CO10-1 Effective Measures on Safety, Security, Hygiene and Disaster Prevention in Laboratories

T. Iimoto[1], M.M. Hasan[1], H. Koike[1], Q. Jin[1], S. Sho[1], K. Fukuda[1], T. Takahashi[2]

[1] The University of Tokyo

[2] Institute for Integrated Radiation and Nuclear Science, Kyoto University

INTRODUCTION: Important aspects of the study can be found in the following keywords, such as safety, security, hygiene and disaster prevention. Nuclear research reactor is one of representative facilities together with these keywords under their operation. It is effective to investigate the latest status on practical measures on these keywords in various facilities including nuclear research reactors, to compare each other among facilities, and to discuss more optimized ones for our positive safety management. Through this process, it is also essential to investigate the latest international and/or national regulations and the movement of revision of them. In addition, development of human resource and public literacy on nuclear science and technology is also within the scope of the research. The total discussion contents and their fruits are directly useful for all relating laboratories.

RESEARCH APPROACH:

General research approach is as follows.

- Measures of safety management during operation or standstill status of the real facilities would be investigated. This information would be used for our research discussion on the positive and more optimized safety management.
- It would not be a single year research, but maybe two to three years research for one theme.
- Information source of facilities would not be only KUR, KUCA or the other facilities in Kyoto University, but also the Kindai university research nuclear reactor or the facility of National Institute of Fusion Science, etc. This research is an active joint-research with these relating facilities and positive researchers on safety management.
- One of the distinctive features of this research is to involve office staffs as cooperators as well as researchers and technical staffs. In The University of Tokyo, most of the members in Division for Environment, Health and Safety are office staffs who knows real situation of safety management in laboratories very well.

Concrete discussion target in FY of 2021 was determined as following two; “local safety management rule for exempted radioactive sources” and “developing a set of educational videos for safety managers and workers in universities on X-ray application”. IAEA safety standards recommend that nuclear regulators use a graded approach in their oversight of nuclear installations – that is, they adapt the rigorousness of their oversight to the likelihood that something could go wrong with the regulated facility or activity, and the severity of consequences should that happen. Our discussion and research fruits are following the strategy and concept fully.

LOCAL SAFETY MANAGEMENT RULE FOR EXEMPTED RADIOACTIVE SOURCES

The radiation risk of exempted radioactive sources is extremely low, therefore the rule of safety management for them should be followed as graded approach basis. The rule determined in The University of Tokyo is;

1. Procedures for receiving, discharging, and disposing of radiation sources should be performed by the department's radiation control personnel.
2. Departmental radiation control personnel should perform the administrative procedures for transferring and receiving radiation sources.
3. The use and storage of radiation sources should be in accordance with the instructions attached to the sources. In the absence of such instructions, the person in charge of radiation control should check them with Japan Radioisotopes Association (JRIAS).
4. The storage location radiation sources should be determined after appropriate consideration based on the circumstances of the department.
5. The person in charge of radiation control in the department should establish a system to periodically check the actual radiation sources.
6. When a radiation source is disposed of, it should be returned and passed to JRIAS.

DEVELOPING EDUCATIONAL VIDEOS IN UNIV. FOR X-RAY APPLICATION:

Safety education system for managers and users of X-ray has been discussed to standardize it in universities. Based on the discussion results, we developed a set of new safety educational videos, which is 10-15 min for each; (1) Laws and regulations concerning X-rays and the university's management system, (2) Methods of managing research x-ray equipment and electron microscopes, (3) Internal inspection methods for X-Ray Generators, and (4) New management methods for very low-hazard X-ray generators. Especially the contents of (4) was prepared as the local rule of The University of Tokyo, based on the graded approach in an optimized safety management concept. These videos will be opened and used from FY 2022 in The University of Tokyo.

CO10-2 Investigation of a method for analyzing chlorine and bromine in volatile liquid samples in neutron activation analysis

K. Ito[1], T. Fujimori[2], K. Oshita[1], S. Fukutani[3], K. Shiota[1], M. Takaoka[1], S. Takahashi[4]

[1]*Department of Environmental Engineering, Graduate School of Engineering, Kyoto University*

[2]*Faculty of Advanced Science and Technology, Ryukoku University*

[3]*KURNS*

[4]*Graduate School of Agriculture, Ehime University*

INTRODUCTION: Among organochlorine and bromine compounds, persistent organic pollutants (POPs) are subject to international regulation, but the number of POPs is increasing year by year, so extractable organochlorine (EOCl) and extractable organobromine (EOBr) have attracted attention as a comprehensive risk assessment including related and alternative substances [1]. However, from a safety perspective, it is necessary to volatilize the liquid content of volatile liquid samples and measure them as solid samples [2]. However, the large chlorine and bromine content of filter paper, which is used as a medium to attach components to, has limited the quantification of EOCl and EOBr. Therefore, the objective of this study was to investigate alternative materials to the filter paper used in sample preparation. Empty samples were prepared using various materials to determine the amount of chlorine and bromine as background, and the ability of those to attach components was compared using extracts of sediment samples.

EXPERIMENTS: Material was prepared in a polyethylene (PE) bag for background measurements (in Table1), binding it with a sealer, and then sealing it with a double PE bag. The weight of the materials was not standardized among the materials, but they were placed in the bags so that they were almost the same in volume. The sediment samples were Soxhlet extracted with toluene and inorganic halogens were removed using sodium sulfate solution, dropped into a PE bag containing materials, allowed to dry and solidify for 12 hours at room temperature and pressure, then bound with a sealer, and further sealed with a double PE bag. As a standard sample, a mixed aqueous solution of ammonium chloride and ammonium bromide was dropped onto filter paper (1/8, unwashed) in a PE bag. Samples were irradiated for 15 min with a thermal neutron flux of $2.0–2.4\times10^{13}$ $cm^{-2}・S^{-1}$ at KURNS. ^{38}Cl ($t_{1/2}$ = 37.18 min, E_γ = 1642, 2168 keV) and ^{80}Br ($t_{1/2}$ = 17.6 min, $E\gamma$ = 616 keV) were measured by using a Ge semiconductor detector for 300 sec. Concentrations in the sediment samples were calculated using the comparison method between those and standard samples minus the amount of chlorine and bromine from the PE bag and each material.

Sample	Contents
No Materials	Only PE Bag
PE Sheet	PE Bag + Cut up PE sheet
Glass Wool	PE Bag + Glass Wool
Washed Filter	PE Bag + Washed Filter Paper[a]
Filter Paper(1/8)	PE Bag + 1/8 size cut Filter Paper
Filter Paper(1/4)	PE Bag + 1/4 size cut Filter Paper

Table1. Prepared sample names and their contents. [a] Filter Paper which washed by ultra pure water and hexane and dried.

RESULTS: Figure1(A) shows the results of the background measurement and Figure1(B) shows the results of the concentration measurement of the sediment. In Figure1(A), filter paper contains more chlorine and bromine than other materials, and the use of filter paper more than doubles the amount of chlorine and bromine of background-origin, so it is better to use other materials. Figure1(B) shows that there was no significant difference in the sediment concentration of about 5 μg/g for any of the materials. Note that the filter paper (1/4 size) has a higher sediment concentration of 9.2 μg/g, but this data includes the effect of background chlorine (especially from filter paper) because the calculation method has not been improved. The results indicate that there is no significant difference in the role of each material in "attracting" extracted components, and it is clear that sediment concentration can be obtained without the inclusion of any media. In addition, the standard error of the sediment concentration showed a large variation when quartz cotton was used.

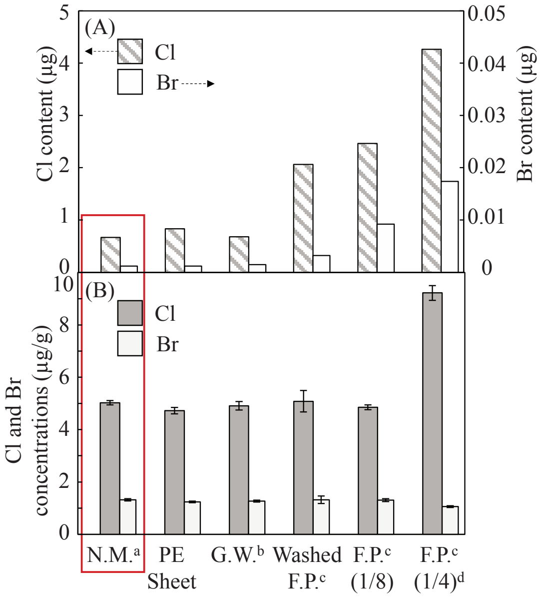

Figure1. (A) is the Cl and Bromine content(μg/g) as backgrounds in each samples. (B) is the concentrations of EOCl and EOBr in the sediment samples. [a]N.M. means No Materials, [b]G.W. means Glass wool, [c]F.P. means Filter Paper.

This study aimed to find an alternative material to filter paper, and it became clear that the most appropriate method was to drop only the extracted solution directly into a PE bag without any contents; the PE bag alone would also serve as a medium for the extracted components, minimizing the amount of chlorine and bromine of background-origin, thus allowing for low-concentration samples to be more accurate calculations can be made. On the other hand, the filter paper was used in the standard sample, and it is desirable to investigate the same method can be applied to aqueous solution in the future.

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CO10-3 Development of the Evaluation Method of Dose Reduction Effects by Reverse Tillage in the Forest Using the Point-Kernel Integration Method

Y. Sogabe[1], M. Yoneda[1], Y. Shimada[1], S. Fukutani[2], M. Ikegami[2]

[1]*Graduate School of Engineering, Kyoto University*
[2]*Institute for Integrated Radiation and Nuclear Science, Kyoto University*

INTRODUCTION: Decontamination of forests contaminated by the Fukushima Daiichi Nuclear Power Plant accident in March 2011 is required. In this study, we considered decontamination using the reverse tillage method as a method to reduce the radiation dose in the air without generating soil to be removed. In this method, the upper layer of soil with a high concentration of radioactive Cs is replaced with the lower layer with a low concentration to decrease the radiation dose in the air. Therefore, we develop a calculation method using QAD-CGGP2R, a direct ray calculation code based on the point-kernel integration method, and G33-GP2R, a sky shine calculation code, as a method for evaluating air dose that also takes land use classification and forest topography conditions into account. Using the developed calculation method and data obtained in actual forests in Fukushima Prefecture for the implementation of our KURNS Collaboration Research, we evaluate the reduction effect of air dose when the reverse tillage is implemented in those forests.

CALCULATION METHOD: The following procedure is used to evaluate the dose reduction effect of the reverse tillage in the forests. 1) Conduct a field survey to measure the density of trees, distribution of Cs concentration in the soil, and distribution of air dose in the forest. 2) Determine the area to be evaluated for radiation dose. In order to calculate the radiation dose in this area, it is necessary to calculate the radiation dose from outside the assessment area, and in determining this calculation area, it is necessary to include sufficiently distant locations that will not have much effect on the calculated air dose in the assessment area. 3) The forest to be calculated is modeled as a collection of rectangular bodies. Determine the spacing of the point sources for splitting the volume sources and the spacing of the scattering points for calculating skyshine. In determining the size of the rectangular bodies for modeling these fields and the spacing, set them as large as possible to save computation time, to the extent that they do not affect the calculated doses at the dosimetry points too much. 4) To perform calculations using existing calculation codes, an input file describing the settings of the above calculation conditions is required. However, because it is difficult to input these settings for each calculation, we developed a program to automatically create the necessary input files and perform the calculations.

The calculation code expresses the area as a collection of rectangles, but the following innovations were made to algorithmize the calculation method and shorten the calculation time. First, we used data from the National Land Information System (NLDIS) as the elevation, and classified land types by visually classifying google earth photos into rough land types, and created a program that automatically identifies which land type each mesh for the calculation is included in. Next, in order to reduce the total amount of calculation while maintaining the accuracy of the calculation in the evaluation target area, the elevation mesh to represent the field and the source mesh to represent the distribution of radiation sources were made larger the further they were from the evaluation target area. Furthermore, for the radioactivity distribution in the subsurface direction, we considered the equivalent depth as the depth at which the calculated value of the dose at the evaluation point is the same whether the radioactivity distribution in the depth direction is taken into account or the total radioactivity in the depth direction is concentrated at a single point. This reduces the number of vertical rectangles and point sources. Then, calculations were performed based on measured data at the site, and the calculation accuracy was verified by comparing it with the measured data of air dose. In this study, we evaluated the dose reduction effects of several construction scenarios, in which the depth, extent, and percentage of the construction work to be done by the reverse tillage were varied. The percentage of construction means the percentage of the construction area that could actually be constructed, because it is difficult to completely construct a certain area due to the presence of tree roots and other factors.

RESULTS: The results of the analysis showed that the error between the measured and calculated values ranged from -38 to 54% (average -4.8%). The main cause of this error was considered to be that the calculation was performed assuming that the distribution of radioactivity in the soil was uniform over the entire area, and the accuracy of the calculation could be improved if the horizontal distribution of radioactivity concentration in the soil was taken into account. The construction scenarios evaluated in this study were the following four patterns. (1) 17m x 20m, with the upper layer (2cm organic layer + 0-20cm soil layer) and the lower layer (20-40cm soil layer) turned over

(2) 17m x 20m with upper layer (2cm organic layer + 0-20cm soil layer) and lower layer (20-50cm soil layer)
(3) 30.6m x 28m, with the upper layer (2cm organic layer + 0-20cm soil layer) and the lower layer (20-50cm soil layer)
(4) 17m x 20m, 80% of upper layer (2cm organic layer + 0-20cm soil layer) and lower layer (20-40cm soil layer) are returned over, and 20% are not turned over. The calculations resulted in air dose reductions of 32-70 (average 57)% for (1), 6-77 (average 63)% for (2), 38-80 (average 70)% for (3), and 29-65 (average 53)% for (4) within the construction area.

CO10-4 Application of KURAMA-II to Radiation Monitoring of Public Facilities in Fukushima Prefecture

A. Maekawa, K. Kusakabe, H. Inoue and M. Tanigaki[1]

Fukushima Prefectural Centre for Environmental Creation
[1]Institute for Integrated Radiation and Nuclear Science, Kyoto University

INTRODUCTION: KURAMA (Kyoto University RAdiation MApping system)-II is a radiation measurement system characterized by its compactness, autonomous operation, and acquisition of pulse-height spectrum data (Fig. 1) [1]. KURAMA-II measures ambient dose equivalent rate (hereafter referred to as air dose rate) and GPS position and automatically transmits them to a dedicated cloud server. We evaluated the effectiveness of a backpack style KURAMA-II (Fig. 2) for the radiation monitoring of public facilities in Fukushima prefecture by comparing it with a NaI(Tl) scintillation survey meter conventionally used in radiation monitoring.

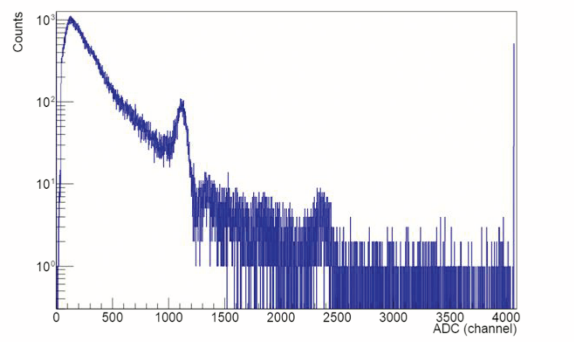

Fig. 1. A typical example of pulse-height spectrum obtained by KURAMA-II measurement.

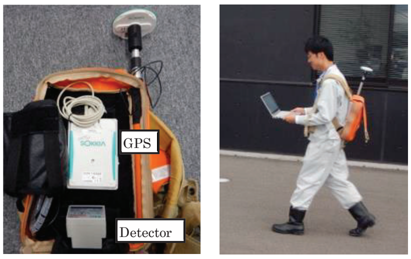

Fig. 2. KURAMA-II in a backpack.

EXPERIMENTS: From 2020 to 2021, the air dose rates of five public facilities were measured by walking with a KURAMA-II in a backpack. The situation of the sites is as follows.

Site A: School grounds and surrounding road
Site B: Gymnasium grounds and surrounding road
Site C: Community center grounds and surrounding road
Site D: School grounds and surrounding road
Site E: Park in the forest

A CsI(Tl) scintillation detector (C12137-01, Hamamatsu Photonics) was used for measurement. The air dose rate and GPS position were measured every 3 seconds. About 400 data sets were obtained at each site. Air dose rates at 10-14 points in each site were measured by a NaI(Tl) scintillation survey meter (TCS-172B, Hitachi) for validity confirmation. Additionally, the air dose rate owing to artificial radionuclide was separately evaluated from the pulse-height spectrum data obtained by KURAMA-II [2].

RESULTS: As shown in Fig.3 and 4, there was no large difference between KURAMA-II results and those by NaI(Tl) survey meter. The dose ratio (artificial/total) was 0.43-0.67 in 2020 and 0.38-0.61 in 2021. From 2020 to 2021, no clear decreasing trend in air dose rate was observed, suggesting that the contribution of short-lived radionuclides could be ignored at the time of 10 years after the accident. Based on the observed pulse height spectra, ^{137}Cs ($T_{1/2}$ = 30.1 y) was estimated to be the dominant artificial radionuclide.

In conclusion, KURAMA-II showed sufficient performance for the radiation monitoring of public facilities.

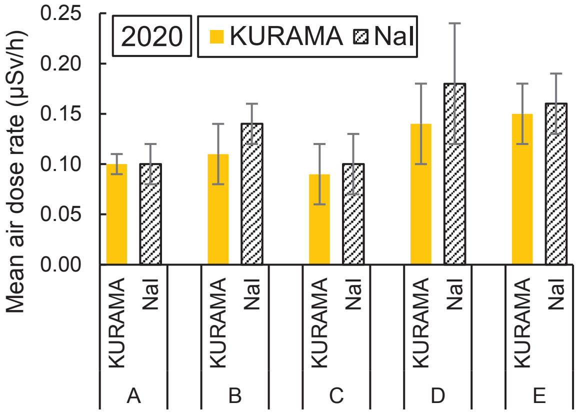

Fig. 3. The result at each site in 2020. Error bars indicate the standard deviation of the measured data.

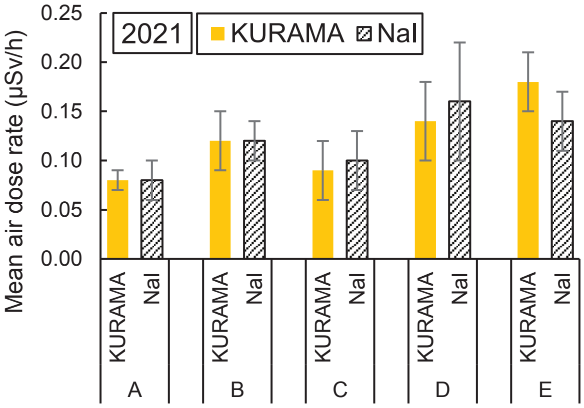

Fig. 4. The result at each site in 2021. Error bars indicate the standard deviation of the measured data.

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CO10-5 Study of FP contamination behavior on structural materials using neutron activation analysis – Study of penetration and elution behavior of Cs -

K. Kondo[1], K. Yoneyama[1], I. Sato[1], E. Suzuki[2]

[1]*Tokyo City University*
[2]*Japan Atomic Energy Agency*

INTRODUCTION: In order to contribute to the elucidation of the mechanism of radioactive contamination, which is one of the issues of NDF6, penetration and elution tests of Cs were conducted on concrete as a structural material in the containment vessel of a nuclear reactor. INAA, PIXE, and ICP-MS were used for quantitative analysis of Cs in these experiments.

EXPERIMENTS: Mortar samples (ordinary portland cement, W/C=0.37, size: 20 mm ×20 mm ×20 mm) were used in the experiments. Acrylic resin was applied to 5 of the 6 surfaces to permit penetration to one surface. Then, (1): mortar penetrated in 10^{-2}M CsOH solution for 10 days and (2): mortar eluted with water for 1 day after (1) were ground 0.5mm ×4 times in depth direction and analyzed by PIXE for each powder obtained during griding. In addition, (3): Mortar penetrated in 10^{-3}M CsOH solution for 10 days and (4): Mortar eluted with water for 1 day after (3) were ground in the same manner, and the powder was analyzed using INAA.

RESULTS: The Cs that penetrated into the mortar eluted 39.0%, 80.9%, 51.6%, and 4.0%, in order from the surface side, and 48.8% for the entire sample. Regarding the penetration behavior, it could be considered that the greater the penetration depth, the harder it is to penetrate. On the other hand, if the migration of Cs was considered to be proportional to the concentration gradient, it could be presumed that the solution in contact with the mortar surface would change from CsOH solution to water containing no Cs, resulting in a larger concentration gradient, and then the Cs concentration profile could be changed like in the red line in Fig. 2. However, it did not exhibit such behavior. This may be due to sites in the cement where Cs is strongly adsorbed, which may complicate diffusion phenomena during the elution. To analyze this elution behavior, it would be important to analyze the distribution of sites where Cs is strongly adsorbed and their ability to adsorb Cs at different depths in the cement.
As to the difference in data due to the difference in analysis method, the Cs elution rate on the mortar surface determined by INAA was 29.6%, although the value determined by PIXE was 39.0% as mentioned above. Considering that INAA detects Cs in the entire sample while PIXE detects Cs on the sample surface, INAA, which can detect Cs in the entire powder obtained during, is considered to be more accurate in determining the elution rate.
In these experiments, only the Cs elution rate at the mortar surface was analyzed by INAA. Next year, we would like to analyze the elution rate in the depth direction to obtain more accurate results.

CONCLUSION: Penetration and elution tests for Cs were conducted on concrete, a structural material, in the reactor containment vessel. The elution behavior of Cs from mortar indicates that analysis may need to take into account the diversity of Cs adsorption sites in mortar.

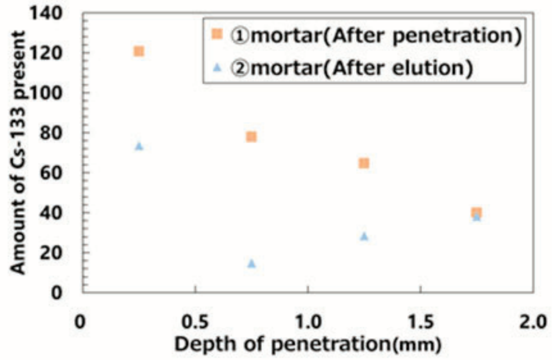

Fig.1 Amount of Cs present at each mortar depth.

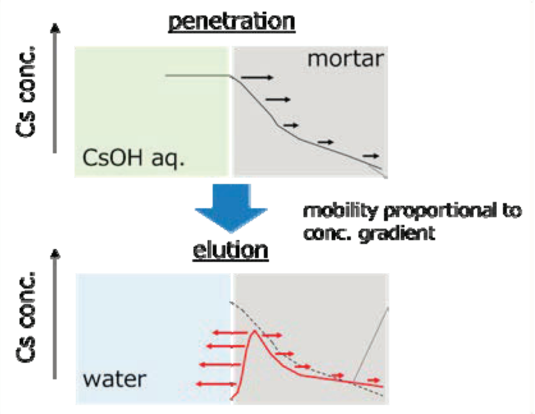

Fig.2 Elution behavior according to concentration gradi-ent (a predicted diagram) .

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