Introduction of Mobile Dosimetry Laboratory in KHNP

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Abstract. Dose assessment for emergency workers was delayed due to the collapse of the dose evaluation system at the site during the Fukushima nuclear accident. Prior to the accident, only fixed whole body counters (WBCs) were fitted, so the role could not be performed by the tsunami. Korea Hydro & Nuclear Power Company (KHNP) has been operating stand-type and bed-type WBC using NaI and HpGe, respectively. Compared to pre-accident Fukushima NPP, it maintains a good operating system in terms of analysis of radionuclide and shielding design. However, it has been operated on a fixed basis within NPP. When WBC is mounted in the vehicle for mobile operation, low center of gravity design and attachment of auxiliary equipment should be considered. Shielding is also important to be able to assess the dose of workers in a high background to a low level below 0.1mSv. Based on comparison between the existing WBC at the KHNP and lightweight WBC, it was considered most efficient for mobile WBCs to follow the shielding type used by the KHNP WBC in consideration of their operation in the event of an accident. We chose a trailer that could only be connected to the vehicle if needed, rather than a truck that was difficult to manage. A scintillator detector with a high measurement efficiency and a shadow shield method to minimize the impact of a high-level background were adopted. Additional radiation portal monitor was required at the hatch to filter out the contamination of the victims and protect the equipment, the radiation zone monitor was added for identification of residential requirements, and automatic correction of measurement signals and air conditioning facilities were considered to ensure safety due to changes in the instrumentation environment. Considering the identification of contamination and security issues, the vehicle's location and surrounding radiation dose rates while moving to the accident site were transferred to the accident control department in real time, and additional systems were constructed that can share dose record of the victims. In addition, space for in-vivo ESR was provided for external dose evaluation. Although the U.S., Japan, France and others are building up their operational experience by introducing mobile dose assessment systems ahead of Korea, it has not been long since Korea introduced them in only a few places. Future procedures need to be established and accumulated operational experience is necessary to improve the system.

Keywords: *Nuclear power plants, Whole-body counting*

1 INTRODUCTION

United States, Germany, France and Japan et al are operating mobile whole body counters (WBCs) of various type such as truck, van and trailer. In United States, mobile WBCs are used for whole body measurement, emergency response to radiation, radioactive environment monitoring and measurement of uranium within human lung. When Three Miles Island accident occurred in 1979, mobile WBCs were needed for workers suspicious of internal contamination because the number of fixed WBCs were insufficient [1]. After Chernobyl nuclear accident in 1986, Germany operated for measurement of I-131 and Cs-134/137, and France is in operation more than 10 vehicles [2]. In Japan, before Fukushima nuclear accident, only fixed WBCs were in Fukushima Daiichi nuclear power plant (FDNPP). Radiation workers could not be given dosimetry for internal exposure by tsunami-induced flooding. Recently, mobile WBCs are operating in Fukushima NPP[3]. At each NPP site of South Korea, there are standing type WBCs with NaI(Tl) detector and bed type WBCs with HpGe detector, respectively. Before the Fukushima nuclear accident, only fixed WBCs were operated as like the FDNPP. Delayed dose assessment of radiation workers due to tsunami by earthquake was a lesson to Korea Hydro & Nuclear Power (KHNP).

2 COMPARISON OF WHOLE BODY MEASURING SYSTEM

Radiation Health Institute (RHI) affiliated to KHNP introduced mobile laboratory dosimetry (MDL) [Fig. 1].

Figure 1: Specification of MDL with WBC, radiation portal monitor and in-vivo ESR.

Length (mm): 9,640 Width (mm): 2,495 Height (mm): 3,980 Weight (kg): 13,970

Firstly, in consideration of volume and weight of equipment on this vehicle, simplification of shield and multiple equipment was planned. However, shielding is important to be able to assess the dose of workers to a low level below 0.1mSv in high background area. We tried to make measurement system lighter and to strengthen the shielding of outer wall of vehicle. Even so, finally, shielding pattern used in fixed WBC of KHNP was applied through comparative analysis between NPP site and lightweight WBC. In lightweight WBC, multiple detectors increase calibration workload and need additional manufacturing of phantom. Separate measuring equipment increase installation area. Open shield reduce shielding ability in accident area. In KHNP WBC, measurement is important with a fixed posture at a certain distance. It has lower minimum detection activity (MDA) [4], standard deviation and good resolution. When nuclear accident occurred, lightweight WBC need new phantom production, additional shielding design and evaluation of calibration environment of the detector [Table 1].

Table 1: Comparison of KHNP WBC and lightweight WBC.

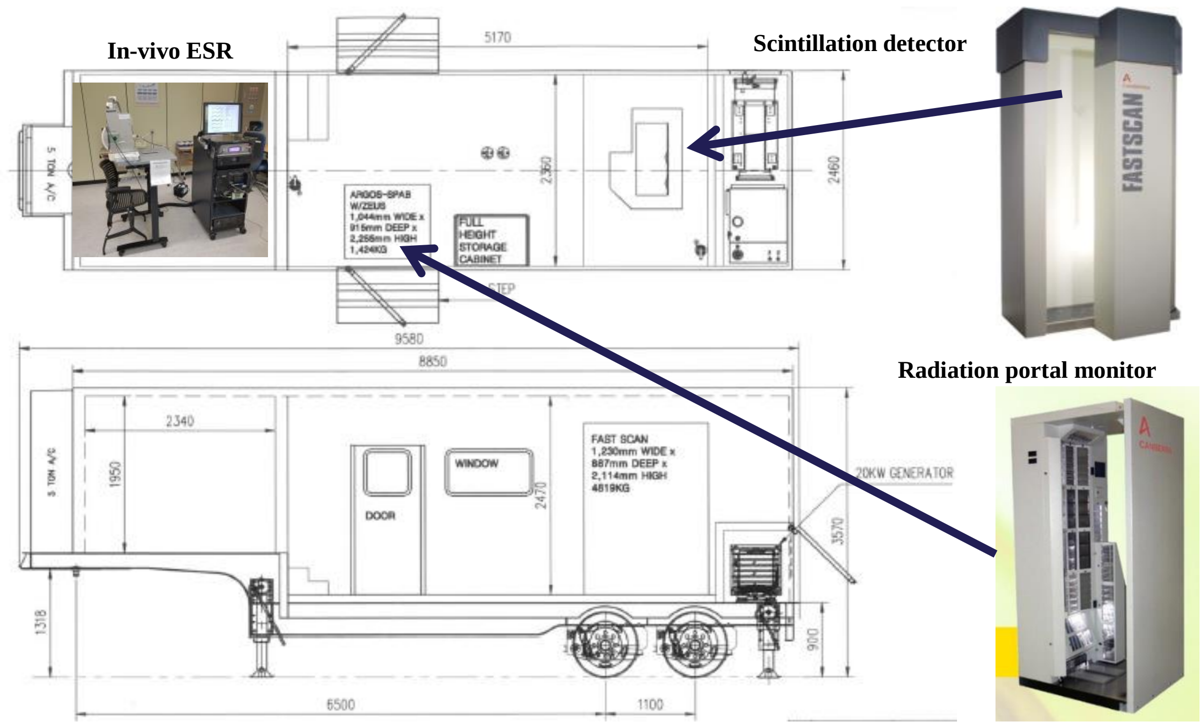
	KHNP WBC	**Lightweight WBC**
Detector	3×5×16 inch NaI(Tl) (2)	3×3 inch NaI(Tl) (8) 2×4×16 inch NaI(Tl) (2)
Calibration phantom	RMC-II phantom	Random phantom
Measurement location	after floor and back contact	floor standard
MDA	≤150 Bq/person	200 Bq/person
Measurement target	measurable lung and thyroid	non-measurable lung and thyroid
Systematic stability	2σ[1]	5σ
Resolution	< 7%	separate resolution analysis software
I-131	direct measurement	separate measuring equipment
Shielding	shadow shield and fixed detector	open shield and adjustable detector

[1] standard deviation

3 DESIGN OF WHOLE BODY MEASURING SYSTEM

As vehicle with low center of gravity, we selected trailer type than truck which has short service life and is difficult to management efficiently. Scintillation detector with high measurement efficiency was equipped for fast radiological triage of contaminated victims and radiation portal monitor were designed for prevention of radioactive contamination in vehicle body and instruments. For external radiation dose assessment using electron spin resonance (ESR) in human tooth enamel, in –vivo ESR was installed in a space inside the vehicle. Shadow shield was applied to minimize the effect of high background and to effectively detect internal exposure. We configured a system that delivers the location of the vehicle moving to the accident site and background radiation using area monitor in real time. Automatic correction and air conditioning facilities were equipped to secure stability according to changes in the measurement environment. A surveillance camera was installed for considering security issues inside vehicle body [Fig. 2].

Figure 2: Design of mobile whole body measuring system.



4 MOBILE WHOLE BODY DETECTOR MODELING

Prior to the whole body measurement, efficiency calibration for the whole body counter is first performed using the phantom representing the human body. In the case of the whole body, Bottle Manikin Absorber (BOMAB) and RMC-II phantoms are used [Fig. 3]. We used MCNPX 2.6 code for Monte Carlo simulation and modeled BOMAB and RMC-II phantom in the ORTEC StandFast II whole body counter [5]. In the case of BOMAB, the distance from the surface of the phantom to the column branch of the measuring part was 15 cm recommended by the manufacturer. In the case of the RMC-II phantom, the exact calibration position was not provided. It was positioned about 90 cm from the bottom. The F8 tally provided by MCNP was used to evaluate the calibration efficiency for nine sections of commonly used calibration energy (280keV-1836keV). Based on the back of the BOMAB, the height is about 90cm from the floor presented by Canberra [6].

In the computer simulation of the whole body measurement using BOMAB, the efficiency of the WBC located in the lower part was about 10% higher than the upper part, whereas in the case of RMC-II, the efficiency of the upper gauge was about 2 times higher than that of the lower part [Fig. 4]. This is because, in the case of BOMAB, the source is spread throughout the whole body, whereas in the RMC-II, the representative part of the whole body is located near the upper WBC. Comparing the overall efficiency, the RMC-II is about 10% higher for all energies than BOMAB. As the result of higher efficiency eventually underestimates the dose, more careful positioning is required when the actual calibration is performed using RMC-II.

Figure 3: Monte Carlo methods of the ORTEC StandFast II whole body counter.

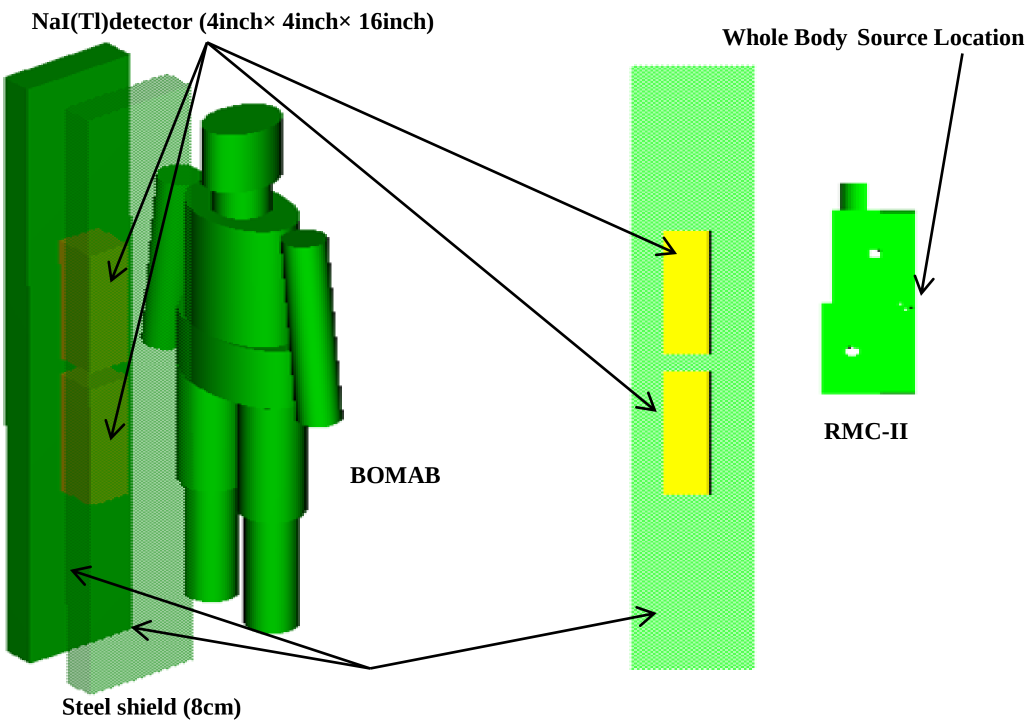
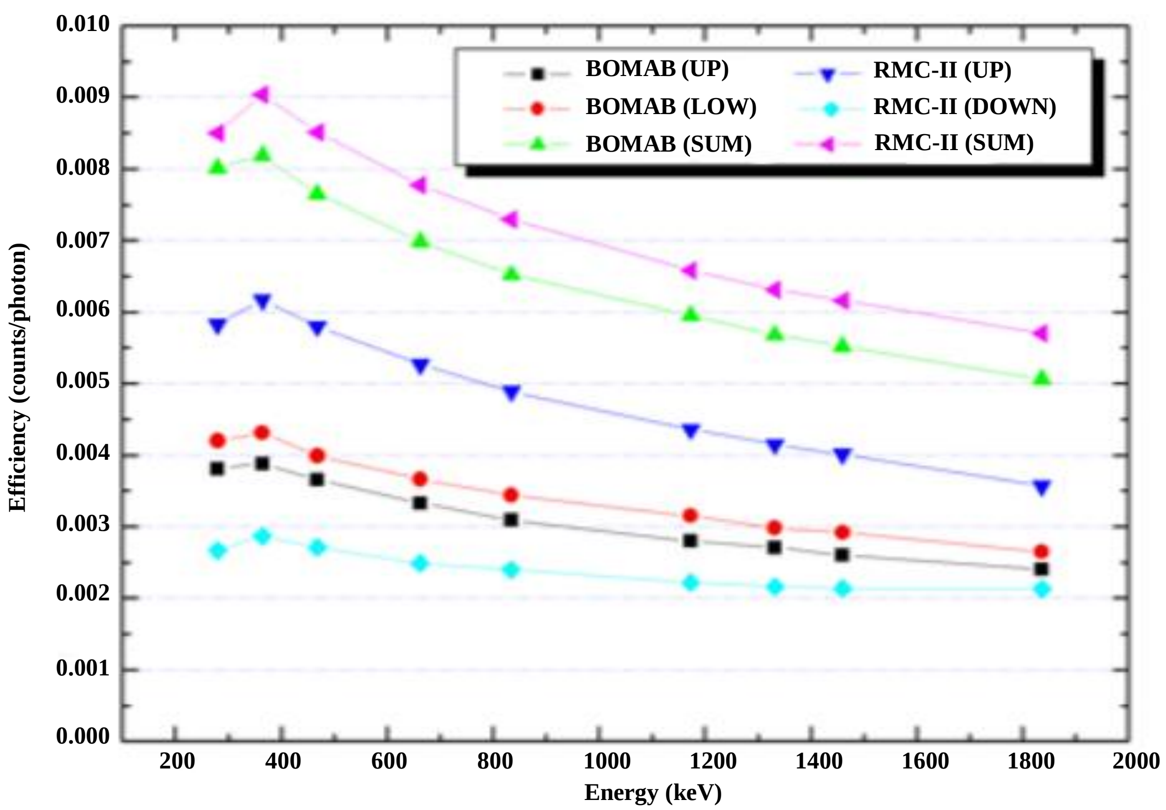


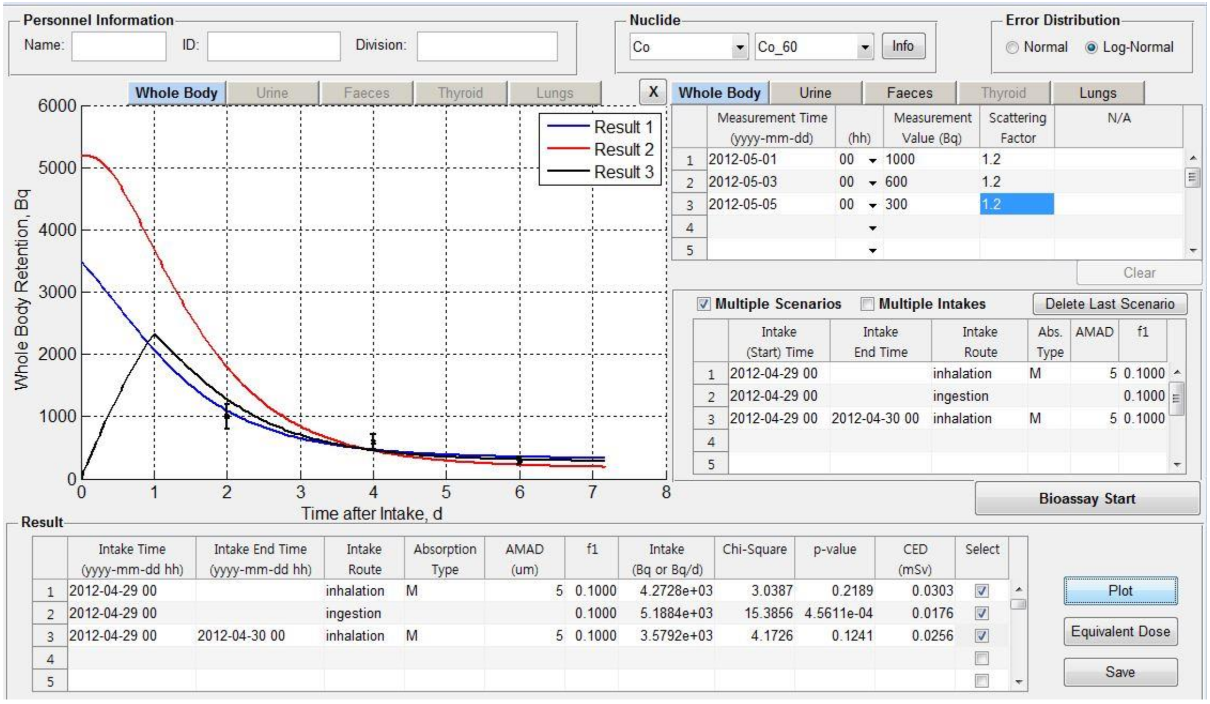
Figure 4: Changes of calibration factors according to detector location and calibration phantoms



5 INTERNAL DOSE ASSESSMENT CODE

KHNP developed worker specific codes based on ICRP103 and IDEAS guidelines for internal dose assessment [7]. This code is a dose evaluation code that generates the patient's residual function and evaluates it for each scenario [Fig. 5].

Figure 5: New internal dose assessment code developed by RHI based on ICRP 103 and IDEAS international guideline.



6 FUTURE OPERATION PLAN

We participate in cross-analysis of internal dose assessment between domestic agencies applying accident scenarios and ARADOS (Asian Radiation DOSimetry group) hosted cross analysis. In addition, in-vivo ESR clinical trials for patients with total body radiation were performed for improvement of external dose assessment in accident site.

In normal situation, MDL is participated in radioactive disaster prevention training and performs environmental monitoring around NPP. Also, it supports health physics center on NPP and radiation monitoring when dismantling NPP. In emergency situation, it moves to radiation boundary area for worker dose monitoring in cooperation with Korea Institute of Nuclear Safety (KINS) and Korea Institute of Radiological and Medical Sciences (KIRAMS).

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