ENVIRA 2019

KNU KYUNGPOOK NATIONAL UNIVERSITY

Preliminary study on the estimation of minimum detectable activity and the efficiency for real-time marine monitoring system

S.Y. Han , S. Maeng, H.Y. Lee, S.J. Park, S.Y. Lim, S.H. Lee

Kyungpook National University

2019.09.09

Presenter: Seung Yeon Han

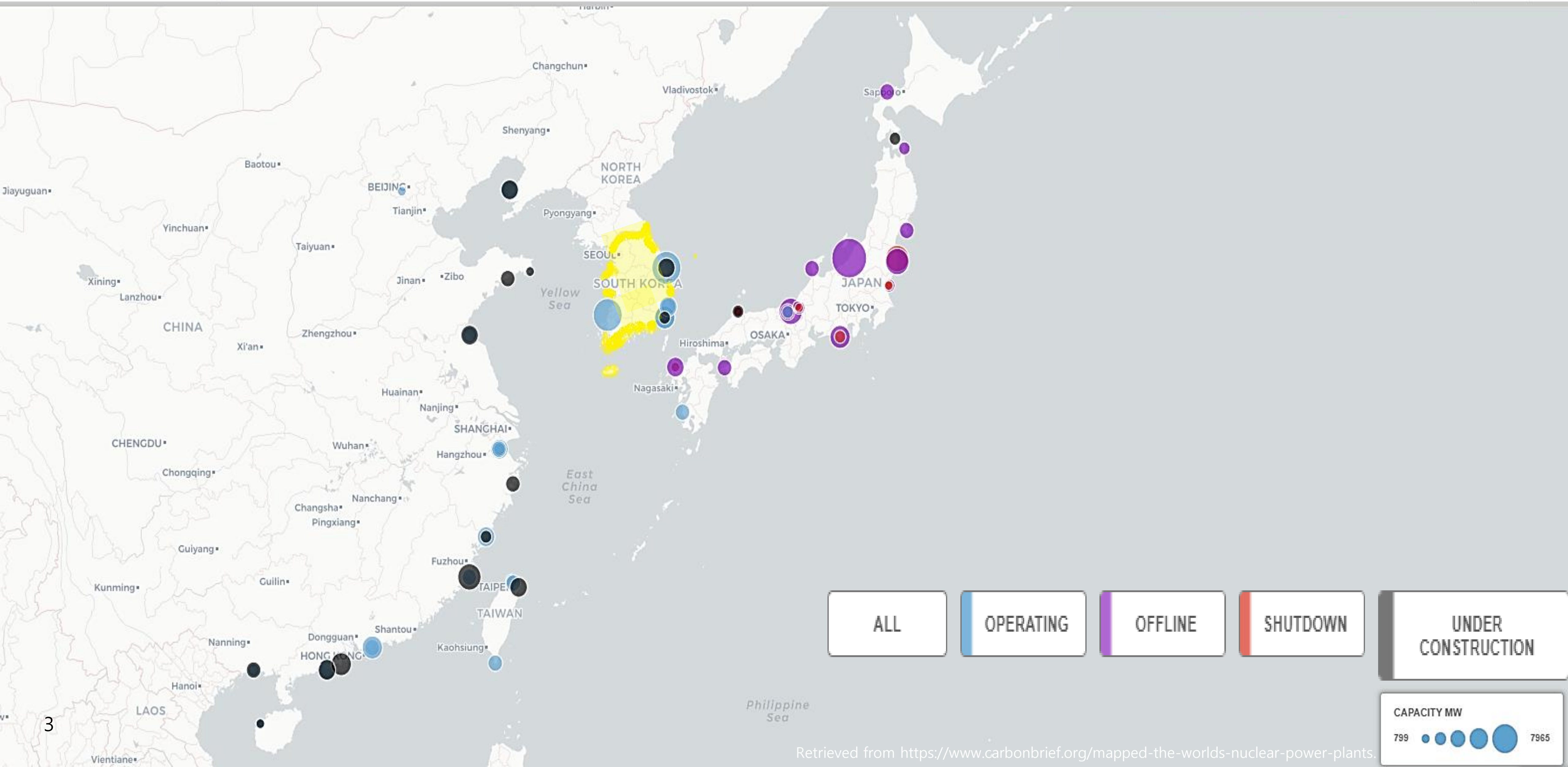
CONTENTS

CarbonBrief
CLEAR ON CLIMATE

MULTIPLE AUTHORS
08.03.2016 | 5:19pm

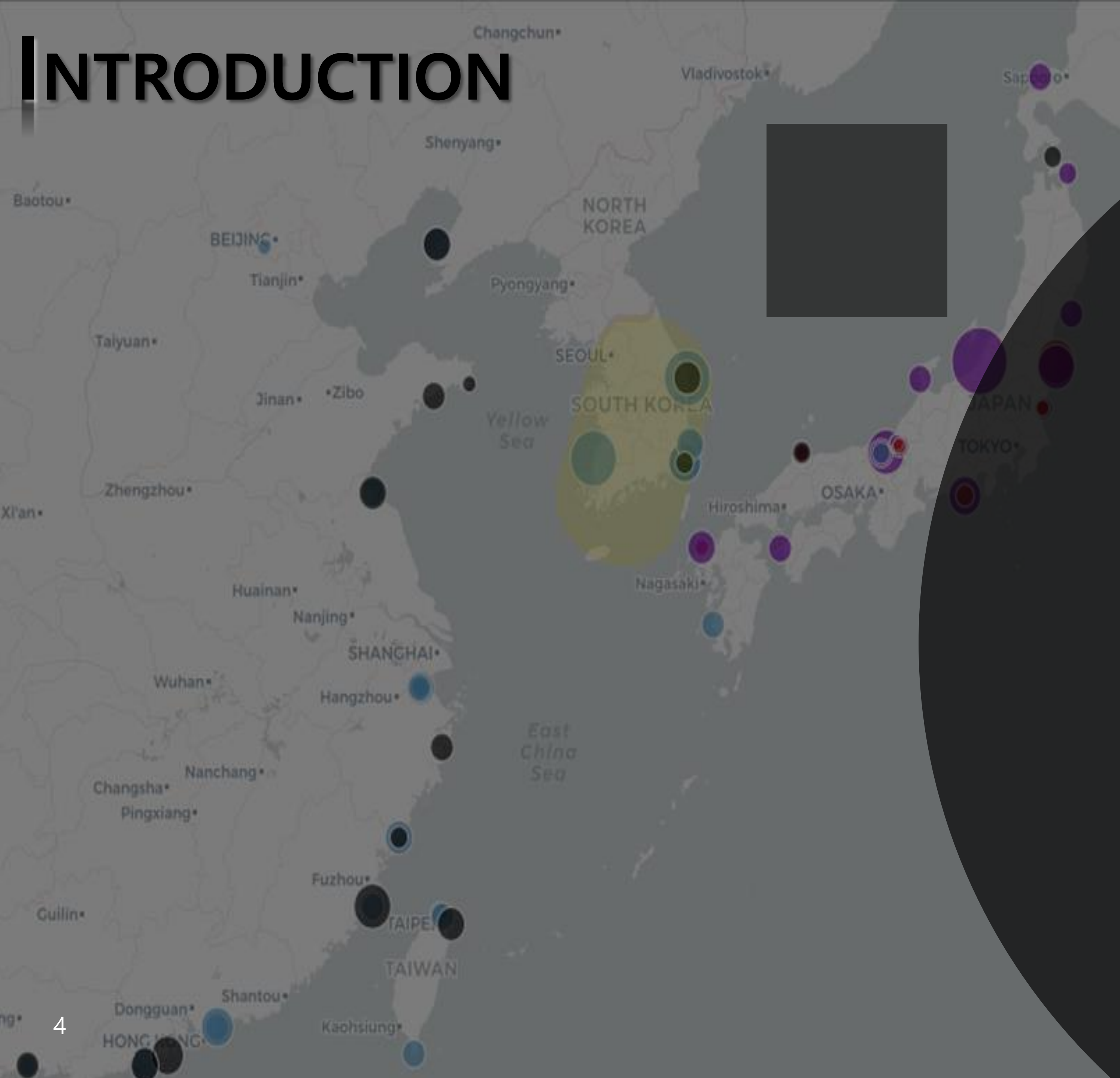
NUCLEAR

Mapped: The world's nuclear power plants



Retrieved from https://www.carbonbrief.org/mapped-the-worlds-nuclear-power-plants.

INTRODUCTION



- Nuclear Power Plant
- Radioactive Waste-dumping
- Nuclear Weapon Testing
- 2011 Fukushima Nuclear Accident

Marine Radioactivity Monitoring (^{137}Cs)

- Marine pollution has become a worldwide concern and the monitoring of marine radioactivity began to play a fundamental role in radiation protection.
- The traditional monitoring method,

  - A large number of samples
  - Skill of chemical pretreatment
  - Long counting time

  → Need for **continuous monitoring system** providing the early pollution warning.
- For real-time marine radiation monitoring in Korea,

  - The Korea Institute of Nuclear Safety (KINS) has chosen **NaI(Tl) scintillation detectors** which have been widely used for in-situ radioactivity measurement.

INTRODUCTION

- **NaI(Tl) scintillator detector**
  - Relatively poor energy resolution
  - Lack of the practical method of efficiency calibration for quantitative analysis of radioactivity in the marine environment.

→ **Monte Carlo simulation** with the MCNP code was performed to make a comparison between measurement and simulations in the **aquatic environment**.

- ✓ Efficiency calibration by measurement and simulation
- ✓ Sensitivity to different ^{40}K background levels
- ✓ ^{137}Cs detection efficiency in peak cps per Bq/L
- ✓ Minimum Detectable Activity (MDA) of ^{137}Cs

MATERIALS AND METHODS

MEASUREMENT & ANALYSIS

- Water tank in laboratory (3Ton)
- Gain Mode: Manual
- Measuring Time: 3 hour
- Water Temp.: 26.6 ℃ ~ 28.9 ℃
- Maestro, Aptec (AMETEK ORTEC)
- MCA (SI DETECTION)
- NaI(Tl) Scintillation Detector (SCIONIX)

SIMULATION

- MCNP6 BETA
- Properties of Materials

  [Reference] PIET-43741-TM-963 PNNL-15870 Rev. 1, Compendium of Material Composition Data for Radiation Transport Modeling, Pacific Northwest National Laboratory.
- Calculation Mode P
- Tally 8
- GEB Option

  [parameters]
  a: -0.0120879 b: 0.0700906 c: -0.1073321
- NPS 10^8

1. MONITORING SYSTEM

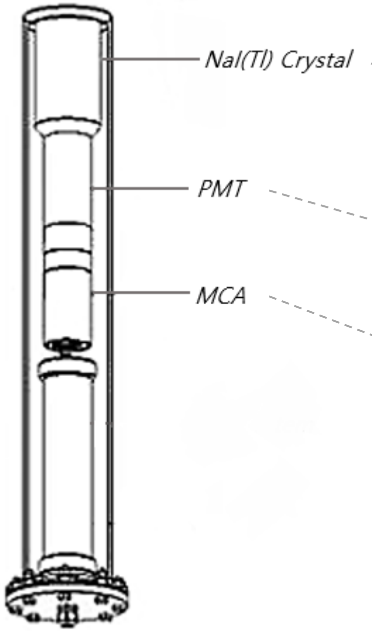


Fig.1
(LEFT) Marine radioactivity monitoring system
(RIGHT) Concept image of marine radioactivity monitoring system,
Retrieved from Marine Environmental Radioactivity Survey, KINS/ER-092,vol.13,2017

Table 1. Specification of System		
NaI(Tl) Scintillation Detector	Crystal Size	3-inch x 3-inch
	Energy Rage	50~3,000 keV
	Resolution	~7% FWHM (662keV, ^{137}Cs)
	Channel	1024
Housing	Material	MC Nylon

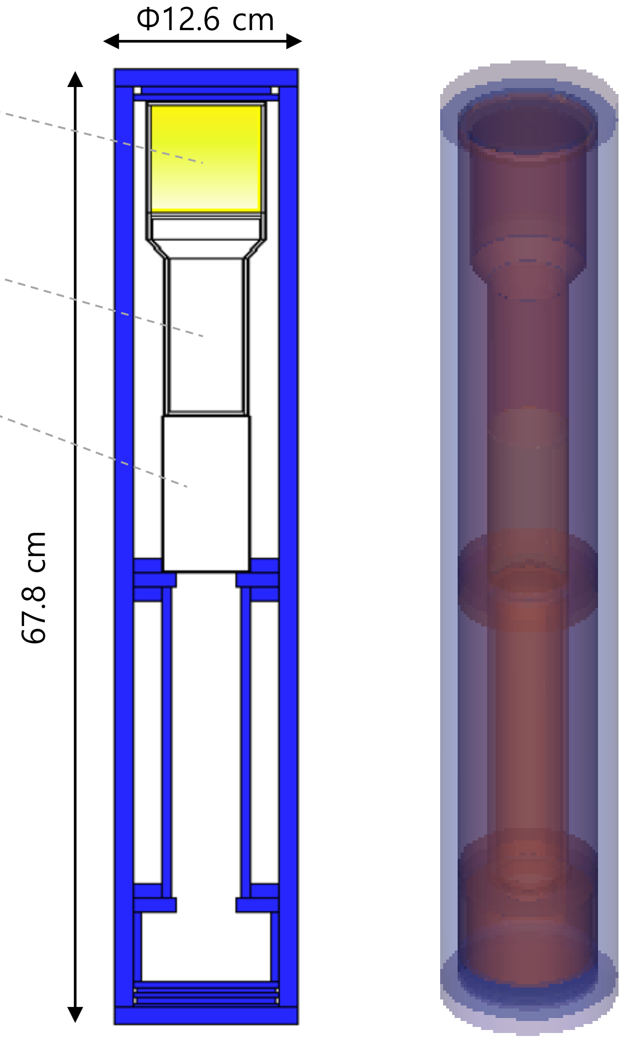
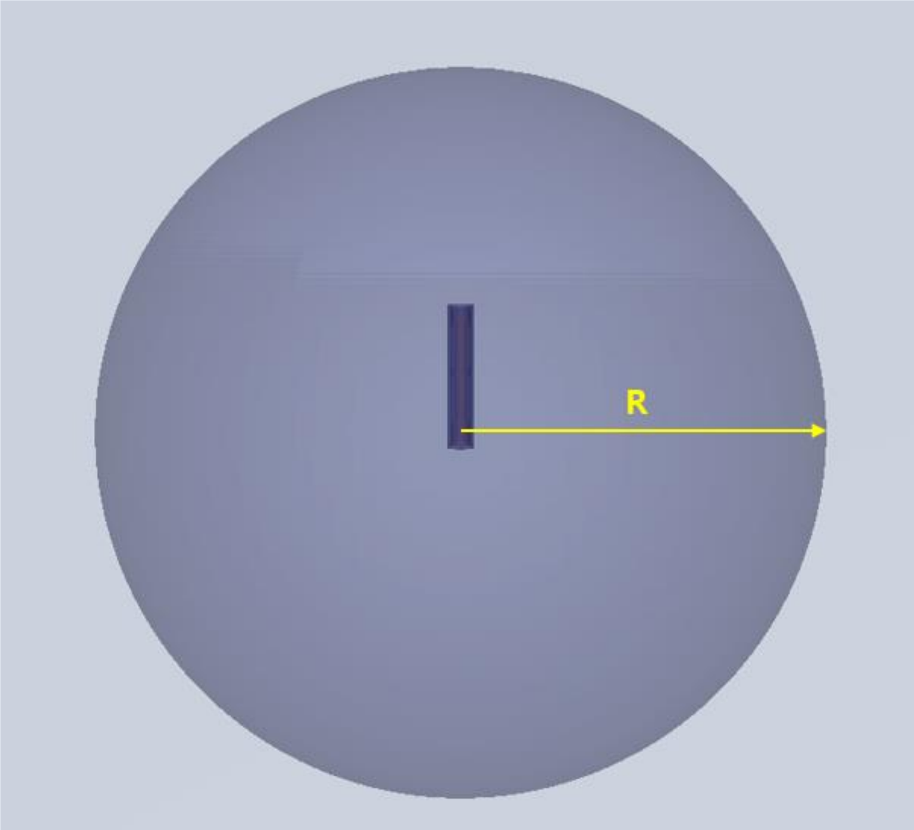


Fig.2
MCNP geometry of marine radioactivity monitoring system

2. EXPERIMENTAL SETUP

1) Water Tank (Aquatic Environment)



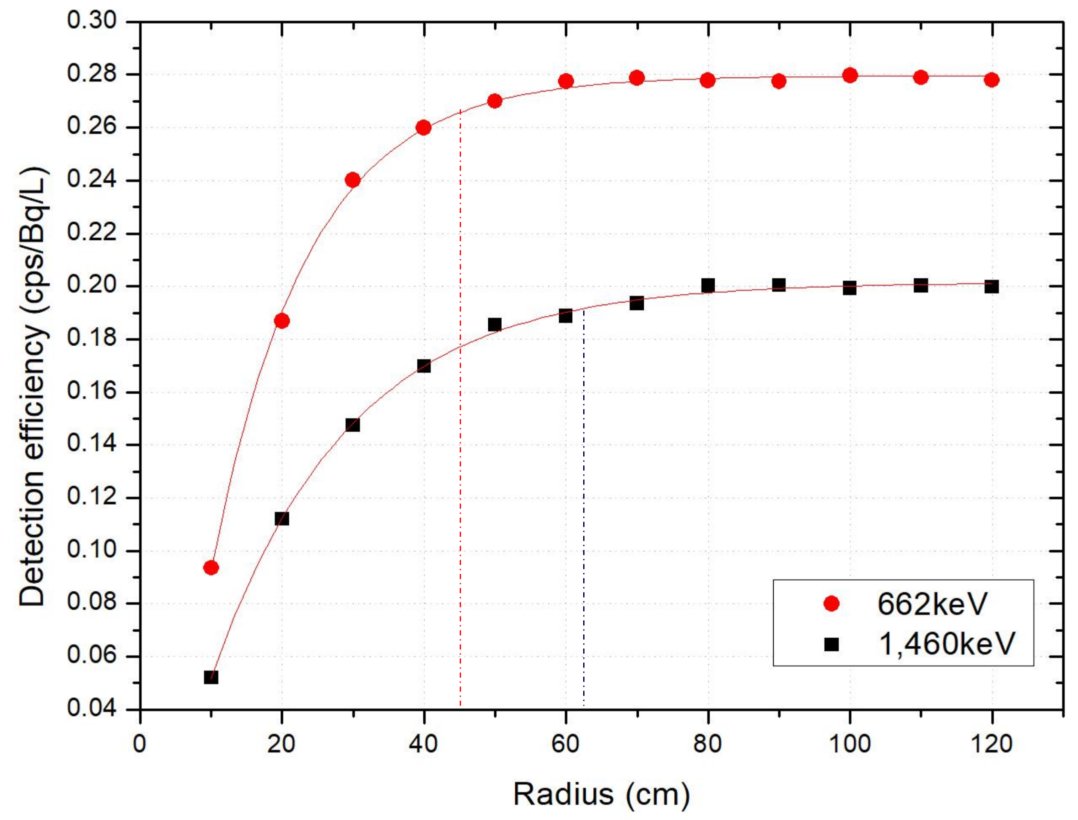


Fig.3

(LEFT) MCNP simulation for calculating effective detection radius of the aquatic environment,

(RIGHT) Detection efficiency of different energies in the aquatic environment

- ✓ Detection Radius
  for **662keV → R = 45cm**, for **1,460keV → R= 62cm (95%)**
- ✓ Maximum Building Load
- ✓ Penetration Probability of ^{40}K Background Level

1) Water Tank (Aquatic Environment)

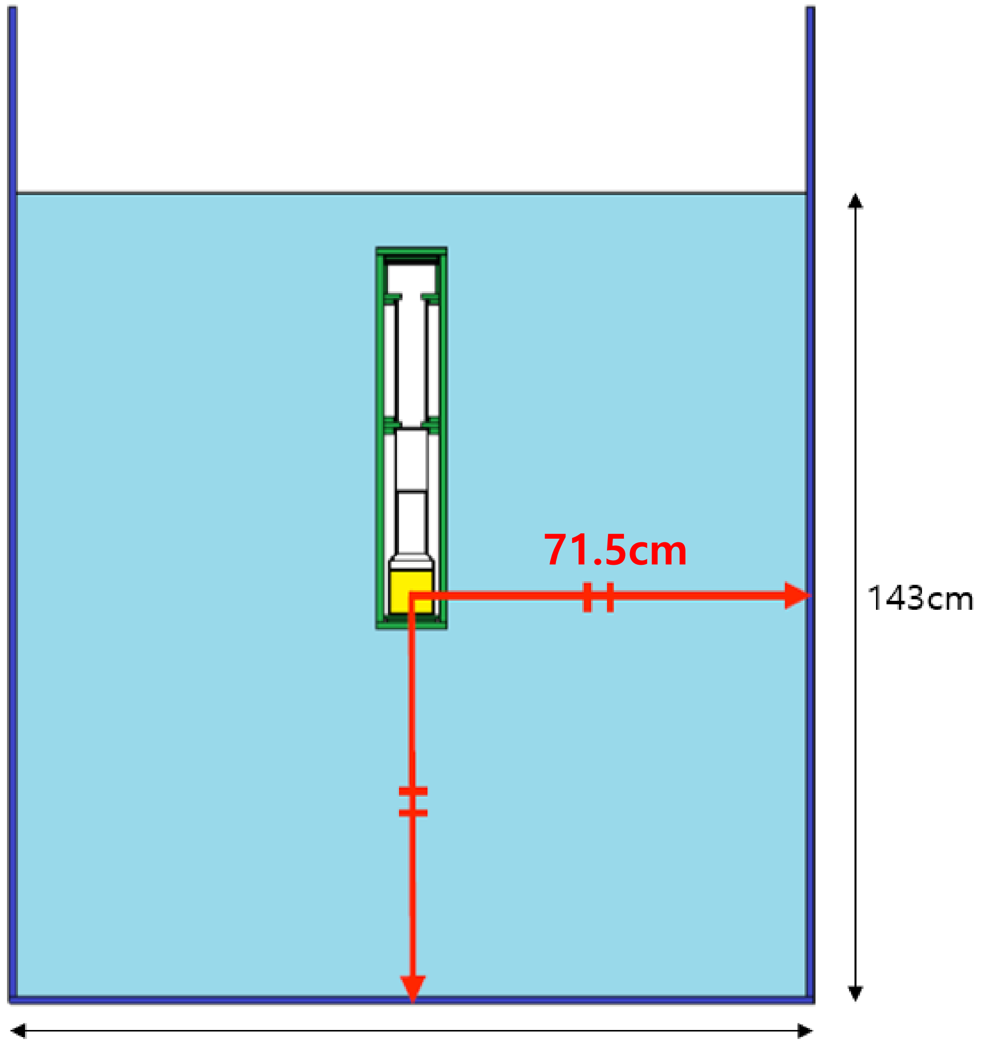


Fig.4

(LEFT) 3-Ton size water tank, (RIGTH) MCNP geometry of monitoring system in water tank

2) Radioactivity Source for Efficiency Calibration

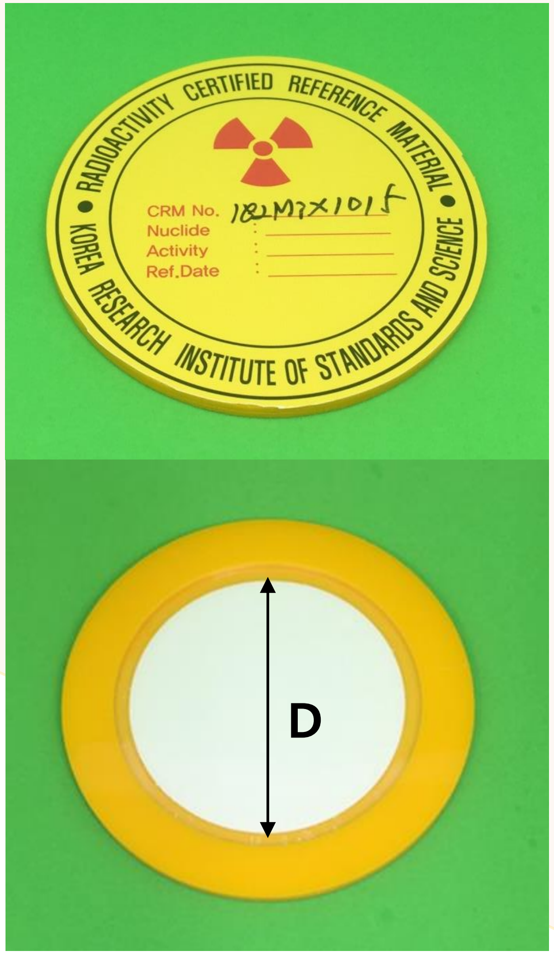


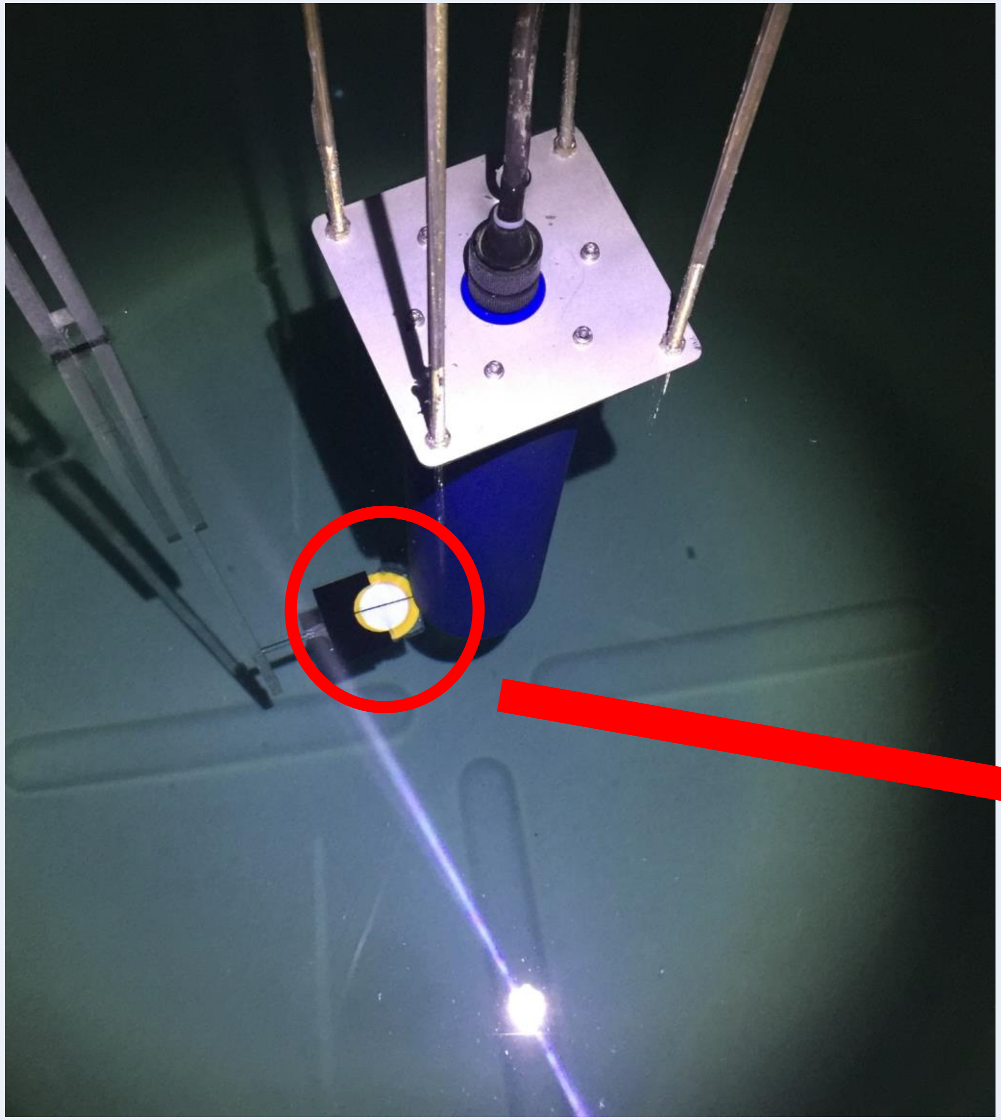
Fig. 5
Radioactivity Certified Reference Materials (CRM) in disc type source (D=47mm)

Table 2. The Specification of Certified Reference Materials in Disc-type Source

Nuclides	Half life [d]		Gamma-ray			Activity		
	Half life	Uncer tainty	Energy [keV]	Emission probability [%]		Activity [Bq]	Uncertainty	
^{241}Am	158004	219	59.54	35.92	0.17	2617	110	4.2%
^{109}Cd	461.9	0.4	88.03	3.66	0.05	12573	510	4.1%
^{57}Co	271.81	0.04	122.06	85.40	0.14	539	22	4.1%
			136.47	10.71	0.15			
^{139}Ce	137.641	0.020	165.86	79.9	0.04	673	27	4.0%
^{51}Cr	27.704	0.004	320.08	9.89	0.02	53875	2200	4.1%
^{113}Sn	115.09	0.03	391.7	64.97	0.17	1245	50	4.0%
^{85}Sr	64.850	0.007	514.00	98.5	0.4	2088	84	4.0%
^{137}Cs	10976	29	661.66	84.99	0.20	1255	51	4.1%
^{60}Co	1925.23	0.29	1173.23	99.85	0.03	1477	59	4.0%
			1332.49	99.98	0.000 6			
^{88}Y	106.63	0.05	898.04	93.7	0.3	3212	130	4.0%
			1836.05	99.34	0.025			

(Certified by Korea Research Institute of Standards and Science, KRISS)

Materials and methods



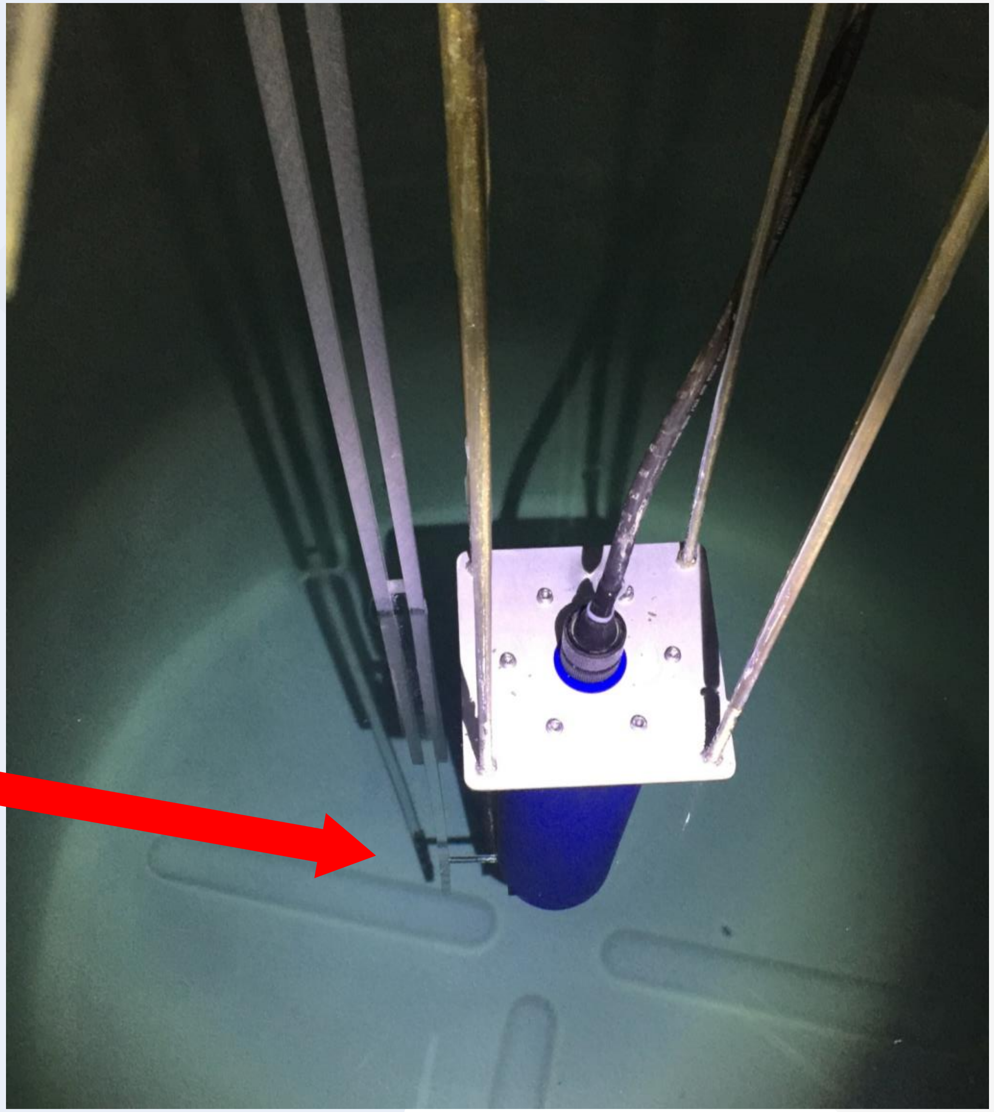


Fig.6 Experimental setup for water tank experiment

3) ^{40}K Background Level

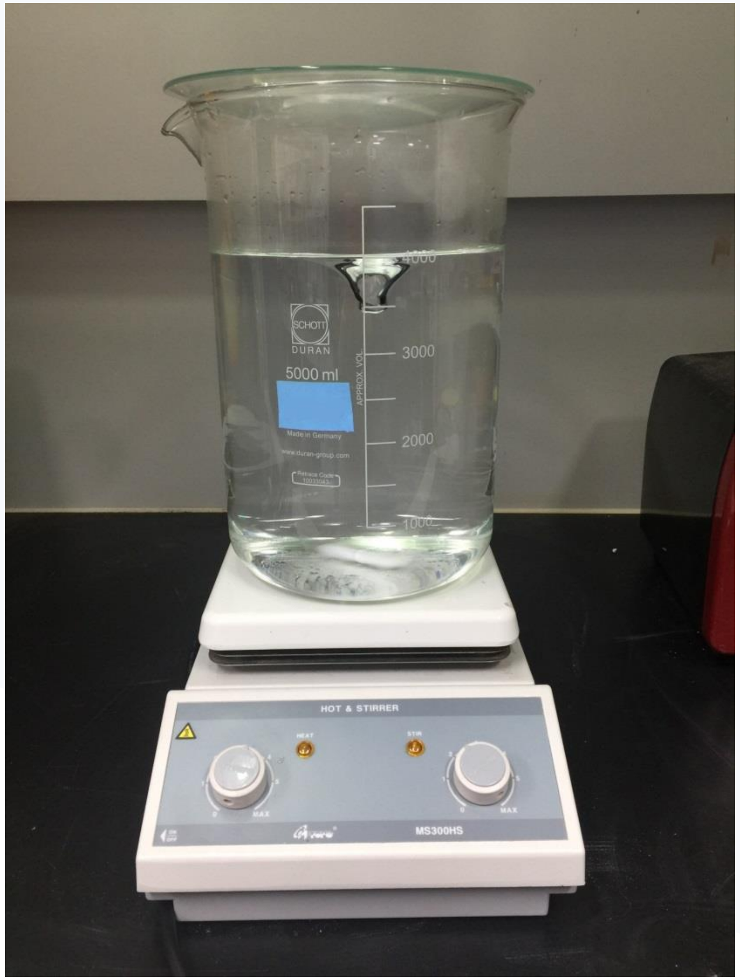


Fig.7
Preparing for diluting natural KCl in water tank

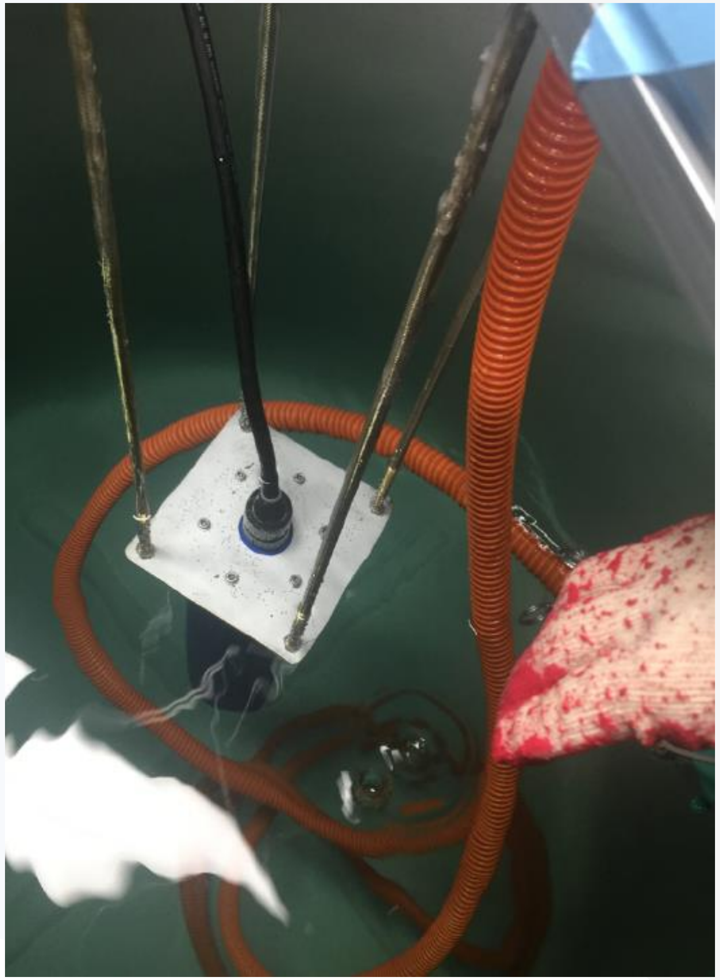


Fig. 8
Circulating system

REULTS

1. COMPARISON OF MEASUREMENT AND SIMULATION

1) CRM Source – Spectra, Detection Efficiency

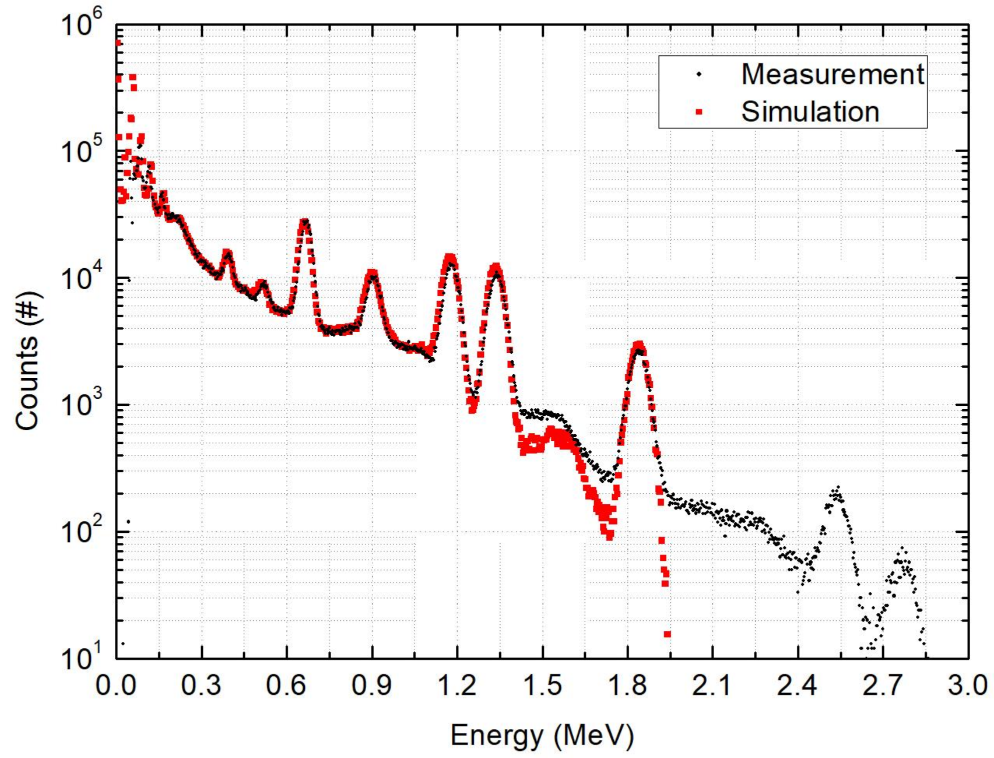


Fig.9
Comparison between simulated and experimental spectra of the NaI(Tl) detector in the case of CRM source in the water tank

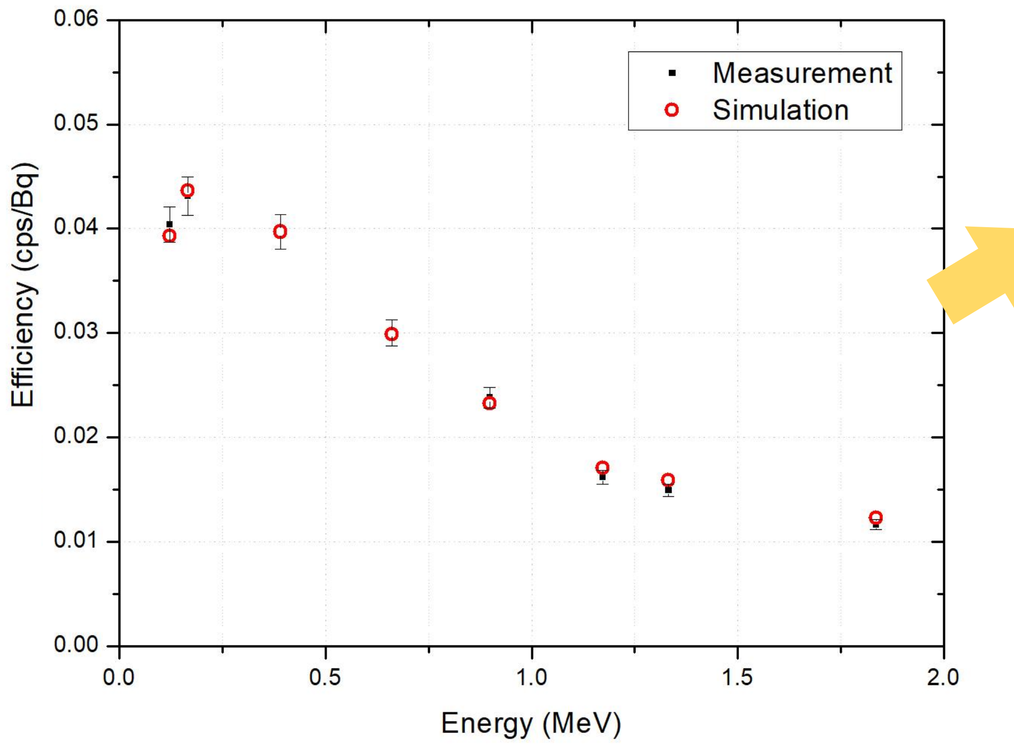
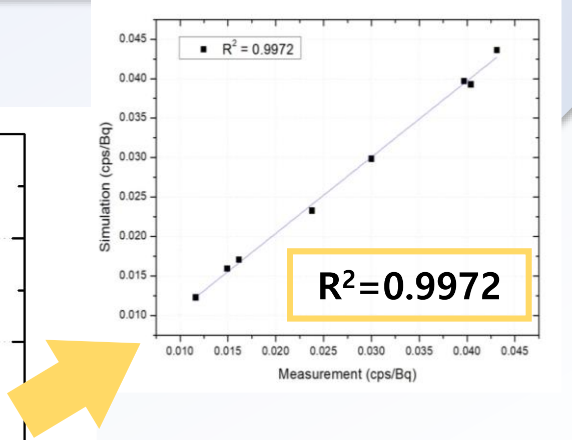


Fig.10
Detection efficiency of simulation and measurement in the water tank



2) Detection efficiency of ^{40}K background levels

Table 3. Measurement in the Water Tank of Different ^{40}K Levels

		CASE 1	CASE 2	CASE 3
^{40}K	Activity [Bq/L]	5.283 ± 0.167	10.125 ± 0.178	14.421 ± 0.264
	cps	0.107	0.202	0.297
	Efficiency [cps/Bq/L]	0.184	0.181	0.187
		Average = 0.184		

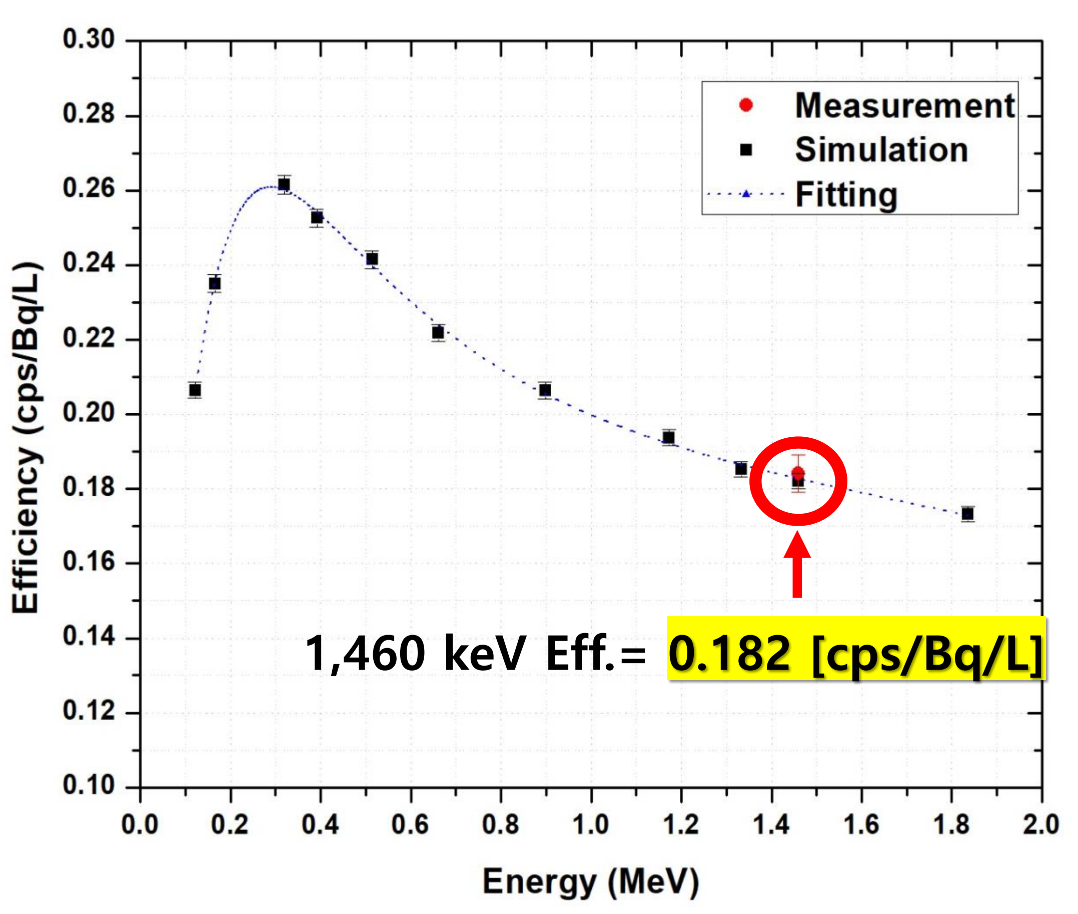


Fig.11
Comparison of detection efficiency in the water tank between simulation and measurement

2. DETECTION EFFICIENCY AND MDA OF ^{137}CS

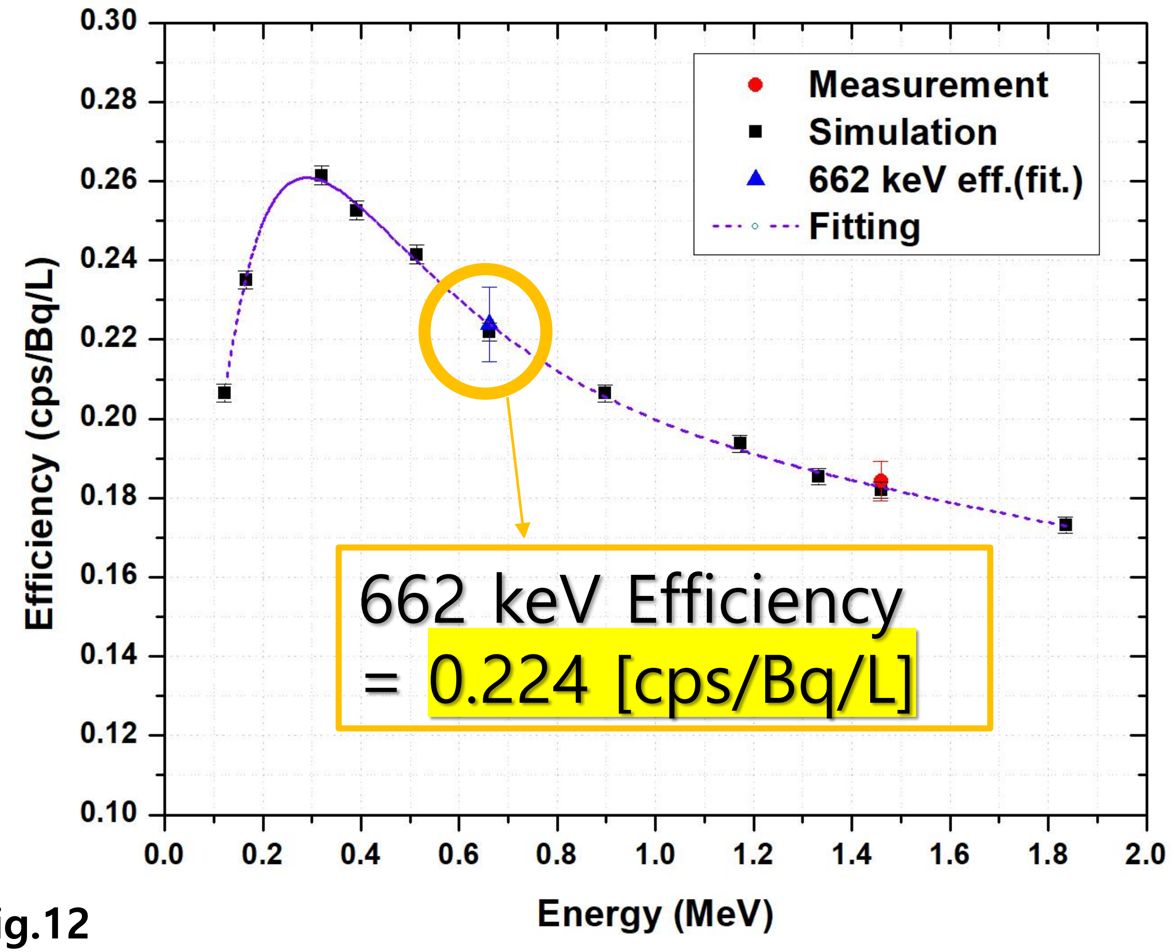


Fig.12
Detection efficiency in the water tank obtained by simulation

Currie Method (1968)

$$MDA(Bq/L) = \frac{L_D}{\varepsilon_m \times I_\gamma \times T}$$

$$L_D = k^2 + 2k\sigma_0 = 2.71 + 4.65B^{1/2}$$

L_D : *Detection Limit [cps]*
B : *Area of Background [count]*
ε_m : *Detection Efficiency [cps/(Bq/L)]*
I_γ : *Emission Probability of Gamma-ray*
T : *Measurement Time [sec]*

Table 4. Estimation of ^{137}Cs MDA in Aquatic Environment

		CASE 1	CASE 2	CASE 3
^{40}K	Activity [Bq/L]	5.283 ± 0.167	10.125 ± 0.178	14.421 ± 0.264
^{137}Cs	MDA [Bq/L]	0.049	0.077	0.085

CONCLUSION

- The continuous monitoring of natural radioactivity is playing a fundamental role in radiation protection, even providing the pollution warning.
- For marine monitoring system with NaI(Tl) detector, there is need of practical method of efficiency calibration for quantitative analysis of radioactivity in the marine environment.
- With Monte Carlo simulation, we conducted the comparisons between measurement and simulations of marine monitoring system in the aquatic environment.
- Measurement and simulation results are matched well → Spectra are similar and detection efficiencies(E) are very close.
- The sensitivity of monitoring system to ^{40}K in the water tank shows a good agreement with measurement and simulation in peak cps per Bq/L.
- ^{137}Cs MDA in the aquatic environment was estimated with simulation values.

THANK YOU FOR LISTENING