measurements. However, there are no ^{3}H measurements in precipitation during the FDNPP accident requiring atmospheric numerical modeling to quantify anthropogenic ^{3}H in Fukushima. To utilize ^{3}H-tracer in Fukushima, we combine simulated anthropogenic ^{3}H released by the FDNPP in 2011 with the long-term time-series of ^{3}H in precipitation from 1950 to present in the Tokyo area, which was scaled to Fukushima area. Using annual ^{3}H in precipitation is 2.86 TU-3.70 TU with an average of 3.37 TU from 2016 to 2021 lead to the scaling factor from Tokyo area to Fukushima city between 1.30 and 1.61. For Fukushima surface water sites, measured ^{3}H concentrations indicate low ^{3}H levels and are utilized to estimate terrestrial water cycle transit times. In addition, we sampled several headwater catchments near Fukushima city for measuring ^{3}H in October 2023 and estimated tritium-tracer mean transit time and subsurface water storage volume after the ALPS-treated water discharge. Therefore, we demonstrate that environmental ^{3}H radioisotope is a useful tracer with developed ^{3}H time-series in precipitation and surface water measurements to evaluate terrestrial water cycle in Fukushima.

Keywords：tritium radioisotope, numerical modeling, stream water, mean transit times

O-03

Investigation of atmospheric tritiated water vapor in Fukushima

HIRAO Shigekazu[*1], KAKIUCHI Hideki[2]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Institute for Environmental Sciences
*Corresponding author：r786@ipc.fukushima-u.ac.jp

There is a need for scientific knowledge to evaluate the environmental impact associated with the release of ALPS-treated water stored at the TEPCO's Fukushima Daiichi Nuclear Power Station（FDNPS）into the ocean. Since an atmospheric transport of radionuclides is the fastest pathway to organisms living on land, it is necessary to first obtain actual measurements of atmospheric concentrations. However, the number of atmospheric monitoring is small compared to the substantial expansion of ocean monitoring. In this study, tritium concentrations in atmospheric water vapor in the vicinity of FDNPS were measured and the relationship between the concentration fluctuations and the source and meteorological conditions were examined. It is revealed that the tritium concentration in atmospheric water vapor was ranged within the variation in the past observation although the tritium concentration obtained was slightly higher than that of the recent background level in Japan. These results would be used for assessment of the environmental impact of tritium near the source.

Keywords：tritiated water vapor, atmospheric concentration, LB7

福島での大気水蒸気中トリチウム調査

平尾茂一[*1]、柿内秀樹[2]

[1]福島大学環境放射能研究所、[2]公益財団法人環境科学技術研究所
*責任著者：s-hirao@ipc.fukushima-u.ac.jp

ALPS処理水の海洋放出前後の環境トリチウムの実態解明は喫緊の課題である。大気拡散過程は陸上に住む生物に至る最も速い経路となるため、まずは大気中濃度の実測値を得る必要がある。しかし、海洋モニタリングが大幅に拡充されたことに比べると、大気モニタリングの数は少ない。本研究では、福島第一原子力発電所の近傍のトリチウムの大気水蒸気中濃度を実測し、濃度変動と発生源および気象状況との関連を検討した。その結果、過去の変動幅の範囲内ではあるが、ごく近傍では近年の日本の一般環境よりもやや高いトリチウム濃度であることが示された。これら結果は発生源付近の環境トリチウム影響評価のための基本的な情報として重要である。

キーワード：大気水蒸気トリチウム、大気濃度、LB7

O-04

Evaluation of molecular tritium deposition onto farmland soil

KAKIUCHI Hideki[*1], NAGAI Masaru[1]

[1]Institute for Environmental Sciences
*Corresponding author：ckhsd@ies.or.jp

Tritium（^{3}H）existed in the atmosphere is as main chemical forms of molecular hydrogen（HT）and water molecule（HTO）. In general, the oxidation rate of hydrogen depends on the activity of soil microorganisms, and is affected by the environment conditions such as soil temperature, soil moisture and porosity. HT is thought to be radiologically less toxic compared to HTO, but HT would be potentially toxic for the public by rapid oxidation of HT to HTO on soil surface. Thus, we evaluated the hydrogen deposition velocity of soils in Rokkasho village, Aomori, Japan. For determination of the hydrogen deposition velocity, the closed chambers with a fan were set on the soils of farmlands where Japanese radish was grown, and changes of HT concentration in the chambers were measured. There were several reports evaluated hydrogen oxidation or deposition on soil surface. The reported deposition velocities were from 1.0×10^{-5} to 3.6×10^{-3}, and the data in our experiments were within this range.

Keywords：molecular hydrogen, tritium, deposition

分子状トリチウムの耕作地土壌への沈着の評価

柿内秀樹[*1]、永井勝[1]

[1]公益財団法人環境科学技術研究所
*責任者：ckhsd@ies.or.jp

大気中のトリチウムは主に分子状水素及び水蒸気として存在している。一般的に分子状水素は土壌表面で微生物により酸化されるが、その速度は環境要因により大きく変化することが知られている。分子状トリチウムは水蒸気状トリチウムと比較して放射線影響は小さいとされているが、環境中で速やかに酸化されるため潜在的にその影響は無視できない。そこで耕作地土壌に実験用チャンバーを設置し、チャンバー内HT濃度変化から沈着速度を評価した。その結果得られた値は、これまでに報告されたものと同レベルであった。

キーワード：分子状水素、トリチウム、沈着

O-05

Radiological impact assessment for the ocean discharge of ALPS treated water

TSUMUNE Daisuke[*1], TSUBONO Takaki[2], MISUMI Kazuhiro[2]

[1]Center for Research in Radiation, Isotopes, and Earth System Sciences, University of Tsukuba, [2]Central Research Institute of Electric Power Industry
*Corresponding author：tsumune.daisuke.gw@u.tsukuba.ac.jp

A radiological impact assessment from the oceanic discharge of ALPS-treated water from the Fukushima Daiichi Nuclear Power Plant was conducted. In this evaluation, a regional ocean model used for replicating ^{137}Cs originating from the Fukushima Daiichi Nuclear Power Plant accident was employed to estimate the spatiotemporal average concentration of released radioactive substances in the maritime area. Due to the substantial spatiotemporal variations caused by mesoscale eddies and the Kuroshio Current, direct comparisons between simulation results and observed data, which exhibit significant fluctuations, are challenging. However, simulated ^{137}Cs concentrations attributable to the direct release contributing to the annual average radioactive concentration distribution were found to align well with the annual averaged observed results. Furthermore, it was confirmed that the annual averaged ^{137}Cs concentration distribution from 2013 to 2016 normalized by the direct release rate exhibited a nearly identical pattern. In other words, knowing the release rate allows the prediction of the annual averaged radioactive concentration distribution. Using this model, the concentration distribution of radioactive substances in the ocean resulting from the oceanic discharge of ALPS-treated water was forecasted. In the assessment of the annual dose using the nearby yearly average concentration, the dominant factor was the ingestion of seafood, and the value was at a level that could be disregarded, approximately 10^{-5} mSv/year.

Keywords：ALPS treated water, regional ocean model, radiological impact assessment

ALPS処理水の海洋放出に対する放射線影響評価

津旨大輔[*1]、坪野考樹[2]、三角和弘[2]

[1]筑波大学放射線・アイソトープ地球システム研究センター、[2]電力中央研究所
*責任著者：tsumune.daisuke.gw@u.tsukuba.ac.jp

福島第一原子力発電所からのALPS処理水の海洋放出に対する放射線影響評価が実施された。この評価では、放射性物質の海域における時空間の平均濃度を推定する必要があり、福島第一原子力発電所事故起源の放射性セシウムの再現計算には海洋モデルが使用された。海洋中の^{137}Cs濃度分布は、中規模渦や黒潮の影響により大きな時空間変動を示すため、シミュレーション結果と観測結果の直接的な比較は難しかった。しかし年平均の^{137}Cs濃度分布のシミュレーション結果は、年平均観測結果とよく一致した。また2013年から2016年までの年平均^{137}Cs濃度分布は、直接漏洩率で正規化するとほぼ同様の分布になった。言い換えれば、放出率が分かれば、年平均の放射性物質濃度分布を予測できることが分かった。このモデルを用いて、ALPS処理水の海洋放出による海洋中の放射性物質濃度分布を予測した。近傍の年間平均放射性物質濃度を用いた被ばく線量評価では、海産物の摂取が支配的であり、その値は10^{-5} mSv/yearのオーダーで無視できるレベルであった。

キーワード：ALPS処理水、領域海洋モデル、放射線影響評価

O-06

Independent evaluation by an advisory board of ten years of research by Institute of Environmental Radioactivity on the consequences of the Fukushima Daiichi accident

Brenda HOWARD*[1], Wolfgang RASKOB[2], Sergey FESENKO[3], YOSHIDA Satoshi[4]

[1]UK Centre for Ecology and Hydrology, United Kingdom, [2]Karlsruhe Institute of Technology, Germany, [3]Russian Academy of Sciences, Russian Institute of Radiology and Agroecology, Russian Federation, [4]Institute for Environmental Sciences, Japan
*Corresponding author：bjho@live.com

The Institute of Environmental Radioactivity was rapidly set up as a research centre at Fukushima University after the Fukushima Daichi accident in 2011. It successfully incorporated several internationally renowned scientists from both Japan and other countries with a range of different relevant expertise. A number of staff at the university also participated in addressing the wide range of challenges that Fukushima Prefecture faced after the accident.

The staff at IER faced various challenges related to:

• the need for local scientific expertise regarding the environmental behaviour of the various radioactive releases in terrestrial forested and agricultural areas, and in freshwater and marine systems in Fukushima Prefecture

• active engagement with, and support to, Fukushima Prefecture

• interaction with affected communities to address local concerns and provide a local source of information about the contamination, its impact on agriculture, forested areas and communities.

The IER set up an Advisory Board from several countries to provide an independent annual evaluation of the approaches adopted by IER and the quality and quantity of ongoing research efforts of the IER. From March 2018 onwards the advisory board attended annual meetings in Fukushima to review the activities of IER with online engagement when covid prevented personal attendance.

The quality and quantity of the various outputs of IER research activities was evaluated by the Advisory Board. The research groups in IER included: Rivers and Lakes, Ocean, Ecosystems, Measurement and Analysis, Speciation Radiochemistry, and Modelling. The Board listened to lectures on the various activities, attended poster sessions, reviewed annual reports, refereed papers and conference contributions through engagement with each topic area leader. The advisory board critically evaluated each subsequent annual report provided by IER and suggested possible improvements that might be made. It also evaluated the quantity and quality of research output of IER including refereed scientific publications, scientific conference papers and the interaction with local organizations and communities.

Poster Presentation for Experts

専門家向けポスター発表

P-01

Spatial and vertical distribution of radiocesium in marine sediment cores of Fukushima Prefecture

Pierre-Alexis CHABOCHE[*1,2], WAKIYAMA Yoshifumi[2], TAKATA Hyoe[2], WADA Toshihiro[2], MISONOU Toshiharu[3], SHIRIBIKI Takehiko[3], FUNAKI Hironori[3]

[1]International Research Fellow of Japan Society for the Promotion of Science (Postdoctoral Fellowships for Research in Japan (Standard)), [2]Institute of Environmental Radioactivity, Fukushima University, [3]Sector of Fukushima Research and Development, Japan Atomic Energy Agency
*Corresponding author：p.chaboche@protonmail.com

The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) incident, triggered by the Great East Japan Earthquake and subsequent tsunami in March 2011, resulted in the release of significant quantities of radionuclides into the terrestrial and marine environments of Fukushima Prefecture. While the activity of radiocesium (i.e., ^{134}Cs and ^{137}Cs) in these environments has decreased since the accident, continuous inputs through rivers draining and eroding the main terrestrial radioactive plume have been measured, maintaining elevated levels of ^{137}Cs in riverine and coastal sediment deposited off the Prefecture's coast. Consequently, identifying the sources of sediment is required to elucidate the links between terrestrial and marine radiocesium dynamics and to anticipate the fate of persistent radionuclides in the environment. Our study aims to implement the fingerprinting technique for quantifying catchment source contributions to coastal sediment and the associated radionuclides deposited off the coast of Fukushima Prefecture. Six targeted coastal sediment cores, ranging from 20 to 60 cm in depth, were collected during cruise campaigns between July and September 2022 at the Ota (n=2), Niida (n=1), and Ukedo (n=3) river mouths. Before gamma spectrometry measurements, sediment cores were opened, cut into 2 cm increments, oven-dried at 50 ℃ for at least 48 h, ground, and passed through a 2-mm sieve. Preliminary findings concerning the spatial and depth distribution of radiocesium in these samples reveal a strong heterogeneity, with the highest radiocesium levels (up to 134 ± 2 and 4882 ± 11 Bq kg^{-1} for ^{134}Cs and ^{137}Cs, respectively) observed in coastal sediment cores situated at the Ukedo river mouth. A strong relationship is observed between the particle size measured in these sediment cores and radiocesium activities, with higher levels observed in finer sediment. Conversely, no traces or low levels of Fukushima-derived radiocesium were detected in the Niida and one sediment core of the Ota River mouths. Importantly, features of the seafloor topography were shown to be significant factors controlling the spatial and depth distribution of radiocesium off Fukushima's coast. Additional measurements are currently conducted to determine the physico-chemical properties of this sediment (XRF core scanner, X-ray CT scanner, elemental geochemical concentration) to identify the optimal combination of tracers. These selected tracers will be incorporated into widely used un-mixing models to quantify source contributions to coastal sediment and develop an original approach for marine environments. This increased knowledge will undoubtedly be useful to understand ^{137}Cs transfer processes between continental and marine environments, as well as for watershed and coastal management in the post-accidental context of the FDNPP.

Keywords：North Pacific Ocean, sediment tracing, heavy rainfall event

P-02

Estimation of Cs-137 fluxes into the ocean: comparison of direct release and river discharge

SATOH Shun[*1], TAKATA Hyoe[2], WAKIYAMA Yoshifumi[2], OHTSUKI Satoru[1]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：s2270054@ipc.fukushima-u.ac.jp

It has been 12 years since the Fukushima Daiichi Nuclear Power Plant（FDNPP）accident in March 2011, and the Cs-137 concentrations in the coastal waters of Fukushima continues to be elevated compared to pre-accident levels. This study focuses on the factors that maintain Cs-137 concentrations in coastal areas, with particular attention to the direct release from the FDNPP and the introduction of Cs-137 deposited on land through rivers. We estimated an annual flux for each source. The flux through rivers was calculated separately for dissolved and particulate phases. The estimated value for direct release decreased after the construction of the seaside impermeable wall at the FDNPP. Furthermore, fluxes may have been affected by other factors such as typhoons and an increase in the production of contaminated water. The flux through rivers exhibited a decreasing trend for dissolved Cs-137, however, flux for particulate Cs-137 almost did not change until 2018. Furthermore, total fluxes of dissolved and particulate Cs-137 during high-flow events may have probably overwhelmed the direct release. Comparison of the Cs-137 concentration between monitoring data in the coastal seawater and estimated values calculated from the fluxes will be discussed in the presentation.

Keywords：Fukushima Daiichi Nuclear Power Plant, direct release, river, flux

事故後のメタデータを用いた福島沿岸海域への放射性セシウムの流入量の推定

佐藤俊[*1]、高田兵衛[2]、脇山義史[2]、大槻哲[1]

[1]福島大学大学院共生システム理工学研究科、[2]福島大学環境放射能研究所
*責任著者：s2270054@ipc.fukushima-u.ac.jp

2011年３月の福島第一原子力発電所(FDNPP)事故から12年経過した現在も、福島沿岸海域で海水中のCs-137濃度が事故前に比べて高い状態が継続している。本研究では沿岸域のCs-137濃度の高止まりの要因として、FDNPPからの直接流入、陸上に沈着したCs-137の河川経由での流入に注目した。それらの経年的な流入量を推定し、福島沿岸海域に与える影響を考察した。河川を経由したCs-137の流入量は溶存態Csと粒子態Csに分けて算出した。直接流入量の推定値は、FDNPPで汚染水対策として設置された海側遮水壁の設置後、減少した。また、台風などの環境要因や、汚染水発生量の増加などに伴い流入量は変化している可能性が考えられる。河川を経由した流入量は、減少傾向がみられた溶存態に対し、粒子態では2018年前後で下げ止まりの傾向があった。また、両者の流入量の比較から、洪水時の河川からの流入量が直接流入量を上回っていた可能性が示された。さらには、沿岸でのCs-137濃度の推定値と実測値との比較をしながら、両流出量の沿岸域への影響についても考察する。

キーワード：福島第一原子力発電所、直接流入、河川、流入量

P-03

Field experimental study of basic mechanisms of dissolved ^{137}Cs concentration seasonality in ponds nearby the Fukushima Daiichi Nuclear Power Plant

Alexei KONOPLEV[*1], KUROSAWA Honoka[2], WAKIYAMA Yoshifumi[1], IGARASHI Yasunori[1], NANBA Kenji[1,3]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [3]Faculty of Symbiotic Systems Science, Fukushima University
[*]Corresponding author：r701@ipc.fukushima-u.ac.jp

Analysis of available monitoring data for freshwaters of accidentally contaminated areas has revealed two basic mechanisms responsible for regular seasonal variations of dissolved ^{137}Cs concentrations in water bodies（increase in summer and decrease in winter）: 1）temperature dependence of radiocesium desorption from sediments to solution, and 2）ion-exchange remobilization of radiocesium by cations of ammonium generated as a result of organic matter decomposition in anoxic conditions. An equation has been derived describing seasonal variations of dissolved radiocesium in water bodies considering two key parameters: water temperature and combined concentration of basic competitive cations. In Fukushima rivers, which are mostly shallow and fast flowing, ammonium concentration is usually negligible. For them the predominant factor of dissolved ^{137}Cs seasonality is temperature dependence of ^{137}Cs desorption. For stagnated stratified waters of ponds, lakes and dam reservoirs in anoxic conditions, the role of ammonium in ^{137}Cs mobilization can be comparable with that of water temperature or even be prevalent. Results of a field experimental study of dissolved ^{137}Cs seasonality in three ponds of Okuma town, located in difficult-to-return zone of the Fukushima Daiichi Nuclear Power Plant, are presented. Filtration of one water sample was carried out *in situ*（at water temperature corresponding to the current temperature of water body）, while the other water sample was filtered in laboratory at room temperature（about 20℃）with a view to investigate influence of temperature and storage on solid-liquid distribution of ^{137}Cs in the collected water samples. Water temperature was measured during sampling using a hydro-chemical probe. Ammonium was measured in the laboratory immediately on return to IER after sampling in a separate sample kept in a cooler during transportation. Potassium was measured in the same sample by ion chromatography. Particulate and dissolved ^{137}Cs in water samples were measured by gamma-spectrometry separately after filtration. Comparison of *in situ* and laboratory filtration results has shown the validity of laboratory filtration for dissolved ^{137}Cs monitoring in water bodies. The proposed model and derived equation describe reasonably well the seasonality of dissolved ^{137}Cs in the investigated ponds. This research was supported by Environmental Radioactivity Research Center（ERAN）Projects I-23-11 and I-23-12.

Keywords：Fukushima, ponds, ^{137}Cs, dissolved, seasonality, sorption-desorption, water temperature, ammonium

P-04

Using ^{137}Cs re-sampling and depth-incremental technique to investigate the fate of Chernobyl-derived particulate ^{137}Cs transferred with sediment fluxes

Maksim M. IVANOV[*1], Valentin GOLOSOV[1,2], Nadezhda IVANOVA[1], Anna USACHEVA[2,3],

Nikolai LUGOVOI[1,2], Nikita DIMCHUK[2,4], Nikita KVASOV[2,4], Polina FOMINIKH[2], Yulia POLETAYEVA[2]

[1]Laboratory of Soil Erosion and River Channel Processes, Faculty of Geography, Lomonosov Moscow State University, [2]Institute of Geography, Russian Academy of Science, [3]Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Russian Academy of Sciences, [4]Moscow Timiryazev Agricultural Academy

[*]Corresponding author: ivanovm@bk.ru

Decades after the Chernobyl accident, accelerated erosion of arable land within contaminated rural landscapes is believed to be the dominant source of particulate ^{137}Cs in riverine systems. Recently the major part of sediments eroded from arable lands re-deposited either within cultivated slopes or in the upper reaches of the fluvial network （slope hollows and dry valleys） due to serious decreasing of erosion during snow-melting in European part of Russia. Re-sampling applied to global ^{137}Cs fallout is widely used method to assess soil redistribution rates within cultivated fields, but it requires decades to be successfully implemented. The given approach hasn't been used in areas with high level of Chernobyl-derived ^{137}Cs initial fallout. The results of the first experience of re-sampling study within the small agricultural catchment in Plavsk district of Tula region are presented. Statistically reliable changes in the ^{137}Cs inventories for time window 1997 - 2023 were identified for the studied cultivated catchment. The mean decrease in ^{137}Cs inventories is about 11% for 26 years. The soil erosion rates determined based on application of conversion models are in a good agreement with results of soil loss calculation using both USLE and WATEM/SEDEM erosion models. The concentration of ^{137}Cs in sediments re-deposited in dry valley bottoms during the post-Chernobyl period experienced a sharp decrease in the first years after Chernobyl-derived ^{137}Cs initial fallout and then remains relatively stable with a smooth downward trend. On average, the concentration decreased by at least more than two times.

Keywords：Chernobyl contamination, ^{137}Cs re-sampling technique, soil erosion, accumulation, fluvial geomorphology

P-05

Tritium and aquatic living organisms: influence, transformation, and accumulation

Lidiia BONDAREVA[*1]

[1]Federal Scientific Center of Hygiene named after F.F. Erisman, Moscow region, Russia
*Corresponding author：lydiabondareva@gmail.com

Tritium is a by-product of many radiochemical reactions in the nuclear industry, and its effects on water organisms, particularly low-dose effects, are worthy of special attention. In the past few decades, the low-dose effects of tritium on aquatic biota have been studied in detail using luminous marine bacteria as model microorganisms as well as during the transformation of fresh tritium water to organically bound tritium. Briefly, despite the low energy of tritium decay, its influence on living organisms in the water environment may be considerable. The activation of aquatic plants' functions in natural reservoirs, due to the low tritium content, may result in unpredictable changes in food chains and an imbalance of natural equilibria. These results confirm that during chronic interaction of tritium with aquatic plants, processes occur associated with the intensive accumulation and retention of tritium in the biological structures of living organisms. The accumulation of tritium in the liver of fish occurs mainly due to the formation of organically bound tritium, and, for the most part, these compounds are non-exchangeable. This leads to the fact that the half-life of tritium in the liver is the longest and reaches 550 days.

Keywords：tritium, living organisms, water environments, organically bound tritium

P-06

Variations in ^{137}Cs concentrations in river and coastal seawater during high-flow events

WAKIYAMA Yoshifumi[*1], SATOH Shun[2], TAKATA Hyoe[1], Pierre-Alexis CHABOCHE[1,3], KUROSAWA Honoka[2]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [3]Japan Society for the Promotion of Science
*Corresponding author：wakiyama@ipc.fukushima-u.ac.jp

High-flow events can result in substantial ^{137}Cs exportation via river to the ocean and increase ^{137}Cs concentrations in coastal seawater. Assessing the linkage of ^{137}Cs dynamics in river-coastal seawater will help to better understand ^{137}Cs transfer processes in terrestrial and marine environments. This study discusses the detailed processes based on results of sample collections under various flow conditions on a river system and its coastal seawater. During September 3-19 (2023), water samples were collected for 13 times at two downstream points of the Ukedo river system (Ukedo and Takase rivers) and 8 times on seashore around its river mouth. During the monitoring period, three high-flow events were observed due to intensive rainfall. ^{137}Cs concentrations in suspended solids at Ukedo and Takase rivers ranged from 7.0 to 67 kBq/kg and from 2.4 to 15 kBq/kg, respectively. The concentrations at peak water discharge phases in Takase river were shown to be higher when ratio of rainfall amount on downstream parts to that on whole catchments were high, but vice versa in the Ukedo river. A high-flow event, associated with Senjo-kousuitai on September 8, exported substantial ^{137}Cs to the ocean. In the seawater sample collected 5 hours after the peak water discharge, ^{137}Cs concentrations reached 2.2 Bq/L of particulate, 0.4 Bq/L of dissolved and 95 kBq/kg in suspended solids. All three concentrations decreased with time to reach the background levels in 10 days after the event. Updated results including analyses of unmeasured samples will be presented in the symposium.

Keywords：coastal seawater, river, Senjo-kousuitai, suspended solids

出水時における河川と沿岸海水の^{137}Cs濃度変動

脇山義史*[1]、佐藤俊[2]、高田兵衛[1]、ピエール－アレクシス・シャボシュ[1,3]、黒澤萌香[2]

[1]福島大学環境放射能研究所、[2]福島大学大学院共生システム理工学研究科、[3]日本学術振興会
*責任著者：wakiyama@ipc.fukushima-u.ac.jp

出水時には、河川から海洋に多量の^{137}Csが流出し、沿岸海水の^{137}Cs濃度を上昇させうることが知られている。河川と沿岸海域における^{137}Csの連動を明らかにすることで、陸域－海洋間の^{137}Cs移行に関する理解の深化が期待される。本研究では、出水時を含む河川水および沿岸海水の分析結果を基に^{137}Cs移行プロセスを検討する。2023年９月３日から19日にかけて、請戸川水系の２地点（請戸川および高瀬川）で各13回、河口周辺の海岸で８回の採水を行った。この期間には３回の出水イベントが観測された。懸濁物質の^{137}Cs濃度は、請戸川で7.0〜67 kBq/kg、高瀬川で2.4〜15 kBq/kgであった。出水ピーク時の懸濁物質の^{137}Cs濃度をみると、流域平均雨量に対して下流地点の雨量が相対的に多いときに高瀬川では高く、請戸川では低くなる傾向がみられた。９月８日の線状降水帯にともなう出水により多量の^{137}Csが流出した。この出水ピークから５時間後に採取した沿岸海水試料では、懸濁態^{137}Cs濃度が2.2 Bq/L、溶存態^{137}Cs濃度が0.4 Bq/L、懸濁物質の^{137}Cs濃度が95 kBq/kgに達した。いずれの濃度も時間経過とともに低下し、出水から10日後にはバックグラウンドレベルとなった。成果報告会では、未測定試料の分析結果を含めて報告を行う。

キーワード：沿岸海水、河川、懸濁物質、線状降水帯

P-07

Long-term ^{137}Cs dynamics after the decontamination at an urban pond

KUROSAWA Honoka[*1], NANBA Kenji[2,3], WADA Toshihiro[3], WAKIYAMA Yoshifumi[3]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Faculty of Symbiotic Systems Science, Fukushima University, [3]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：s2271004@ipc.fukushima-u.ac.jp

Relatively-high ^{137}Cs concentrations in water bodies in urban pond and river were suggested, but only a few studies investigated ^{137}Cs dynamics in urban area. This study presents long-term trends of ^{137}Cs dynamics in an urban pond after its decontamination and discussed the urban-specific processes. The study site is an urban pond（surface area: 32,800 m^2）in center of Koriyama City, Fukushima Prefecture, and it was decontaminated by bottom sediment removal in 2017. Bottom sediment, pond water, inflow water and outflow water were collected from 2018 to 2022 and analyzed for ^{137}Cs concentration, particle size distribution and carbon-nitrogen stable isotope ratios. Annual mean values of total ^{137}Cs concentration in pond water decreased from 0.95 Bq/L in 2018 to 0.16 Bq/L in 2019 and comparable in following years. The mean ^{137}Cs concentration in SS in the inflow water was 5.7 kBq/kg, which was about three times higher than those in the Abukuma River in corresponding years. After decontamination, the mean ^{137}Cs inventory in bottom sediment did not change（0.27-0.34 MBq/m^2）, but its spatial variability got greater. ^{137}Cs concentration in bottom sediment showed a significant positive correlation with specific surface area and δ^{15}N. These results suggest that inflowed fine particles of urban origin with high ^{137}Cs concentration resulted in the greater spatial variability.

Keywords：^{137}Cs, pond, urban area, specific surface area, δ^{15}N

都市域ため池における除染後の長期的な^{137}Cs動態

黒澤萌香[*1]、難波謙二[2,3]、和田敏裕[3]、脇山義史[3]

[1]福島大学大学院共生システム理工学研究科、[2]福島大学共生システム理工学類、[3]福島大学環境放射能研究所
*責任著者：s2271004@ipc.fukushima-u.ac.jp

都市域では水圏の^{137}Cs濃度が相対的に高いことが報告されているが、その^{137}Cs動態を調べた研究は少ない。本研究では、除染された都市域ため池において、長期的な^{137}Cs動態を調べ、都市域の影響を検討した。調査地は福島県郡山市の市街地にある、2017年度に底質除去による除染が行われたため池（水面積32,800 m^2）である。2018年から2022年にかけて、池水、流入水、流出水および底質を採集し、^{137}Cs濃度、粒度分布、炭素窒素安定同位体比を分析した。池水の全^{137}Cs濃度の年平均値は、2018年には0.95 Bq/Lと高い値を示したが、2019年に0.16 Bq/Lまで低下し、以降同様の値を示した。流入水の懸濁物質の平均^{137}Cs濃度は5.7 kBq/kgと、同時期における阿武隈川本流の値の約３倍の値であった。底質の平均^{137}Csインベントリは0.27-0.34 MBq/m^{2}の範囲で推移したが、時間経過とともに地点間差が大きくなった。また、底質の^{137}Cs濃度は、比表面積、δ^{15}Nとの間に有意な正の相関を示しており、除染後に流入した細粒成分の沈降により^{137}Csインベントリの空間的ばらつきが大きくなったと考えられた。

キーワード：^{137}Cs、ため池、都市域、比表面積、δ^{15}N

P-08

Distribution of ^{137}Cs concentrations in the urban hydrosphere

SUZUKI Nobuhiro[*1], WAKIYAMA Yoshifumi[2], TAKATA Hyoe[2], TAKASE Tsugiko[3],
KUROSAWA Honoka[1]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Institute of Environmental Radioactivity, Fukushima University, [3]Faculty of Symbiotic Systems Science, Fukushima University
*Corresponding author：s2371007@ipc.fukushima-u.ac.jp

The ^{137}Cs concentrations of suspended solids and dissolved form in urban areas are higher than those in forests and agricultural lands, and it is possible that water quality conditions and causative agents unique to urban areas contribute to maintaining high ^{137}Cs concentrations. However, few studies have investigated the distribution of ^{137}Cs concentrations in urban areas. In this study, water samples of 40 L each were collected at 17 locations in Koriyama on August 30 and 31, 2023. Water samples were collected at seven locations along the Sakabutaike/Araike/Hagaike pathway, which is a small flow path across the central area of the city, two locations along the Ouse River, four locations along the Minami River, two locations along the Abukuma River, a major river, and two locations in the urban area. The ^{137}Cs concentrations in suspended solids ranged from 0.5 to 5.4 kBg/kg and tended to be higher downstream than upstream in all watersheds, ranging from 1.5 to 3.9 kBg/kg in the upper and lower reaches of the Ouse River. The positive correlation between the ^{137}Cs concentration in suspended solids and δ^{15}N suggests that the ^{137}Cs concentration increases as it passes through urban areas. In order to analyze the causative agent, image analysis using imaging plates of suspended solids and elemental analysis of heavy metals and other substances are being conducted. The results of these analyses will be included in the report.

Keywords：irrigation pond, river, suspended solids, imaging plate

都市域の水圏における^{137}Cs濃度分布

鈴木信弘[*1]、脇山義史[2]、高田兵衛[2]、高瀬つぎ子[3]、黒澤萌香[1]

[1]福島大学大学院共生システム理工学研究科、[2]福島大学環境放射能研究所、[3]福島大学共生システム理工学類
*責任者：s2371007@ipc.fukushima-u.ac.jp

都市域における懸濁態及び溶存態^{137}Cs濃度は、森林・農地などに比べて高いという報告があり、都市に特有の水質条件や原因物質が^{137}Cs濃度を高く維持させる要因になっている可能性がある。しかしながら、都市における^{137}Cs濃度分布を調査した事例は少ない。本研究では、2023年8月30、31日に郡山の17か所で各40Lの採水を行った。採水個所は、市街地中心域を横断する少量流動経路である酒蓋池/荒池/芳賀池経路7か所、ため池がない河川である逢瀬川2か所、流域にため池がある南川4か所、主要河川の阿武隈川2か所、及び市街地内2か所で行った。懸濁態^{137}Cs濃度は、0.004〜0.5 Bq/L、溶存態^{137}Cs濃度は、0.003〜0.03 Bq/Lであった。懸濁物質の^{137}Cs濃度は、0.5〜5.4 kBg/kgの範囲を示し、阿武隈川上下流で0.5から1.1 kBg/kg、逢瀬川上下流で1.5から3.9 kBg/kgとなるなどいずれの流域でも上流より下流の方が^{137}Cs濃度が高くなる傾向が見られた。また、懸濁物質の^{137}Cs濃度とδ^{15}Nが正の相関を示すことから、都市域を通過することで、^{137}Cs濃度が高くなることが示唆された。原因物質の解析のため、懸濁物質のイメージングプレートによる画像解析、及び重金属等物質の元素分析を行っている。報告会ではこれらの分析結果を含めて報告する。

キーワード：ため池、河川、懸濁物質、イメージングプレート

P–09

Spatial pattern of water chemistry including radiocesium concentration in Arakawa River, Fukushima Prefecture

IGARASHI Yasunori[*1], FUKUSHIMA Keitaro[*2,3], SAITO Asuka[3]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Graduate School of Food and Agricultural Sciences, Fukushima University, [3]Faculty of Food and Agricultural Sciences, Fukushima University
*Corresponding author：y-igarashi@ipc.fukushima-u.ac.jp, fmktaro@agri.fukushima-u.ac.jp

The Arakawa River, which is one of the major tributaries of the Abukuma River, flows through Fukushima City, Fukushima Prefecture, and has been selected as the "river with the best water quality in Japan" by Ministry of Land, Infrastructure, Transport, and Tourism（MLIT）for 13 consecutive years. However, it is unknown why the water chemistry meets the standard value（COD）in this river. Our aim of this study is to clarify the spatial pattern and determining factors of river water chemistry. We investigated spatial variations of river water chemistry including pH, concentrations of major cations and anions including ammonium, nitrate and phosphate, and suspended sediments as well as dissolved and particulate ^{137}Cs concentrations in June and October 2023. We found（1）pH decreased considerably in the middle reaches of Arakawa River because of the mixing of strongly acidic tributary originating from the volcano,（2）precipitation of some heavy metals on the riverbed due to neutralizing strongly acidic tributary river by neutral main river. This process forms an environment unfavorable for aquatic livings, which is one of the possible factors in meeting the water standard by MLIT. We will report the spatial variations of dissolved and particulate ^{137}Cs in this river system, and discuss the factors determining the variations of river water chemistry.

Keywords：spatial pattern, water chemistry, ^{137}Cs in river

福島市内を流れる荒川の水質形成機構と^{137}Cs流出の実態

五十嵐康記[*1]、福島慶太郎[*2,3]、斎藤あすか[3]

[1]福島大学環境放射能研究所、[2]福島大学食農学研究科、[3]福島大学食農学類
*責任著者：y-igarashi@ipc.fukushima-u.ac.jp、fmktaro@agri.fukushima-u.ac.jp

福島県福島市を流れる阿武隈川水系の一級河川・荒川は、国土交通省による「水質が最も良好な河川」に13年連続選出されている。しかしながら、その水質形成プロセスについて明らかではない。そこで本研究では、荒川の水質の空間パターンと、水質を決定する要因を明らかにすることを目的とした。目的の達成のため、2023年6月と10月に荒川・松川・油井川を対象に広域的な採水と化学分析を行った。松川・油井川を対象に含めた意図は、酸性が強いと考えられた荒川との比較のためである。本研究では、溶存態及び懸濁態^{137}Csについても調査を行い、福島第一原発事故から12年経過した現在の実態について、水質形成プロセスと関連付けることも本研究の狙いの一つとした。広域採水の結果, 荒川中流付近で火山に由来する強酸性の支流河川・須川が合流することで荒川のpHが低下すること、一方で須川のpHが上昇することで溶存していた一部の重金属イオンが荒川河床に沈殿することが観察された。このことから、生物が生息しにくい環境が形成され、国土交通省の水質基準を満たしていることが推察された。本発表では, 溶存態及び懸濁態^{137}Csの広域調査の結果を合わせて、荒川の水質形成について考察する。

キーワード：空間パターン、水質、河川中の^{137}Cs

P-10

Relationship between ^{137}Cs concentration in water and Japanese dace（*Pseudaspius hakonensis*）in lakes in Fukushima Prefecture

INOMATA Ayame[*1], TAKASAKI Kazuyoshi[2], TOMIYA Atsushi[3], ENOMOTO Masahiro[2], FUNAKI Yuto[4], SHIMAMURA Shinya[1], WADA Toshihiro[5]

[1]Fukushima Prefectural Inland Water Fisheries Experiment Station, [2]Fukushima Prefectural Fisheries and Marine Science Research Centre, [3]Fukushima Prefectural Fisheries Office, [4]Fukushima Prefectural Fisheries Resources Research Institute, [5]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：inomata_ayame_01@pref.fukushima.lg.jp

After the Fukushima Daiichi Nuclear Power Plant accident, some fish species that exceeded the regulatory limit of radiocesium（100 Bq/kg-wet）have still been found in some rivers and lakes in Fukushima Prefecture. In order to obtain a forecast of future ^{137}Cs contamination, it is necessary to elucidate the transfer and accumulation mechanisms of ^{137}Cs within the inland water ecosystem. In this study, in order to understand the transfer and accumulation status of ^{137}Cs from lake water to fish, we compared the ecological half-lives of Japanese dace（< 20 cm total length）and concentration ratios of ^{137}Cs from water（dissolved form）to fish in 5 lakes in Fukushima Prefecture. The results showed that the ecological half-lives and concentration ratios differed depending on the lakes, and it was considered necessary to examine the transfer and accumulation process of ^{137}Cs from lake water to Japanese dace for each lake.

Keywords：Japanese dace, lake water, ^{137}Cs, ecological half-life, concentration ratio

福島県内湖沼における湖水とウグイの^{137}Cs濃度の関係

猪俣絢女[*1]、鷹﨑和義[2]、冨谷敦[3]、榎本昌宏[2]、舟木優斗[4]、島村信也[1]、和田敏裕[5]

[1]福島県内水面水産試験場、[2]福島県水産海洋研究センター、[3]福島県水産事務所、[4]福島県水産資源研究所、[5]福島大学環境放射能研究所
*責任者：inomata_ayame_01@pref.fukushima.lg.jp

福島第一原発の事故後、本県の一部の河川・湖沼では未だ^{137}Cs濃度が国の基準値を超える魚種が確認されている。今後の^{137}Csによる汚染の見通しを得るためには、内水面生態系内での^{137}Csの移行・蓄積状況を把握することが必要である。本研究では、湖水から魚類への^{137}Csの移行・蓄積状況を把握するため、県内５湖沼を対象に、全長20cm未満のウグイの生態学的半減期及び湖水溶存態と魚体の^{137}Cs濃度の濃度比を比較した。その結果、生態学的半減期・濃縮係数は湖沼によって異なることが示され、湖水からウグイへの^{137}Csの移行・蓄積状況は湖沼ごとに検討することが必要であると考えられた。

キーワード：ウグイ、湖水、^{137}Cs、生態学的半減期、濃縮係数

P-11

Voluntary inspection results of radioactive Cs concentration of marine products in Fukushima and examples of voluntary shipping restrictions

TAKASAKI Kazuyoshi[*1]

[1]Fukushima Prefectural Fisheries and Marine Science Research Centre
*Corresponding author：takasaki_kazuyoshi_01@pref.fukushima.lg.jp

Fukushima Prefectural Fisheries Cooperative Association（FPFCA）has been conducting screening for radioactive Cs concentration on all fish species before shipping the catch since June 2012. If the screening shows that the fish exceeds 25 Bq/kg, the shipment of the relevant fish species will be temporarily suspended and undergo a detailed inspection by Fukushima Prefecture, and if the test exceeds 50 Bq/kg, the shipment and operation will be suspended until safety is confirmed. The number of samples for voluntary testing was 104,599, which was higher than the number of samples for emergency monitoring by Fukushima Prefecture（77,079, for seafood）until September 2023. In addition, there were 20 cases of temporary suspension of shipments and 13 cases of voluntary restraint of shipments and operation. Five of the cases of voluntary restraint on shipments and operation were taken based on measurements exceeding 50 Bq/kg other than screening inspections. Based on the above, it can be said that FPFCA is extremely careful in handling shipments of marine products while confirming safety using a huge amount of data.

Keywords：radioactive Cs, self-inspection（screening）, self-restraint in shipping

福島県産水産物の放射性Cs濃度の自主検査結果及び出荷自粛事例

鷹﨑和義[*1]

[1]福島県水産海洋研究センター
*責任著者：takasaki_kazuyoshi_01@pref.fukushima.lg.jp

福島県漁業協同組合連合会(県漁連)は、2012年６月から、漁獲物を出荷する前に全魚種を対象として放射性Cs濃度のスクリーニングを自主的に実施している。自主検査で25 Bq/kgを超過した場合は当該魚種の出荷を一時停止して福島県の精密検査を受け、精密検査で50 Bq/kgを超過した場合は安全性が確認されるまで出荷・操業を自粛することとしている。2023年２月の自主検査及び精密検査で50 Bq/kgを超過するスズキが確認され、県漁連は３月末までスズキの出荷・操業を自粛した。本研究では、2023年９月までの自主検査結果及び出荷自粛事例を整理して、これまでの取組の評価と今後の課題の抽出を目的とした。
自主検査の検体数は104,599で、福島県の緊急時モニタリングの検体数(77,079、水産物対象)よりも多かった。また、出荷自粛事例は、出荷一時停止が20件、出荷・操業自粛が13件の合計33件であり、後者のうち５件は、自主検査以外(福島県のモニタリング結果等)における50 Bq/kg超過を踏まえた措置であった。以上のことから、県漁連は、膨大な量のデータを用いて安全性を確認しながら、水産物を極めて慎重に出荷していると言える。また、出荷自粛事例が多かった魚種はスズキ(５回)、クロソイ(３回)であり、今後、これらの魚種で25 Bq/kgを超える個体が出現する原因を解明する必要がある。

キーワード：放射性Cs、自主検査(スクリーニング)、出荷自粛

P-12

Impacts of wildfire on desorption of radionuclide and subsequent wash-offs in the Chornobyl Exclusion Zone

IGARASHI Yasunori[*1], Valentyn PROTSAK[2], Gennady LAPTEV[2], Igor MALOSHTAN[2], Dmitry SAMOILOV[3], Serhii KIRIEIEV[3], ONDA Yuichi[4], Alexei KONOPLEV[1]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Ukrainian Hydrometeorological Institute, National Academy of Sciences of Ukraine, [3]Chernobyl Ecocentre, State Agency of Ukraine on Exclusion Zone Management, [4]Center for Research in Radiation, Isotopes, and Earth System Sciences, University of Tsukuba
*Corresponding author：y-igarashi@ipc.fukushima-u.ac.jp

The objective of this study is to determine the speciation of ^{137}Cs and ^{90}Sr in the ash and soil. And to reveal the impact of the wildfires on concentrations of ^{137}Cs and ^{90}Sr in river water in Chornobyl. To accomplish this objective, extraction tests were conducted using ash and soil samples collected immediately after the 2020 fires to determine the water-soluble and exchangeable fractions of ^{137}Cs and ^{90}Sr in the ash and soil. Long-term river-water radionuclide concentration records were also analyzed. The results showed that the solid–liquid distribution coefficient (K_d) of ash was significantly lower than that of soil for ^{137}Cs, while for ^{90}Sr there was no significant difference in K_d between ash and soil. Analysis of river water data indicated that ^{90}Sr concentrations higher than the Ukrainian drinking water standard (> 2 Bq/L) were observed more frequently following wildfires in the Sakhan River. The fires increased ^{90}Sr concentrations over the following two years, particularly in the spring, when snowmelt causes substantial releases, and in the summer and autumn, when surface flows occurred. High ^{90}Sr concentrations were observed only within the Chornobyl Exclusion Zone, so additional human uptake of or dose exposure to ^{90}Sr from river water is not expected.

Keywords：wildfire, desorption, radionuclide, wash-offs, Chornobyl

チョルノービリにおける山火事は放射性核種の溶出とその後の流出にどのような影響を与えるのか？

五十嵐康記[*1]、バレンティン・プロサック[2]、ゲナディー・ラプテフ[2]、イーゴリ・マロシュタン[2]、ドミトリー・サモイロフ[3]、セルヒー・キリエフ[3]、恩田裕一[4]、アレクセイ・コノプリョフ[1]

[1]福島大学環境放射能研究所、[2]ウクライナ水文気象研究所、[3]チョルノービリエコセンター、[4]筑波大学放射線・アイソトープ地球システム研究センター
*責任著者：y-igarashi@ipc.fukushima-u.ac.jp

本研究の目的は、灰と土壌中に含まれる^{137}Csと^{90}Srの存在形態を明らかにし、チョルノービリの河川水中の^{137}Csと^{90}Sr濃度に対する森林火災の影響を明らかにすることである。この目的を達成するため、2020年の火災直後に採取された灰と土壌試料を用いて抽出試験を行い、灰と土壌中の^{137}Csと^{90}Srの水溶性画分と交換性画分を測定した。また、長期にわたる河川水の放射性核種濃度の記録も分析した。その結果、^{137}Csについては、灰の固液分配係数(K_d)が土壌のそれよりも有意に低かったが、^{90}Srについては、灰と土壌の間でK_dに有意差はなかった。河川水データの分析から、サハン川流域での森林火災の後、ウクライナの飲料水基準(> 2 Bq/L)より高い^{90}Sr濃度がより頻繁に観測されることが示された。この火災は、その後の2年間、特に雪解け水が大量に放出される春と、地表流が発生する夏と秋に^{90}Sr濃度を上昇さることがわかった。しかしながら、高濃度の^{90}Srが観測されたのはチョルノービリ規制区域内だけであり、河川水からの^{90}Srの人体への取り込みや被曝は予想されなかった。

キーワード：山火事、溶出、放射性核種、流出、チョルノービリ

P-13

Consecutive sexual maturation observed in a rock shell population in the vicinity of the Fukushima Daiichi Nuclear Power Plant, Japan

HORIGUCHI Toshihiro[*1], ARAMAKI Takafumi[1], NAKAJIMA Daisuke[1], KODAMA Keita[1], KINTSU Hiroyuki[1], MORISHITA Fumihiro[2]

[1]National Institute for Environmental Studies, [2]Graduate School of Integrated Sciences for Life, Hiroshima University
*Corresponding author：thorigu@nies.go.jp

In 2012, after the accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP) that followed the Tohoku earthquake and tsunami in March 2011, no rock shell (*Reishia clavigera*; Gastropoda) specimens were found near the plant from Hirono to Futaba Beach (a distance of approximately 30 km). In July 2016, however, rock shells were again found to inhabit the area. From April 2017 to May 2019, we collected rock shell specimens monthly at a site near the FDNPP (Okuma) and at a reference site～120 km south of the FDNPP (Hiraiso). We examined the gonads of the specimens histologically to evaluate their reproductive cycle and sexual maturation. The gonads of the rock shells collected at Okuma,～1 km south of the FDNPP, exhibited consecutive sexual maturation (CSM) during the 2 years from April 2017 to May 2019, whereas sexual maturation of the gonads of specimens collected at Hiraiso was observed only in summer. The CSM of the gonads of the specimens collected at Okuma might not represent a temporary phenomenon but rather a site-specific phenotype, possibly caused by specific environmental factors near the FDNPP. Here, we will show results from the following field surveys, regarding duration and geographical range when and where CSM has been observed, possible recovery from CSM if the rock shells are kept in the laboratory (under different circumstances from the site near FDNPP), concentrations of tritium and other chemical substances in seawater close to FDNPP, to discuss about the causal factor(s) and induction mechanism for CSM in the rock shell.

Keywords：Fukushima Daiichi Nuclear Power Plant, rock shell, ecological effects, consecutive sexual maturation

福島第一原子力発電所近傍の肉食性巻貝イボニシにみられる生殖異常：通年成熟現象

堀口敏宏[*1]、荒巻能史[1]、中島大介[1]、児玉圭太[1]、近都浩之[1]、森下文浩[2]

[1]国立環境研究所、[2]広島大学大学院統合生命科学研究科
*責任著者：thorigu@nies.go.jp

演者らは、2011年12月14日以降、福島第一原子力発電所(1F)近傍で潮間帯調査を継続してきた。震災・原発事故後に姿を消したイボニシが2016年7月に大熊町夫沢(1Fの南側約1km)で初めて観察され、イボニシの"空白地帯"が消失したため、2017年4月以降、大熊町夫沢でイボニシの性成熟や産卵行動等に関する調査を毎月進めてきた。その結果、大熊町夫沢のイボニシは2019年5月まで2年以上に亘って性的に成熟した状態が継続していること(通年成熟現象)が明らかになった。イボニシは、本来、年1回、夏季に性成熟することが知られており、通年成熟現象は異常である。ここでは、その後、現在までの調査によって明らかになった、通年成熟現象の継続期間、通年成熟現象が観察される地理的範囲、棲息環境が変われば通年成熟は停止もしくは軽減するか、通年成熟個体に何らかの生理学的変化が生じているか、などの知見を現地の海水の化学分析結果も交えながら紹介し、通年成熟現象の原因とメカニズムを考察する。

キーワード：福島第一原子力発電所、イボニシ *Reishia clavigera*、生態影響、通年成熟

P-14

Testing new methods to reduce ^{137}Cs and ^{90}Sr contamination of freshwater fish

Polina PAVLENKO*[1,4], WADA Toshihiro[3], Vasyl YOSCHENKO[3], Valery KASHPAROV[1,2]

[1]Ukrainian Institute of Agricultural Radiology of National University of Life and Environmental Sciences of Ukraine, [2]Norwegian University of Life Sciences, Norway, [3]Institute of Environmental Radioactivity, Fukushima University, [4]Graduate School of Symbiotic Systems Science and Technology, Fukushima University
*Corresponding author：polina.pavlenko97@gmail.com

Recently, series of experiments testing new methods to reduce radioactive contamination of freshwater fish with ^{137}Cs and ^{90}Sr were conducted in natural conditions of Chornobyl exclusion zone along with experiments in laboratory conditions. The methods tested included feeding fish diets supplemented with Prussian blue in the form of potassium ferric hexacyanoferrate（KFCF）KFe[Fe(CN)$_6$], keeping radioactively contaminated fish in "clean" water, and culinary treatment（boiling）of bones and flesh tissues of radioactively contaminated fish.

The experiments carried out in Chornobyl Exclusion Zone showed a significant difference in the activity concentration of ^{137}Cs in the muscle tissue of fish fed with KFCF compared to fish without clean feeding. Depending on the level of KFCF in the feed, the activity concentration of ^{137}Cs in muscle tissue was reduced by a factor of 7-27. On the contrary, keeping fish in "clean" water did not show the expected decrease of ^{90}Sr in muscle and bone tissues of fish. Further research is needed to investigate the long-term behavior of strontium in fish tissues. A culinary treatment experiment showed that it is appropriate to establish permissible levels of ^{90}Sr only in the flesh of the fish, as the processing retention factors of ^{90}Sr during cooking of broth from bone tissue of fish from the contaminated lake within Chornobyl Exclusion Zone were less than 0.01.

Keywords：^{137}Cs, ^{90}Sr, countermeasures, Chornobyl Exclusion Zone

P-15

Combined remote sensing and modelling of the state of Chornobyl forests in terms of productivity, radioactive contamination, and economic use

Dmytrii HOLIAKA[*1], Valeriia MOROZOVA[1], Roman ZADOROZHNIUK[1], Vasyl YOSCHENKO[2],

Sviatoslav LEVCHUK[1], Jim T. SMITH[3], Nicholas A. BERESFORD[4], Oleksii KIVA[5],

Hans Christoffer TYLDUM[6], Deborah H. OUGHTON[6], Maryna HOLIAKA[1], IGARASHI Yasunori[2],

Oleksandr-Ralf CHERNIAIEV[1], Oleksandr LESNIK[1], Ihor CHYZHEVSKYI[7], KATO Hiroaki[8],

Petro DIACHUK[9], NANBA Kenji[2], ONDA Yuichi[8], Valery KASHPAROV[1]

[1]National University of Life and Environmental Sciences of Ukraine, [2]Institute of Environmental Radioactivity, Fukushima University, [3]University of Portsmouth, [4]UK Centre for Ecology and Hydrology Lancaster, [5]Kyiv Academic University, [6]Norwegian University of Life Sciences, [7]State Specialized Enterprise "Ecocentre", [8]Center for Research in Radiation, Isotopes, and Earth System Sciences, University of Tsukuba, [9]Polissia National University

*Corresponding author：holiaka@nubip.edu.ua

The Chornobyl Exclusion Zone has not only a highly radioactive contamination, but, since 2022, it has also become one of the areas in the world with the highest density of land mines. Therefore, forestry activities are often impossible within this area, making development of remote sensing methods of forestry resources essential. This study presents a comprehensive assessment of the economic value（growing stock）, ecosystem services（biomass）, and radioecological parameters（^{90}Sr and ^{137}Cs contents in wood）of the Chornobyl forests. Different approaches using data from terrestrial field measurements, Unmanned Aerial Vehicle（UAV）aerial photography, and satellite images（Sentinel-1 and 2）, were implemented with further comparison of their output results. The XGBoost algorithm was carried out to simulate the listed parameters. Although remote methods of estimating the studied parameters were significantly less accurate than those based on terrestrial field measurements, estimating growing stock and biomass based on the UAV surveys demonstrated a high explanatory ability（confidence interval for R^2 was [0.87; 0.95]）. However, the models created for determining the ^{90}Sr and ^{137}Cs concentrations in wood based on UAV data were unreliable. Satellite data enabled the generation of statistically significant predictions for all studied parameters：growing stock（R^2 [0.50–0.69]）, aboveground biomass of tree stand（R^2 [0.45–0.71]）, and aggregated transfer factor coefficients for ^{90}Sr（R^2 [0.17–0.37]）and ^{137}Cs（R^2 [0.23–0.39]）from soil into trunk wood.

Keywords：Chornobyl forest, XGBoost, UAV, satellite data, radionuclides, biomass

P-16

Assessment of the effects of ionizing radiation in bees – BEERAD

Béatrice GAGNAIRE*[1], NANBA Kenji[2], Jean-Marc BONZOM[1], Jean-Luc BRUNET[3], Margot CREVET[1], Nicolas DUBOURG[1], ISHINIWA Hiroko[2], NAGATA Hiroko[2], Michel PELISSIER[3], Luc BELZUNCES[3]

[1]Institute for Radiation Protection and Nuclear Safety, France, [2]Institute of Environmental Radioactivity, Fukushima University, [3]National Research Institute for Agriculture, Food and the Environment, France
*Corresponding author：beatrice.gagnaire@irsn.fr

The risk assessment linked to the radiocontamination of the environment after a nuclear accident is a major ecological issue. However, it is still surrounded by controversial results and conclusions on the real impact of such events on flora and fauna inhabiting the targeted zones. Moreover, the potential underlying mechanisms of the action of ionizing radiation（IR）are poorly known. Therefore, it is important to acquire data on the potential effects of IR on ecosystems both in experimental and realistic conditions. The objective of the BEERAD project is, using a pluri-disciplinary approach, to increase the knowledge of effects and mechanisms of action of IR on physiology and populations of honeybees in the context of chronic exposure（i.e., exposure of a significant period of time relative to the lifespan of exposed organisms）and at low dose rates（sublethal ecotoxicity）in realistic conditions, i.e., on the field and in the laboratory. However, very few data exist on this subject, and it seems important to conduct studies that will serve as a basis to better evaluate the impacts of IR on animal health using honeybees. The presentation will focus on the experiment of implantation of hives realized around the Fukushima Nuclear Power Plant from April to October 2023.

Keywords：ionizing radiation, honeybee *Apis mellifera*, physiology, biomarkers, Fukushima NPP

P-17

Soil biodiversity and functional processes in radio-contaminated forests (Fukushima Prefecture, Japan)

Quentin LAMBERT[1], Olivier ARMANT[1], Anne-Sophie BENOISTON[2], Yvan CAPOWIEZ[3], Stephan HÄTTENSCHWILER[4], Amaia IRIBAR-PELOZUELO[2], KANEKO Nobuhiro[5], Sylvain LAMOTHE[2], NANBA Kenji[6], Vasyl YOSCHENKO[6], WADA Toshihiro[6], Jean-Marc BONZOM[1], Franck GILBERT[*2]

[1]Institute for Radiation Protection and Nuclear Safety, France, [2]Centre de Recherche sur la Biodiversité et l'Environnement, France, [3]National Research Institute for Agriculture, Food and the Environment, France, [4]Centre d'Ecologie Fonctionnelle et Evolutive, France, [5]Faculty of Food and Agricultural Sciences, Fukushima University, [6]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：franck.gilbert@univ-tlse3.fr

The objectives of the collaborative French-Japanese RINSHŌ project are to study the in situ effects of radio-contamination on both soil biodiversity (microorganisms and eukaryotes) and two associated functional processes: leaf litter decomposition and soil bioturbation, in forests of Fukushima Prefecture (representing approximately 70% of the total radio-contaminated land area). Indeed, those two integrative processes are specifically investigated because they are related to the transfer and the transformation of organic matter and are carried out by interacting organisms belonging to various soil biological compartments and ecological niches (from bacteria to macrofauna, epifauna and endofauna). Our hypotheses are: (i) radio-contamination has an impact on soil biodiversity, (ii) radio-contamination has an impact on the activity of soil organisms and the processes they drive, (iii) the impact of radio-contamination is dose-dependent.

In the November-December 2023 period, 6 *Cryptomeria japonica* forest sites of Fukushima Prefecture positioned along a radio-contamination gradient were equipped with experimental units (5 units per site). These units were composed, among other devices, of: fine and large mesh *C. japonica* litter bags; deposition zones of fluorescent tracers (luminophores); TMS-4 TMOS dataloggers; dosimeter columns. Samplings for both eDNA (bacteria and eukaryotes compartments) and physico-chemical analyses of soils and litter were also realized.

Collection of experimental devices and complementary samplings will be carried out after 6 and 12 months of experimentation.

Keywords：Fukushima Prefecture, ionizing radiation, forest, soil communities, functional processes

P-18

Long-term transfer of radiocesium by hydrological processes within forest following Fukushima Dai-ichi Nuclear Power Plant accident

KATO Hiroaki[*1], NIWANO Yuma[1], ONDA Yuichi[1]

[1]Center for Research in Radiation, Isotopes, and Earth System Sciences, University of Tsukuba
*Corresponding author：kato.hiroaki.ka@u.tsukuba.ac.jp

Over 12 years of rigorous field data collection following the Fukushima Daiichi Nuclear Power Plant accident, we provide insights into the distribution and migration of radiocesium in Japanese forests. Our findings highlight the intricate mechanisms governing radiocesium transfer between the atmosphere, canopy, and soil, driven by hydrological processes and forest headwater catchment discharge. Based on extensive field monitoring in experimental forest regions and watersheds in Fukushima Prefecture's Kawamata and Namie towns, we uncover key differences in radionuclide transfer rates between Fukushima and Chornobyl, synthesizing previous research. Our study sheds light on transfer phenomena within forests with potential long-term implications for radionuclide distribution, offering critical insights for environmental management and future research.

Keywords：Fukushima Dai-ichi NPP accident, radiocesium, forest, distribution, transfer mechanisms

福島第一原子力発電所事故後の森林内における水文学的過程による放射性セシウムの長期移行

加藤弘亮[*1]、庭野佑真[1]、恩田裕一[1]

[1]筑波大学放射線・アイソトープ地球システム研究センター
*責任著者：kato.hiroaki.ka@u.tsukuba.ac.jp

東京電力福島第一原子力発電所の事故後、12年にわたる厳密なフィールドデータ収集の結果、日本の森林における放射性セシウムの分布と移動に関する知見が得られた。その結果、水文学的プロセスと森林源流域から流出プロセスにともなう、大気、樹冠、土壌間の放射性セシウム移行を支配する複雑なメカニズムが明らかになった。福島県川俣町と浪江町の調査林分と試験流域における広範なフィールドモニタリングに基づき、福島とチョルノービリにおける放射性核種の移行率の重要な違いを明らかにし、これまでの研究を総合した。本研究は、放射性核種の分布に長期的な影響を及ぼす可能性のある森林内の移行現象に光を当て、環境管理と今後の研究に重要な洞察を提供する。

キーワード：福島第一原子力発電所事故、放射性セシウム、森林、分布、移行メカニズム

P–19

Effects of downward migration of Cs-137 on its concentration in fine roots of Japanese cedar in Fukushima

TAKAHASHI Junko[*1], SASAKI Takuya[1], IGUCHI Satoshi[1], ONDA Yuichi[1]

[1]Center for Research in Radiation, Isotopes, and Earth System Sciences, University of Tsukuba
*Corresponding author：takahashi.junko.ka@u.tsukuba.ac.jp

Radiocesium（Cs-137）deposited on forests was intercepted by the canopy, then migrated to the litter layer and eventually to the soil layer, where some of it has been absorbed by roots and circulated through the forest ecosystem for a long time. In other words, the amount of Cs-137 uptake by roots will control the long-term dynamics in the forest ecosystem in the future, temporal changes in Cs-137 in tree roots have rarely been reported. In this study, we investigated the Cs-137 concentration and inventory in the soil and very fine（VF）roots（< 0.5 mm）of Japanese cedar from 2011 to 2020.
The Cs-137 inventory in the soil increased over time due to the migration from the forest canopy and litter layers, whereas that in the VF roots decreased in 2020. Especially, the Cs-137 inventory in the VF roots in the 0-2 cm of soil reached 89% in 2012; however, it decreased with time to approximately 43% in 2020. It was concluded that the downward migration of Cs-137 in the litter and soil layers caused a shift in the peak of depth distribution of Cs-137 in the soil from the peak of depth distribution of VF root biomass and reduced root uptake. This natural downward migration process can be regarded as a "self-cleaning" of the forest ecosystem, resulting in a decrease in the air dose rate and the amount of Cs-137 absorbed by roots.

Keywords：tree root, forest soil, Cs-137, downward migration, self-cleaning

スギ林細根中のCs-137濃度に対するCs-137下方移行の影響

高橋純子[*1]、佐々木拓哉[1]、井口啓[1]、恩田裕一[1]

[1]筑波大学放射線・アイソトープ地球システム研究センター
*責任著者：takahashi.junko.ka@u.tsukuba.ac.jp

森林に沈着した放射性セシウム（Cs-137）は、樹冠によって遮断され、降雨やリターフォールを通じて徐々にリター層、そして最終的には土壌層へと移行し、その一部は根に吸収され、長期間にわたって森林生態系を循環する。言い換えれば、根によるCs-137の吸収量が今後の森林生態系の長期的な動態を支配することになるが、樹木の根におけるCs-137の時間的な変化はほとんど報告されていない。本研究では、2011年から2020年にかけて、スギの土壌およびVery Fine（VF）根（< 0.5 mm）中のCs-137濃度とインベントリーを調査した。土壌中のCs-137インベントリーは、樹冠やリター層からの下方移行により時間とともに増加したが、VF根中のCs-137インベントリーは2020年には減少した。特に、土壌0-2 cmのVF根中のCs-137インベントリーは2012年に89%に達したが、時間とともに減少し、2020年には約43%になった。リター層および土壌中のCs-137の下方移行により、土壌中のCs-137深度分布のピークがVF根のバイオマスの深度分布のピークからずれることで根による吸収量が減少したと考えられた。すなわち、除染によってCs-137を除去せずとも、下方移行の促進によって空間線量率の低下と吸収量の減少というself-cleaningが期待できる。

キーワード：樹木根、森林土壌、Cs-137、下方移行、セルフクリーニング

P-20

Evaluation of radiocesium uptake from food and water by starry flounder, an euryhaline fish, under different salinity conditions

MANOME Yuuki[*1], WADA Toshihiro[1,2]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：s2270055@ipc.fukushima-u.ac.jp

Fish uptake radiocesium from two routes: food and water. Freshwater fish have been contaminated by ^{137}Cs for a longer period than marine fish after the Fukushima Daiichi Nuclear Powar Plant accident. Based on the above, we first conducted rearing experiments that evaluated ^{137}Cs uptake from food by starry flounder, an euryhaline fish, under different salinity conditions（freshwater, brackish water, and seawater）. Results reported at the IER Annual Symposium last year showed that the ^{137}Cs uptake from food was faster in freshwater or brackish water than in seawater. Then, we conducted a rearing experiment that can evaluate ^{137}Cs uptake from water under different salinity conditions using the same species. The obtained results revealed that the ^{137}Cs uptake in seawater is faster than that in freshwater or brackish water: the opposite results of ^{137}Cs uptake from food. Factors influencing these results may include（1）large differences in K concentrations between freshwater and seawater and（2）the differences in osmoregulatory physiology in fish. These findings clearly represent a fundamental and important physiological mechanism that can explain the different radiocesium decreasing trends in freshwater and marine fish after the Fukushima accident.

Keywords：fish, radiocesium, salinity, ecological half-life, bioaccumulation, rearing experiment

広塩性魚ヌマガレイを用いた異なる塩分条件下における餌および水からの放射性セシウム取込評価

馬目由季[*1]、和田敏裕[1,2]

[1]福島大学共生システム理工学研究科、[2]福島大学環境放射能研究所
*責任著者：s2270055@ipc.fukushima-u.ac.jp

魚類は、餌生物と環境水の2つの経路から放射性Csを取込む。魚類の生体内において、Csは同じアルカリ金属元素のKと同じような挙動を示すため、K濃度が大きく異なる淡水と海水では、餌と水でCsの取込や排出に関わるメカニズムが異なると予想される。実際、福島原発事故後、淡水魚は海水魚に比べ放射性Csによる汚染が長期化している。以上を踏まえ、まず、広塩性魚ヌマガレイを対象に、異なる塩分条件下（淡水、汽水、海水）での餌からの放射性Cs取込試験を行った。その結果、餌からの取込は海水よりも淡水で早いことが明らかとなった（第9回IER成果報告会で報告）。そこで次に、同種を対象に、異なる塩分濃度条件下での水からの放射性Csの取込試験を行った。その結果、海水における放射性Csの取込が、淡水・汽水よりも早いことを同一魚種の飼育試験により初めて解明した。今回得られた水からの放射性Csの取込結果は、昨年報告した餌からの放射性Csの取込結果と真逆であった。これらに影響を及ぼす要因として、（1）淡水と海水におけるK濃度の大きな違いや（2）魚類の浸透圧調節に関わる生理的機能の違いが考えられる。本知見は、福島第一原発事故後の淡水魚と海水魚の放射性セシウム汚染の推移を説明する上で、根本的かつ重要な生理的メカニズムを示していると考えられる。

キーワード：魚類、放射性Cs、塩分濃度、生物学的半減期、生物蓄積、飼育

P-21

Distribution of radioactive cesium-rich microparticles in forest soils at difficult-to-return zone

WAKI Hiromichi[*1], TATSUNO Takahiro[2,3], NIHEI Naoto[4], KAKUMA Minato[1], NAGASAWA Waka[5], SAYAMA Yo[6], WADA Toshihiro[2], MURAKAMI Masashi[5], OHTE Nobuhito[1]

[1]Graduate School of Informatics, Kyoto University, [2]Institute of Environmental Radioactivity, Fukushima University, [3]Research Faculty of Agriculture, Hokkaido University, [4]Faculty of Food and Agricultural Sciences, Fukushima University, [5]Graduate School of Science, Chiba University, [6]Faculty of Agriculture, Kyoto University
*Corresponding author：waki.hiromichi.54s@st.kyoto-u.ac.jp

A large amount of radionuclides was released into the environment due to the Fukushima Daiichi Nuclear Power Plant accident in March 2011. In the accident, radioactive cesium-rich microparticles （CsMPs） were also released. However, little is known about the behavior of CsMPs in forests where large amounts of radionuclide remain. This study aimed to obtain fundamental insights into the discharge processes of CsMPs. Soil samples were collected along the topography of small forested catchments and analyzed. The topographic distribution patterns of ^{137}Cs demonstrate that the discharge of ^{137}Cs from the forested catchments can be explained by the sedimentation of eroded soils from the upper part to the bottom of the slope and bank erosion. Furthermore, similar topographic distribution patterns were observed between ^{137}Cs and CsMPs. This indicates that the discharge of CsMPs can be driven by sedimentation of eroded soils on the slope and bank erosion. Additionally, CsMPs were found in the deeper soil parts in areas where the soil was unaffected by erosion and sedimentation, although ^{137}Cs generally exhibit limited downward movement. This result indicates that the downward migration of CsMPs could potentially alter the depth profile of ^{137}Cs in the future.

Keywords：radioactive cesium-rich microparticles, small forested catchment, soil erosion, downward migration

帰還困難区域内の森林土壌における高濃度放射性セシウム含有粒子の分布

脇嘉理[*1]、辰野宇大[2,3]、二瓶直登[4]、角間海七渡[1]、長澤和佳[5]、佐山葉[6]、和田敏裕[2]、村上正志[5]、大手信人[1]

[1]京都大学大学院情報学研究科、[2]福島大学環境放射能研究所、[3]北海道大学大学院農学研究院、
[4]福島大学食農学類、[5]千葉大学大学院理学研究院、[6]京都大学農学部
*責任著者：waki.hiromichi.54s@st.kyoto-u.ac.jp

2011年3月に発生した福島第一原子力発電所の事故により、多量の放射性物質が環境中に放出された。この事故では、高濃度放射性セシウム粒子(CsMPs)が放出されたことが知られている。しかし、放射性物質を多量に蓄積している森林において、CsMPsの挙動はこれまで明らかにされていない。本研究では、河川上流の森林小流域において、CsMPsの流出過程に関する基礎的知見を得ることを目的とした。地形に沿って土壌を採取して分析したところ、^{137}Csの地形的な分布パターンから、森林小流域からの^{137}Csの流出が、斜面上部で侵食された土砂の堆積と渓岸侵食で説明されることが示された。また、^{137}CsとCsMPsの地形的な分布パターンは類似していた。この結果は、森林小流域におけるCsMPsの流出挙動が、斜面上の土砂の侵食と堆積、および渓岸侵食によって駆動されることを示している。また、一般に^{137}Csは土壌中を下方移動しにくいが、侵食や堆積に影響されていない土壌において、深層にもCsMPsが存在した。この結果は、CsMPsが土壌中を下方移動することで、将来的に^{137}Csの深度分布が変化する可能性を示している。

キーワード：高濃度放射性セシウム含有粒子、森林小流域、土壌侵食、下方移動

P-22

Radiocesium concentrations in fish from a dam reservoir and forest rivers in Ukedo River system

KODAMA Fuya[*1], KANASASHI Tsutomu[2], WADA Toshihiro[2]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：s2370050@ipc.fukushima-u.ac.jp

The watershed of Ukedo River system has been heavily contaminated by radiocesium after the Fukushima Daiichi Nuclear Power Plant accident. Even in 2023, some freshwater fish in the river system still exceeded the Japanese regulatory limit of radiocesium for general foodstuff（100 Bq/kg）. To understand the radiocesium contamination levels, we measured ^{137}Cs concentration in fish in the river system. In summer 2023, we collected masu salmon and charr from Kayatsuka and Kodeya rivers, and from Ogaki Dam Reservoir. Japanese dace and pond smelt were also collected from the reservoir. In addition, water, aquatic insects, bottom sediments, and plankton were collected to measure their ^{137}Cs. Masu salmon showed positive "size effect" in all the sites, and the individuals collected from rivers had higher ^{137}Cs concentrations than those from the reservoir. Size effect was also observed for charr and Japanese dace. Most of individuals collected in the river system exceeded 100 Bq/kg（98.0-3,340 Bq/kg）. Our data will become a basis for evaluating seasonal changes of ^{137}Cs concentrations in fish and surrounding environments in the future.

Keywords：^{137}Cs, freshwater fish, charr, masu salmon, Japanese dace

請戸川水系のダムと渓流河川に生息する魚類の放射性セシウム濃度

児玉楓弥[*1]、金指努[2]、和田敏裕[2]

[1]福島大学大学院共生システム理工学研究科、[2]福島大学環境放射能研究所
*責任著者：s2370050@ipc.fukushima-u.ac.jp

請戸川水系は原発事故により最も放射性セシウムに汚染された水系であり、一般食品の出荷基準値である100 Bq/kgを超える渓流魚が2023年の調査でも確認されている。将来的な請戸川水系における魚類の出荷制限解除や漁業活動の再開に向け、放射性セシウムの汚染状況を詳しく知る必要がある。福島県浜通り浪江町に位置する請戸川水系のダムである大柿ダム、ダム上流の小出谷川、ダム下流の萱塚川（大柿下）の三か所で調査を行った。河川ではイワナ、ヤマメ、ダムではヤマメ、ウグイ、ワカサギを対象魚類として採取を行い、^{137}Cs濃度を測定した。また、環境水、底質、水生昆虫、植物などの採取、深度ごとの水温、空間線量などの環境データの記録も行った。2023年夏季の調査においてヤマメの^{137}Cs濃度について注目すると、すべての調査地点でサイズ効果（全長が大きいほど^{137}Cs濃度が高くなる傾向）が確認できた。その他、本研究では次の4つの結果が得られた；①ダムと比べて渓流域に生息するヤマメのほうが高い^{137}Cs濃度が検出された、②同河川に生息するイワナとヤマメの^{137}Cs濃度を比較すると、ヤマメのほうが高い傾向を示した、③イワナ、ウグイにもサイズ効果が確認された、④測定した個体のほぼすべてが100 Bq/kgを超えた（最大約3,340 Bq/kg、最低98 Bq/kg）。本結果は、魚類や環境試料の^{137}Cs濃度の季節変化を明らかにする上での基礎データを示した。

キーワード：^{137}Cs、淡水魚、ヤマメ、イワナ、ウグイ

P-23

Relationships in radiocesium concentration among dead leaves, aquatic insects (Lepidostomatidae), and their excretion

KANASASHI Tsutomu[*1], WADA Toshihiro[1]

[1]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：t.kanasashi@ier.fukushima-u.ac.jp

Since most of the forests contaminated by radioactive cesium (r-Cs) due to the Fukushima Daiichi Nuclear Power Plant accident have not been decontaminated, headwater stream ecosystems that depend on organic matters such as dead leaves from forests as primary products were also contaminated by r-Cs. We believe that clarification of r-Cs transferring from dead leaves to aquatic insects that feed on them will clear the process of r-Cs transferring to predatorial fish in the headwater stream ecosystems. Aquatic insects feeding on dead leaves excrete particulate organic matters (FPOM), which is a source of nutrients for organisms in upstream rivers. Therefore, if dead leaves are contaminated with r-Cs, it is expected that FPOM will also contain r-Cs and spread contamination in the upstream ecosystems, but no information on r-Cs in FPOM excreted by aquatic insects is available. In this study, larvae of aquatic insects (Lepidostomatidae), which mainly feed on dead leaves in streams, were fed with those of *Magnolia obovata*, with high r-Cs concentrations, and then, we compared and analyzed relationships of ^{137}Cs concentrations among the dead leaves, larvae and FPOM. Throughout the experimental periods (4-120 hours), the order of ^{137}Cs concentrations was FPOM > dead leaves > larvae, and linear relationships were observed among these three groups.

Keywords：riparian forest, aquatic insect, FPOM, FDNPP accident

カクツツトビケラ科幼虫の摂食・排泄による枯死葉の放射性セシウム濃度変化とその要因

金指努[*1]、和田敏裕[1]

[1]福島大学環境放射能研究所
*責任著者：t.kanasashi@ier.fukushima-u.ac.jp

福島第一原子力発電所事故により放射性Csに汚染された森林のほとんどが除染されていないため、森林からの枯死葉等の有機物を一次生産者として依存している渓流生態系も放射性Csに汚染されている。枯死葉から、それを摂食する水生昆虫への放射性Cs移行解明は、渓流生態系の魚類等、上位の捕食者への放射性Cs移行解明につながると考える。また、枯死葉を摂食する水生昆虫は、粒子状有機物（FPOM）を排泄し、渓流もしくは下流側の生物の養分源になる。そのため、枯死葉が放射性Csで汚染されていると、このFPOMにも放射性Csが含まれ、汚染が拡散されることが予想されるが、水生昆虫が排泄したFPOMの放射性Csに関する情報は認められない。上記のことから、本研究では、渓流に堆積した枯死葉を主に摂食するカクツツトビケラ科（Lepidostomatidae）水生昆虫の幼虫（以下、幼虫）に、放射性Cs濃度が高いホオノキ（*Magnolia obovata*）の枯死葉を与え、枯死葉—幼虫—FPOMの放射性Cs濃度を比較・解析した。ホオノキ枯死葉を2022年の落葉期以降に採取し、幼虫を2023年４～10月の実験開始前日に採取し、一定水温の環境下で飼育し、120時間までの任意の期間、摂食実験を行った。実験期間を通して、Cs-137濃度の高さはFPOM＞枯死葉＞幼虫になり、これら三者の間には、実験期間に影響されず、線形関係を示した。

キーワード：渓畔林、水生昆虫、FPOM、福島第一原子力発電所事故

P-24

BEECONECT: A connected flower to measure the effects of radioactive contamination on the cognitive health of pollinators

Kristine ABENIS[1], Loïc GOULEFERT[1], Christian LUBAT[2], NANBA Kenji[3], MIZUSAWA Leiko[4], Béatrice GAGNAIRE[5], Margot CREVET[5], Olivier ARMANT[5], Jean-Marc BONZOM[5], Mathieu LIHOREAU*[1]

[1]Research Center on Animal Cognition (CRCA-CBI), French National Centre for Scientific Research (CNRS), University of Toulouse, France, [2]BeeGuard, Labège, France, [3]Institute of Environmental Radioactivity, Fukushima University, [4]Faculty of Human Development and Culture, Fukushima University, [5]Institute for Radioprotection and Nuclear Safety (IRSN), Radionuclide Ecology and Ecotoxicology Laboratory, PSE-ENV/SERPEN, Cadarache, France
*Corresponding author：mathieu.lihoreau@univ-tlse3.fr

Insect pollinators are vital to the maintenance of terrestrial ecosystems and global food security. Bees, wasps, flies, and butterflies heavily rely on learning and memory to forage on flowers. However, these cognitive abilities can be disrupted by environmental stressors, which can have dramatic consequences on populations if food supply is compromised. Our aim in BEECONECT is to study the effects of radioactive contamination on the cognitive health of pollinators in Fukushima Prefecture. To mass phenotype the cognitive health of pollinators, we developed an automated and non-invasive "flower", i.e., Y-maze device in which individual insects must learn to find a sucrose reward, that operate continuously without the need of experimenters. Our system uses on-board artificial intelligence, enabling recognition of individual insects and species. Our preliminary analysis indicates reduced learning abilities in wild Japanese yellow hornets exposed to high radiation levels. Our plan for 2024 is to run a more extensive analysis of the cognitive health of honey bees and some wild pollinators using six flowers placed in sites characterized by different levels of radio-contamination. Our flower is the first automated cognitive test ever deployed to measure cognition in insects. Once validated, it will provide an extremely powerful tool to accurately quantify the risks of radioactive contamination (and many other stress factors) for pollinator populations and their associated ecosystem services.

Keywords：pollinators, cognition, learning and memory, mass phenotyping, radioactive contamination, resilience

P–25

Study of the effects of environmental radiocontamination on the metabolism of an amphibian, the tree frog

Léa DASQUE[*1,2], Damien ROUSSEL[2], Jean-Marc BONZOM[1], Olivier ARMANT[1], Clément CAR[1], André GILLES[3], NANBA Kenji[4], ISHINIWA Hiroko[4], WADA Toshihiro[4], Sandrine FRELON[1], Nathalie MONDY[2]

[1]Institute for Radioprotection and Nuclear Safety（IRSN）, Radionuclide Ecology and Ecotoxicology Laboratory, PSE-ENV/SERPEN, [2]Université Claude Bernard Lyon, [3]Université Aix Marseille, [4]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：lea.dasque@irsn.fr

The Fukushima nuclear accident（2011）led to radioactive releases into the environment, resulting in chronic exposure to ionizing radiation（IR）for wildlife living in these areas. Several studies have demonstrated that chronic and low-dose exposure to IR can impact the energy metabolism of various species. In this context, we measured the activity of two enzymes involved in energy metabolism in the thoracic muscles and liver of male Japanese tree frogs（Dryophytes japonicus）collected during the reproductive period in 2022 in Fukushima Prefecture along a gradient of exposure to ionizing radiation. In the trunk muscles, which are very active for calling during the breeding period, the activity of citrate synthase and lactate dehydrogenase increases with the dose of ionizing radiation absorbed by the tree frogs. This could suggest a response of aerobic and anaerobic metabolisms adjusted to cope with the increased energetic demands of the breeding period and compensate for the energetic costs associated with the dose received. In the liver, the organ of detoxification, we observed no effect of radioactivity dose on enzymatic activities, suggesting no dose-related increase in maintenance energy. To further investigate these results, we will evaluate the relationship between these modifications and the production of energy-intensive sexual signals, i.e., male tree frog's call during the breeding season.

Keywords：ecophysiology, energy metabolism, tree frog, ionizing radiation, Fukushima

P-26

Repeated DNA sequences of the centromere region in three species of the genus *Myodes*：Establishment of FISH probes for dicentric chromosomal analysis

ISHINIWA Hiroko[*1], Olena BURDO[2], NAKATA Akifumi[3], Donovan ANDERSON[4], MIURA Tomisato[4]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Institute for Nuclear Research National Academy of Sciences of Ukraine, [3]Faculty of Pharmaceutical Sciences, Hokkaido University of Science, [4]Institute of Radiation Emergency Medicine, Hirosaki University
*Corresponding author：ishiniwa@ier.fukushima-u.ac.jp

Dicentric chromosomes（Dic）are chromosome aberrations caused by radiation exposure. As their occurrence correlates with radiation dose, Dic analysis serves as a biodosimetry method. However, accurately identifying Dic requires a high level of expertise and skill, presenting a challenge for prompt analysis. In this study, we aimed to improve the efficiency of chromosome analysis in rodents – organisms with numerous acrocentric chromosomes that are particularly difficult to identify Dic. Our approach involved the development of fluorescence *in situ* hybridization（FISH）probes to visualize the centromere region by fluorescent staining. We utilized the repeated sequence motif found in the centromere region of voles（genus *Microtus*）and applied it to three species of voles belonging to genus *Myodes*. Our findings indicate that the repeated sequence motif could be identified in all chromosomes except the Y chromosome, of the Grey red-backed vole（*Myodes rufocanus*）and Northern red-backed vole（*M. rutilus*）. In the bank vole（*M. glareolus*）, not all chromosomes showed the motifs. The presence or absence of repeated sequences motif in the centromere region among phylogenetically related species is also observed in other taxa such as humans. This observation suggests that these sequences may have been acquired or lost during evolution in voles.

Keywords：dicentric chromosome, centromere, Msat-160, *Myodes*, vole

Myodes属３種におけるセントロメア領域の反復DNA配列：二動原体染色体解析に向けたFISHプローブの作成

石庭寛子[*1]、オレナ・ブルドー[2]、中田章史[3]、ドノヴァン・アンダーソン[4]、三浦富智[4]

[1]福島大学環境放射能研究所、[2]ウクライナ国立科学アカデミー原子力研究所、[3]北海道科学大学薬学部、[4]弘前大学被ばく医療総合研究所
*責任著者：ishiniwa@ier.fukushima-u.ac.jp

二動原体染色体とは放射線被ばくによって起こる染色体異常である。その発生頻度は被ばく線量に比例することからバイオドシメトリ（生物学的線量測定）として評価手法が確立されている。しかしながら、二動原体染色体の特定は高度な専門知識と技術が必要とされ、識別の難解さが解析を妨げる要因となっている。本研究では、特に識別が難しい末端動原体型染色体を多く持つ齧歯類の染色体解析の効率化を目指し、セントロメア領域を蛍光染色して視覚化するFISHプローブの作成を行なった。ハタネズミ類のセントロメア領域で発見されている反復配列をヤチネズミ類（Myodes属）３種に適用したところ、エゾヤチネズミ（*Myodes rufocanus*）とヒメヤチネズミ（*M. rutilus*）ではY染色体を除くすべての染色体で反復配列を確認できたが、ヨーロッパヤチネズミ（*M. glareolus*）では一部の染色体で確認されなかった。系統的に近縁な種内におけるセントロメア領域の反復配列の在・不在は、ヒトなど他の分類群にも見られることから、ヤチネズミ類でも同様に進化の過程で獲得・欠失した可能性が示唆された。

キーワード：二動原体染色体、セントロメア、Msat-160、*Myodes*、ハタネズミ類

P-27

Distribution and seasonality of ^{137}Cs activity in terrestrial and aquatic ecosystems in the difficult-to-return zone

YAMAGUCHI Daisuke[*1], KANASASHI Tsutomu[2], ISHINIWA Hiroko[2], WADA Toshihiro[2]

[1]Graduate School of Symbiotic Science and Technology, Fukushima University, [2]Institute of Environmental Radioactivity, Fukushima University
*Corresponding author：s2270057@ipc.fukushima-u.ac.jp

Radiocesium released by the Fukushima Daiichi Nuclear Power Plant accident remains in the environment and is taken up by wild animals and plants through food webs. Since ^{137}Cs in forests is circulated through trees, the ^{137}Cs concentrations in forests tends to be higher than that in human living areas. In addition, fallen leaves and other materials migrate into rivers, and pond, and thereby transfer ^{137}Cs to aquatic ecosystems. But few studies have analyzed the dynamics of ^{137}Cs in multiple ecosystems, and clarified the transfer of ^{137}Cs of plants and animals living in the transition zone. In this study, we measured ^{137}Cs concentrations in the environmental samples and multiple species collected at Shimofukazawa Pond and the surrounding terrestrial area in the difficult-to-return zone in Futaba Town, and compared the concentrations and examined seasonal changes. As a result, ^{137}Cs concentrations in soil and sediments were higher than in organisms. Among plants and animals, leaves of *Chengiopanax sciadophylloides* showed extremely high values（34,200Bq/kg）, but excluding some species, the values of ^{137}Cs concentrations in biota in terrestrial and aquatic areas were relatively similar. In largemouth bass, individuals in the summer 2023 showed higher ^{137}Cs concentrations than those at other seasons. These results demonstrated that, approximately 13 years after the FDNPP accident, most of the ^{137}Cs in the difficult-to-return zone has transferred to soil and sediments, while the ^{137}Cs concentrations of animals and plants in terrestrial and aquatic areas showed high variability depending on their species and seasons.

Keywords：wild plants and animals, forest ecosystem, aquatic ecosystem, ^{137}Cs concentrations

帰還困難区域の陸域・水域生態系における^{137}Cs濃度分布と季節性

山口大輔[*1]、金指努[2]、石庭寛子[2]、和田敏裕[2]

[1]福島大学大学院共生システム理工学研究科、[2]福島大学環境放射能研究所
*責任者者：s2270057@ipc.fukushima-u.ac.jp

福島第一原子力発電所事故により放出された^{137}Csは現在でも環境中に留まり、食物網などを介して野生動植物に取り込まれている。森林内^{137}Cs濃度は人の生活圏内に比べて高く、森林内の^{137}Csは樹木などを通して循環することが原因の一つである。さらに落ち葉などが河川・湖沼などに移行することで森林内の^{137}Csが水域生態系に移行する。これまで、^{137}Csの動態について、森林や河川・湖沼など、各生態系を対象とした研究事例は多数報告されているものの、陸域・水域を含めた複数の生態系を対象とした研究事例は少ない。本研究では、双葉町の帰還困難区域内の下深沢ため池（水域）及びその周辺（陸域）に生息する複数の生物種や環境中の^{137}Cs濃度測定を行い、濃度の比較や季節変化の検討を行った。結果として土壌や堆積物の^{137}Cs濃度は生物よりも高かった。動植物の中では、一部の種で極めて高い値（例：コシアブラ最大34,200 Bq/kg）を示す一方、それらの種を除くと陸域・水域の動植物^{137}Cs濃度の値は比較的近い値を示した。オオクチバスでは2023年の夏季の個体は他の時期の個体に比べて高い^{137}Cs濃度を示した。原発事故から約13年が経過した現在、帰還困難区域内の^{137}Csの多くは、森林土壌や池底堆積物に移行する一方で、陸域・水域に生息する動植物の種や季節によって、^{137}Cs濃度に大きな偏りが生じることが示された。

キーワード：野生動植物、^{137}Cs濃度、水域生態系、陸域生態系

P-28

Polychaete（*Perinereis aibuhitensis*）rearing experiment in seawater containing radiocesium

URYU Junya[*1], ITO Takayuki[1], YAMANOBE Takahiro[1]

[1]Fukushima Prefectural Research Institute of Fisheries Resources
*Corresponding author：uryu_junya_01@pref.fukushima.lg.jp

In general, marine organisms are known to uptake radiocesium primarily from seawater and prey organisms. In order to investigate the uptake of radiocesium from seawater, we conducted a rearing experiment with polychaetes using seawater containing radiocesium. Approximately 500 g of polychaetes housed in a 45 L glass tank at a water temperature of 12℃ and the experiment was conducted without feeding. Rearing seawater was prepared using radiocesium extracted from forest soil, with the salinity adjusted to 25‰ and the radiocesium concentration set at 1 Bq/L. Polychaetes were taken up 7, 14, and 28 days after the start of the rearing experiment and measured for radiocesium concentrations. The radiocesium concentrations in polychaetes were 6.6-9.6 Bq/kg-wet, 10.1-12.4 Bq/kg-wet, and 10.2-15.8 Bq/kg-wet at 7, 14, and 28 days, respectively. Considering that the rearing seawater was at 1 Bq/L, the internal radiocesium concentrations in the polychaetes exceeded 10 times that of the rearing water. The initial radiocesium concentration in the polychaete at the beginning of the experiment was non-detectable （ND）. This suggests that the internal radiocesium in the polychaete was uptake from the rearing seawater, reaching concentrations up to approximately 15 times higher.

Keywords：radiocesium, polychaete（*Perinereis aibuhitensis*）, prey organisms

放射性Csを含む海水でのアオゴカイ飼育試験

瓜生純也[*1]、伊藤貴之[1]、山野辺貴寛[1]

[1]福島県水産資源研究所
*責任者：uryu_junya_01@pref.fukushima.lg.jp

一般に、海産生物は放射性Csを主に海水や餌生物から取り込むと言われている。海水からの放射性Csの取り込み量を調査するため、放射性Csを含む海水でアオゴカイの飼育試験を行った。アオゴカイ500gを60cm水槽(45L)に収容し、水温12℃、無給餌で飼育試験を行った。飼育海水は、森林土壌から抽出した放射性Csを用いて、塩分濃度25‰、放射性Cs濃度を１Bq/Lに調整した。アオゴカイは実験開始から７日後、14日後、28日後に取り上げ、放射性Cs濃度を測定した。測定の結果、７日後の放射性Csは6.6〜9.6 Bq/kg-wet、14日後は10.1〜12.4 Bq/kg-wet、28日後は10.2〜15.8 Bq/kg-wetであった。
飼育海水は１Bq/Lであることから、アオゴカイ体内の放射性Csは飼育海水の10倍以上の濃度に上昇していた。実験開始時におけるアオゴカイの放射性Cs濃度はNDであったことから、アオゴカイ体内の放射性Csは飼育海水から放射性Csを取り込み、最大で15倍程度まで上昇していた。

キーワード：放射性Cs、アオゴカイ、餌生物

P–29

Development of a highly sensitive analytical method for ultra-trace ^{99}Tc in environmental water

TAKAMI Kei[1], NABEYAMA Yuki[1], HATSUKAWA Yuichi[2], TSUKADA Kazuaki[3], ASAI Masato[3], SUEKI Keisuke[4], YAMASAKI Shinya[4], TAKAKU Yuichi[4], SAKAGUCHI Aya[*4]

[1]School of Science and Engineering, University of Tsukuba, [2]National Institutes for Quantum and Radiological Science and Technology, [3]Japan Atomic Energy Agency, [4]Institute of Pure and Applied Sciences, University of Tsukuba
*Corresponding author：ayaskgc@ied.tsukuba.ac.jp

The monitoring of ^{99}Tc in environmental waters, especially for seawater, is essential due to the physico-chemical properties of [99]Tc. However, the determination of ultra-trace levels of ^{99}Tc in environmental water is quite difficult, because of the use of large amounts of seawater and the requirement for complicated chemical separation for both radiometric analysis and mass spectrometry. In this study, we attempt to construct a trace level of ^{99}Tc measurement method by improving the sensitivity of ICP-MS and developing of a simple Tc separation method from seawater. In addition, the production of [95m]Tc tracer by the nuclear reaction of ^{95}Mo(p, n) [95m]Tc is also conducted.

Keywords：technetium, anthropogenic radionuclides, mass spectrometry

環境水中の極微量[99]Tc高感度分析法の開発

高見佳[1]、鍋山雄樹[1]、初川雄一[2]、塚田和明[3]、浅井雅人[3]、末木啓介[4]、山崎信哉[4]、高久雄一[4]、坂口綾[*4]

[1]筑波大学理工学群化学類、[2]量子科学技術研究開発機構、[3]日本原子力研究開発機構、[4]筑波大学数理物質系
*責任者：ayaskgc@ied.tsukuba.ac.jp

[99]Tcはその物理化学的特性から、環境特に海洋におけるモニタリングが必須である。しかし、海水中極微量[99]Tc分析には大量の海水から煩雑な化学分離により濃縮・精製が必要であり放射線分析や質量分析ともに困難である。そこで、ICP-MSの高感度化、海水からの簡便なTc分離法について検討し、極微量[99]Tcの迅速・簡便な定量を試みた。また、^{95}Mo(p, n)反応による[95m]Tcトレーサー製造も試みた。

キーワード：テクネチウム、人工放射性核種、質量分析

P-30

Kinetic study of electrochemically formed silver iodide for the rapid and selective recovery of iodide ion in environmental water

YAMASAKI Shinya*[1], TAKEDA Ryoji[1]

[1]Center for Research in Radiation, Isotopes, and Earth System Sciences, University of Tsukuba
*Corresponding author：s-yamasaki@ied.tsukuba.ac.jp

It is important to quantify the concentration of iodine in each chemical form because the transfer behavior and biological effects of iodine in the environment differ depending on the chemical form. In this study, we investigated the kinetic contribution of the electrochemical recovery method for iodide ions that we have developed previously. A silver wire electrode（~200mm^2）was used as the working electrode, an Ag/AgCl electrode（3M NaCl）as the reference electrode, and a platinum electrode as the counter electrode. The surface area of the working electrode and the amount of solution were varied to examine the concentration behavior of I- on the electrode surface. A constant potential electrolysis was performed by adding 3 kBq of ^{125}I to the reaction solution. The concentration of I- in the solution before and after the reaction was determined using an NaI scintillator, and the recovery rate was obtained. As an environmental sample, water collected from Matsumi Pond in the University of Tsukuba was used by filtered through a 0.45 μm filter. For comparison, the I- concentration in the environmental sample was determined by HPLC-ICP-MS and compared with the results of this electrochemical method. The experimental results showed that the reaction reached a steady state more quickly as the ratio of electrode area to solution volume increased. The recovery rate increased as the total concentration of I- increased. Analysis of the actual sample yielded values on the same order of magnitude as those obtained by HPLC-ICP-MS.

Keywords：speciation, constant potential electrolysis, iodine-125

環境水中ヨウ化物イオンの迅速かつ選択的回収に向けた電気化学的手法の速度論的検討

山崎信哉*[1]、武田凌治[1]

[1]筑波大学放射線・アイソトープ地球システム研究センター
*責任者：s-yamasaki@ied.tsukuba.ac.jp

放射性ヨウ素の環境中における移行挙動や生体影響はその化学形態ごとに異なるため、化学形態別に濃度定量することが重要である。本研究では、これまでに構築してきたヨウ化物イオンを電気化学的に回収する方法について、その速度論的な寄与について検討を行った。作用電極には銀ワイヤー電極（~200mm^2）、参照電極はAg/AgCl電極（3M NaCl）、対極は白金電極を用いた。電極の面積及び溶液量を変化させて、電極表面へのI-の濃集挙動を調べた。反応溶液には^{125}Iを3 kBq加え、定電位電解を行った。反応前後の溶液中のI-濃度をNaIシンチレーターにより求め、回収率を得た。実試料として、筑波大学内の松美池で採取した水を0.45 μmのフィルターでろ過して用いた。また、比較のため、HPLC-ICP-MSにより試料中のI-濃度を求め、本電気化学的手法の結果と比較した。実験の結果、電極面積と溶液量の比が大きくなるほど反応が速やかに定常状態に達した。また、回収率はI-の全濃度が高くなるにつれて上昇した。実試料を分析した結果、HPLC-ICP-MSにより求めた値と同オーダーの値が得られた。

キーワード：スペシエーション、定電位電解、ヨウ素-125

P–31

Variation of ^{137}Cs activity concentration in flooded and pore water in paddy fields and its transfer to rice

TSUKADA Hirofumi[*1], SAITO Takashi[2], HIRAYAMA Takashi[3], MATSUOKA Hiroaki[3], NAKAO Atsushi[4]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]Department of Agriculture, Forestry and Fisheries, Fukushima Prefecture, [3]Hama Agricultural Regeneration Research Centre, Fukushima Prefectural Agricultural Technology Centre, [4]Department of Life and Environmental Sciences, Kyoto Prefectural University
*Corresponding author：hirot@ipc.fukushima-u.ac.jp

Caesium-137（^{137}Cs）is a major anthropogenic radionuclide released into the environment as a result of the 2011 TEPCO's Fukushima Daiichi Nuclear Reactor Station accident, and parts of Hamadori in Fukushima are still in a difficult return zone. In the specified reconstruction and revitalization bases where air dose rates have been reduced due to decontamination, evacuation orders were lifted by 2023 and residents began returning home. In anticipation of the resumption of farming after their return, rice is being cultivated in experimental rice paddies. In this study, we investigated ^{137}Cs in inlet water, flooded water, and pore water, and discussed the transfer of ^{137}Cs to rice. Water samples were collected biweekly over six times from five sites in Hamadori（Okuma, Minamisoma and Katsurao）over the 2018–2022 cultivation periods to measure dissolved ^{137}Cs activity concentration, potassium（K）, and ammonium（NH$_4$）concentrations. The activity concentrations of ^{137}Cs in the inlet water and flooded water were uniform below 0.1 Bq L^{-1}, and significant differences were observed at some sites. The activity concentration of ^{137}Cs in pore water under anaerobic condition increased with increasing NH$_4$ concentration, markedly to reach a value 20-fold higher than that in flooded water. However, the ^{137}Cs/K ratio in flooded water and pore water remained uniform throughout waterlogging period, and even if the ^{137}Cs activity concentration in pore water increases, the K concentration increases at the same time. And there was no change in the competitive absorption relationship between the two absorbed by rice plants. Therefore, even if the ^{137}Cs activity concentration in the porewater is elevated, it is considered that rice uptake of ^{137}Cs is not necessarily enhanced during the waterlogging period due to appropriate K application.

Keywords：^{137}Cs/K ratio, NH$_4$, waterlogging period, competitive absorption

田面水および間隙水中^{137}Cs濃度の変化とイネへの移行

塚田祥文[*1]、齋藤隆[2]、平山孝[3]、松岡宏明[3]、中尾淳[4]

[1]福島大学環境放射能研究所、[2]福島県農業振興課、[3]福島県農業総合センター浜地域農業再生研究センター、[4]京都府立大学生命環境科学研究科
*責任著者：hirot@ipc.fukushima-u.ac.jp

セシウム-137（^{137}Cs）は、2011年の東京電力福島第一原子力発電所事故によって環境中に放出された主要な人工放射性核種であり、未だに浜通りの一部は帰還困難区域となっている。除染等による空間線量率の低減化が行われた特定復興再生拠点では、2023年までに避難指示が解除され、住民の帰還が始まった。そこで帰還後の営農再開を見据え、試験水田によるイネの栽培を行っている。ここでは、水田に供給される灌漑水、田面水および間隙水の^{137}Csについて調査し、イネへの^{137}Cs移行について考察した。2018年から2022年に浜通りの５地点（大熊町・南相馬市・葛尾村）で６回に亘り、イネ栽培期間に水口水・田面水・間隙水を２週間毎に採取し、溶存態^{137}Cs、アンモニウム（NH$_4$）、カリウム（K）濃度を測定した。水口水と田面水中^{137}Cs濃度は、0.1 Bq L^{-1}以下で一様な濃度にあり、両者で有意差の見られる地点があった。還元的な環境にある間隙水中^{137}Cs濃度は、NH$_4$濃度の上昇に伴い増加し、田面水の20倍にも達した。しかしながら、田面水と間隙水の^{137}Cs/K濃度比は栽培期間を通して一様にあり、間隙水中^{137}Cs濃度が増加したとしても同時にK濃度も増加した。よって、イネに吸収される両者の競合的な吸収関係に変化はなかった。従って、間隙水^{137}Cs濃度が増加しても、適正なK施用によりイネへの吸収抑制が働いていると考えられる。

キーワード：^{137}Cs/K比、NH$_4$、湛水期、競合的な吸収

P-32

Environmental transfer parameter values for internal dose assessment obtained by QST-NIRS in 2011-2022

TAGAMI Keiko[*1], UCHIDA Shigeo[1]

[1]National Institute of Radiological Sciences, National Institutes for Quantum Science and Technology, Institute for Radiological Science
*Corresponding author：tagami.keiko@qst.go.jp

The IAEA has published Tecdoc-1927 (2020), which collates environmental transfer parameters reported after the Fukushima Daiichi Nuclear Power Plant accident. Various organizations cooperated to publish this tecdoc including data over several years since the accident. However, the geometric mean values are mainly shown in tables, and thus little individual data are listed. To make the data available, we compiled parameter data collected by QST-NIRS in 2011-2022 (QST-R-27, https://repo.qst.go.jp/records/86615), and here, some important results were reported.

Shortly after the accident occurred, we started to collect plant samples thus the data were used. We also used open available food monitoring data to calculate parameter values. It was found that lower retention of radioiodine than radiocaesium in plants. Once retained in plants, both radionuclides decreased with similar environmental half-lives, with a geometric mean value of 6-8 d. The translocation from contaminated parts to non-contaminated parts was greater for radiocaesium than for radioiodine. In the long term, we investigated radiocaesium concentrations in trees and herbaceous plants and found that decreasing rates of radiocaesium from both types of plants can be described by using two components, fast and slow half-life fractions. Other parameter values are also available in the report.

Keywords：radioiodine, radiocaesium, environmental half-lives, food monitoring data

量研－放医研によって2011-2022年に収集された内部被ばく線量評価のための環境移行パラメータ値について

田上恵子[*1]、内田滋夫[1]

[1]量子科学技術研究開発機構　放射線医学研究所
*責任者：tagami.keiko@qst.go.jp

近年IAEAから福島第一原発事故後の環境移行パラメータを集めたTecdoc-1927(2020)が発行され、多様な機関からの報告値が、事故後から数年間程度の経時変化も含め記載されている。しかし主に幾何平均値が表として示され、個別データは少ない。そこで貴重なパラメータデータを個別に扱えるようにすることを目的とし、事故後から2022年まで、内部被ばくに着目しつつ量研－放医研において収集したデータをまとめた（QST-R-27, https://repo.qst.go.jp/records/86615）。今回はその成果について報告する。

我々は主に植物試料の収集を進めると共に、食品モニタリングデータ等も活用しつつパラメータデータを導出した。その結果、降下した放射性物質の植物による保持（遮断係数）は、放射性Iの方が放射性Csよりも低いことがわかった。ただし、一旦植物に保持された放射性IとCsは、どちらも同程度の環境半減期で減少し、その幾何平均値は6-8日であった。なお、汚染した部位から非汚染部位への転流は、放射性Csの方がIよりも大きかった。長期的には木本および草本植物の放射性Csを調査し、どちらの植物のタイプでも環境半減期が早い成分と遅い成分の２つに分けられることを明らかにした。その他、土壌-土壌溶液間分配係数、土壌-農作物移行係数、家畜への移行、野生の食品への面移行係数、環境水から魚介類への濃縮係数等も公開している。

キーワード：放射性ヨウ素、放射性セシウム、環境半減期、食品モニタリングデータ

P–33

Cesium separation from aqueous waste matrices using crown ether functionalized mesoporous silica

Rashedul Islam RIPON[*1,2], Zinnat A. BEGUM[3,7], Bashir Ahmmad ARIMA[4], OGATA Makoto[5], TAKAGAI Yoshitaka[6], Ismail M. M. RAHMAN[*7]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Department of Chemistry, Mawlana Bhashani Science and Technology University, Bangladesh, [3]Department of Civil Engineering, Southern University Bangladesh, Bangladesh, [4]Graduate School of Science and Engineering, Yamagata University, [5]Faculty of Food and Agricultural Sciences, Fukushima University, [6]Faculty of Symbiotic Systems Science, Cluster of Science and Technology, Fukushima University, [7]Institute of Environmental Radioactivity, Fukushima University

*Corresponding author: ripon.chemmbstu@gmail.com, immrahman@ipc.fukushima-u.ac.jp

Radiocesium（r-Cs: ^{137}Cs; $t_{1/2}$, 30.2 yrs; chemical analog of K）separation from environmental wastewater has become an emerging issue for protecting public health in the aftermath of the Chornobyl and Fukushima accidents. The current work focuses on the development of an efficient solid-phase adsorbent material, DFDB18C6@SBA-NH₂, encompassing a macrocyclic ligand（diformyl dibenzo-18-crown-6-ether, DFDB18C6）covalently attached to mesoporous Santa Barbara Amorphous-15（SBA-15）, for r-Cs removal from environmental wastewater. The batch adsorption technique was utilized to investigate the adsorbent's behavior towards Cs. Various operating variables were systematically optimized, including solution pH, reaction time, initial ion concentration, and presence of competing ions. The adsorbent FDDB18C6@SBA-NH₂ has considerable Cs adsorption capacity at pH 6. The FDDB18C6@SBA-NH₂ exhibits rapid Cs adsorption, and the adsorption kinetic is governed by the pseudo-second-order model. The Langmuir adsorption isotherm model fits the experimental adsorption data well, indicating that the Cs adsorption is probably a monolayer adsorption process. Hence, the crown ether functionalized mesoporous silica adsorbent can be used to separate r-Cs from aqueous waste matrices.

Keywords：radiocesium, separation, crown ether, solid phase adsorbent, adsorption

P-34

Physical and chemical traits of cesium and strontium tolerance in velvet grass（*Holcus lanatus* L.）

Bayezid M. KHAN[1,2], M. Ferdous ALAM[1,3], Zinnat A. BEGUM[1,4], Ismail M. M. RAHMAN[*1]

[1]Institute of Environmental Radioactivity, Fukushima University, [2]University of Chittagong, Bangladesh, [3]Atomic Energy Research Establishment, Bangladesh, [4]Southern University Bangladesh
[*]Corresponding author：immrahman@ipc.fukushima-u.ac.jp

Unusual environmental intrusion of radiocesium（r-Cs）and radiostrontium（r-Sr）from nuclear reactors and fuel reprocessing plants, as well as nuclear power plant accidents like those in Chornobyl and Fukushima, has raised concerns regarding potential health risks through soil-to-crop transfer and subsequent human exposure. The enrichment of soil with potassium（K）and calcium（Ca）has been identified as a strategy to reduce the plant uptake of r-Cs or r-Sr. However, the impact of these changes in uptake on plant growth remains insufficiently understood. This study aims to investigate the effects of r-Cs and r-Sr on the growth of seedlings of the wild grass *Holcus lanatus* L. cultivated in hydroponic solutions, using stable Cs or Sr isotopes as the corresponding analogs of r-Cs and r-Sr. The findings reveal that higher concentrations of Cs and Sr（≥ 4 mg L^{-1}）inhibit seedling growth, while lower concentrations （≤ 1 mg L^{-1}）exhibit no significant effect. The *H. lanatus* demonstrates moderate tolerance to Cs and strong tolerance to Sr. The supplementation of K and Ca in soils amended with Cs or Sr isotopes further reduces the uptake of these elements in the *H. lanatus*. In addition, introducing Cs or Sr to the soil alters the influx rates of various nutrient elements into *H. lanatus*. These results suggest that *H. lanatus* may represent a viable option for cultivation in r-Cs and r-Sr contaminated grasslands.

Keywords：wild grass, cesium, strontium, tolerance, growth traits

P-35

Temporal change of ^{137}Cs fractions in archived soil samples collected from Fukushima Prefecture in 2011

YANAGIGAWA Kento[1], TATSUNO Takahiro[2,3], TSUKADA Hirofumi*[2]

[1]Graduate School of Symbiotic Systems Science and Technology, Fukushima University, [2]Institute of Environmental Radioactivity, Fukushima University, [3]Research Faculty of Agriculture, Hokkaido University
*Corresponding author：hirot@ipc.fukushima-u.ac.jp

Huge amounts of radionuclides were released into the environment by the Fukushima Daiichi Nuclear Power Station（FDNPS）accident and deposited onto the surrounding and the northwest direction from the FDNPS. Ceasium-137 is a relatively long half-life and present in the soil for a long time and is known to exist in several fractions. In this study, 55 archived soil samples（1,080-196,000 Bq kg^{-1} DW）collected from June-July 2011 from within a 20 km zone of the FDNPS were analysed for ^{137}Cs in the soils using a sequential extraction method, and the soils were repeatedly wetted and dried to accelerate changes over time. The mean values of the fractions of exchangeable, bound-to-organic and strongly bounded ^{137}Cs were 11.8, 10.2 and 79.8%, respectively. Three fractions in the soils after ageing were 8.33, 9.64 and 81.3%, with significantly decreasing in the exchangeable fraction and with increasing in the strongly bound fraction, while ^{137}Cs in the bound-to-organic fraction did not change with aging. The study utilised the archived soil samples provided by the Nuclear Regulation Authority and managed by the Institute of Environmental Radioactivity, Fukushima University.

Keywords：archived soil sample, sequential extraction methods, exchangeable fraction

2011年に福島県から採取した土壌アーカイブ試料の^{137}Cs存在形態の経時変化に関する研究

柳川賢斗[1]、辰野宇大[2,3]、塚田祥文*[2]

[1]福島大学共生システム理工学研究科、[2]福島大学環境放射能研究所、[3]北海道大学農学研究院
*責任者：hirot@ipc.fukushima-u.ac.jp

2011年の東京電力福島第一原子力発電所（FDNPS）事故により、主に原発周辺と北西方向の広い範囲に放射性核種が拡散、土壌を汚染した。そのうち^{137}Csは半減期が比較的長く、長期間土壌中に残留する。土壌中^{137}Csは、幾つかの存在形態にあることが知られている。本研究では、2011年6月～7月にかけてFDNPSから半径20km圏内から採取された55試料の土壌アーカイブ試料（1,080～196,000 Bq kg^{-1} DW）について逐次抽出法で、土壌中^{137}Csの交換態・有機物結合態・強固結合態の存在形態分析を行った。また、湿潤−乾燥を繰り返すエイジング処理を行い、存在形態の経時的変化を求め、エイジングによる存在形態割合の変化を求めた。エイジング前の交換態、有機物結合態、強固結合態^{137}Csの存在割合の平均値は、それぞれ11.8、10.2および79.8%、エイジング後に8.33、9.64および81.3%となり、交換態割合が有意に減少し、一方で強固結合態割合が増加した。また、有機物結合態割合はエイジングによる有意な変化が見られなかった。本研究は、原子力規制庁が提供し、福島大学環境放射能研究所が管理する土壌アーカイブ試料を活用しました。

キーワード：土壌アーカイブ試料、逐次抽出、交換態、有機物結合態、強固結合態

P-36

Modeling the impact of forest fires in the Chornobyl Exclusion Zone on radionuclide contamination of surface waters

Oleksandr PYLYPENKO[1], Mykola TALERKO[2], Mark ZHELEZNYAK[*3]

[1]Institute Mathematical Machines and System Problems NAS Ukraine, [2]Institute for Safety Problems of Nuclear Power Plants NASU, [3]Institute of Environmental Radioactivity, Fukushima University
[*]Corresponding author：zheleznyak.m@gmail.com

The problem of secondary radioactive contamination due to forest fires in the Chernobyl Exclusion Zone （CEZ） became especially important after the beginning of the military invasion of Russian Federation into Ukraine across the Belarus-Ukrainian border through the CEZ. The temporary occupation of CEZ and the military activities during its liberation caused a number of forest fires. The problem is still acute due to the risk of new military invasions into the CEZ and natural wildfires. Taking into account that the Pripyat River and Kyiv Reservoir of the Dnipro River are the main pathways of radionuclide transport from CEZ to the Kyiv city agglomeration, the task is to assess the impact of the maximum potential wildfires in the CEZ on the contamination of Dnipro River at Kyiv. This task is solved by the implementation of the Lagrangian atmospheric dispersion model LEDI for simulating the fallout of ^{137}Cs and ^{90}Sr on water surface and watershed in CEZ and on Kyiv reservoir, watershed wash-off model RETRACE and one -dimensional river／reservoir model RIVTOX. The models have been retested and calibrated using the data that were collected and systematized during the JST-JICA SATREPS project. The comparative role of the fallout on the watershed and on the water surface is analyzed. We conclude that the wildfires in CEZ could not cause a notable increase in the water concentration of ^{137}Cs and ^{90}Sr outside the CEZ.

Keywords：Chornobyl Exclusion Zone, forest fires, ^{90}Sr, ^{137}Cs, modeling, atmospheric dispersion, rivers

P-37

Simulation of tritium releases into the atmosphere during the Fukushima accident and into the ocean due to planned discharge of treated water

Alexandre CAUQUOIN[*1], Maksym GUSYEV[2], KOMURO Yoshiki[3], Hayoung BONG[1], OKAZAKI Atsushi[4], YOSHIMURA Kei[1]

[1]Institute of Industrial Science, The University of Tokyo, [2]Institute of Environmental Radioactivity, Fukushima University, [3]Japan Agency for Marine-Earth Science and Technology, [4]Institute for Advanced Academic Research/Center for Environmental Remote Sensing, Chiba University
*Corresponding author：cauquoin@iis.u-tokyo.ac.jp

Following the accident at the Fukushima Daiichi Nuclear Power Plant（FDNPP）in March 2011, large quantities of radioactive materials were released into the atmosphere and ocean. Since the FDNPP nuclear accident, Tokyo Electric Power Company（TEPCO）operators have been implementing measures to reduce groundwater inflow into the FDNPP damaged reactor buildings while pumping water to cool the nuclear reactors and fuel debris. The resulting huge water volume began the discharge into the ocean from August 2023, after being treated by an Advanced Liquid Processing System（ALPS）to remove radionuclides for acceptable discharge levels except tritium. Tritium releases from the FDNPP accident and the ALPS treated water raise questions about the impact on tritium in precipitation in Japan, the removal time of anthropogenic tritium in groundwater and the oceanic transport of tritium from released ALPS treated water.

In this two-part study, we present:

（1）The modeling of tritium in precipitation during the FDNPP accident using an atmosphere global climate model. We found good agreement with the tritium in precipitation observations in Japan for 2011 and subsequent years.

（2）A sensitivity simulation of tritium concentration in the ocean due to planned ALPS treated water release in the next decades by TEPCO using an ocean global climate model. Simulated tritium concentrations in the North Pacific Ocean vary between 0.01 and 3 Bq/m^3, well below the natural tritium level（approximately 50 Bq/m^3）.

Keywords：tritium, global climate models, Fukushima nuclear power plant, atmosphere, ocean