Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

[ANSTO Experience]
Evaluation of filters in RSPCS (Reactor Service Pool Cooling System) and HWL (Hot Water Layer) in OPAL research reactor at ANSTO (Australian Nuclear Science and Technology Organization) using Gamma Spectrometry System and Liquid Scintillation Counter

Jimin Lee [a], Robin Foy [b], Seongmoon Jung [a] , Hyeonsuk Park [a] , Sung-Joon Ye [a*]
[a]*Program in Biomedical Radiation Sciences, Department of Transdisciplinary Studies,*
Graduate School of Convergence Science and Technology, Seoul National Univ., Seoul, Korea
[b]*Australian Nuclear Science and Technology Organization, Radiation Protection Services Dept.,*
New Illawarra Rd. & Rutherford Ave., Lucas Heights, NSW 2234, Australia
[*]*Corresponding author: sye@snu.ac.kr*

1. Introduction

Being part of KONICOF 2015 Nuclear Global Internship Program, I worked with radiation protection services at ANSTO which is Australian Nuclear Science and Technology Organization. ANSTO has a research reactor, OPAL (Open Pool Australian Lightwater reactor) which is a state-of-art 20 MW reactor for various purposes. In OPAL reactor, there are many kinds of radionuclides produced from various reactions in pool water and those should be identified and quantified for the safe use of OPAL [1,2]. To do that, it is essential to check the efficiency of filters which are able to remove the radioactive substance from the reactor pool water. There are two main water circuits in OPAL which are RSPCS (Reactor Service Pool Cooling System) and HWL (Hot Water Layer) water circuits. The reactor service pool is connected to the reactor pool via a transfer canal and provides a working area and storage space for the spent and other materials. [3] Also, HWL is the upper part of the reactor pool water and it minimize radiation dose rates at the pool surface. [4] We collected water samples from these circuits and measured the radioactivity by using Gamma Spectrometry System (GSS) and Liquid Scintillation Counter (LSC) to evaluate the filters.

2. Materials and Methods

In this section, a role of RSPCS water filtration system and HWL filtration system, details of GSS and LSC and water sample preparation method are introduced

2.1 RSPCS Water Filtration System

The main purpose of the Reactor Water Purification System (RWPS) is to maintain the quality of the water in the Reactor Pool and Service Pool within specifications. This is achieved by pumping the cooling water from the Reactor Pool and Service Pool through a filter and an ion exchange column. The system removes water impurities such as dust, corrosion and activated particles to keep the conductivity below 1 μS/cm and to provide high optical quality.

In addition, this system is capable of purifying the entire inventory contained in the Reactor and Service Pools Cooling System (RSPCS) and Primary Cooling System (PCS) within 21 hours. The RWPS comprises two purification circuits each with 100% capacity. One is in operation while the other is on standby.

Each purification circuit is comprised of a filter, ion exchange column, resins trap, and related pipes, valves and instruments. The ion exchange columns are loaded with mixed bed resins and retain anionic and cationic impurities. These columns also act as depth filters that retain smaller solids particles with diameter less than the filter mesh.

Even though the RWPS is well established step by step, but radiation protection services department would like to double-check the filters' function using GSS and LSC.

2.2 HWL Filtration System

The Hot Water Layer Purification System (HWLPS) consists of a filter, an ion exchange column and related pipelines, valves and instruments. The HWLPS removes impurities dissolved in the water and keeps water conductivity levels below 1 μS/cm, non-dissolved solids concentration below 0.5 ppm, and optical qualities high. The coolant flowing through the HWLPS is demineralized pool water.

The filter receives water discharged from the HWLS Pumps and collects suspended solids in the water stream, retaining particles larger than 50 μm. The ion exchange column has mixed bed resins that retain anionic and cationic impurities. This column also acts as a depth filter by retaining very small solid particles with a diameter smaller than the filter mesh. In addition, the resin trap ensures that no resin from the column is released into the circuit and potentially returned to the Reactor Pool.

Like the RWPS, we would like to double-check the HWLPS filters' function using GSS and LSC.

2.3 Gamma Spectrometry System (GSS)

A gamma spectrometry system or gamma-ray spectrometer is an instrument for measuring the spectrum of the intensity of gamma radiation versus the energy of each photon. The most common detectors of the system include sodium iodide (NaI) scintillation counters and high purity germanium (HPGe) detectors which are semiconductor detectors. This system is used for various purposes such as assessment of natural radioactivity in small mineral or sea water samples. [5,6,7,8]

The system we used is in building 11 (Building 11 is Waste Operations building and it has many measurement facilities such as Gamma Spectrometry System and Liquid Scintillation Counter. Their main purpose is to measure and manage the waste water from OPAL pool.). It consists of the HPGe detector which provides significantly improved energy resolution in comparison to sodium iodide detectors.

The following picture is the ORTEC Gamma Spectrometry System in building 11. Its detector type is P-type and Co-axial, window is Aluminium, energy range is from 50 to 2000keV and the efficiency is 15%.

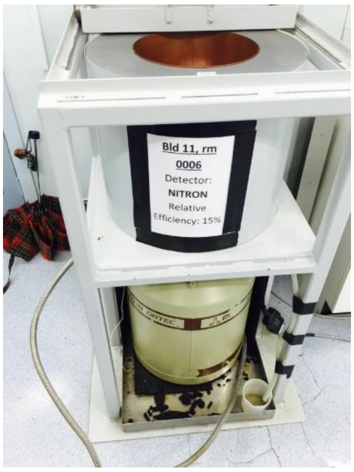

Fig. 1. ORTEC Gamma Spectrometry System in Building 11

2.4 Liquid Scintillation Counter (LSC)

Liquid Scintillation Counter (LSC) measures activity of a sample of radioactive material. [8,10,11] To measure the activity, samples are dissolved in a scintillation cocktail which has luminescence properties. The scintillator converts ionizing radiation from the radionuclide into photons of light (scintillation). The intensity of the light produced during scintillation is proportional to the initial energy of the beta particle. By placing a vial containing a radionuclide and scintillation cocktail into a dark detection enclosure (the instrument's detector), the scintillation counter can measure photon intensity. A photosensitive device amplifies the light emitted from the sample vials and the amplified signal is converted to pulses of electrical energy and registered as counts. The counts that are collected and sorted are used to generate the sample spectrum.

The first picture is inside of the LSC in building 11 (Tri-Carb 3100TR) [9] and second picture is a liquid scintillation cocktail which is ULTIMA GOLD XR.

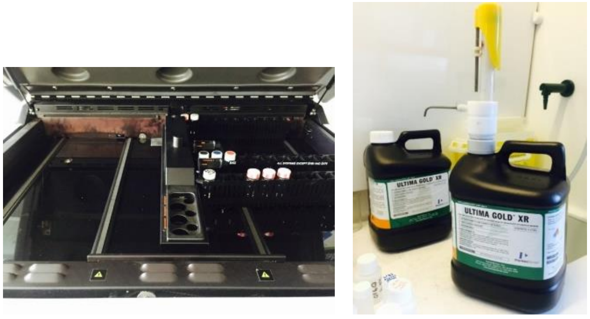

Fig. 2. Inside of Liquid Scintillation Counter and Liquid Scintillation Cocktail in Building 11

2.5 Water Sample Preparation

To evaluate the efficiency of filters in RSPCS and HWL, 500ml of water samples from each of points which are RSPCS inlet (before the filter), outlet (after the filter), HWL inlet and outlet were collected. 450ml of each water sample was measured by GSS and 50ml of it was measured by LSC for 3 days in a row. For LSC, a sample should be prepared in a proper way, so every sample was evaporated into 20ml and allowed to cool for at least 10 minutes and put together with 1ml of 1M Nitric acid, 4ml of demineralized water and 10ml of ultima Gold AB which is liquid scintillation cocktail.

3. Results and Discussion

The following tables are results from the measurements by using GSS and LSC. First of all, table 1 and 2 are measurement results of OPAL water samples from LSC for 3 days in a row. First water samples were taken from RSPCS inlet/outlet and HWL inlet/outlet each on Nov. 6 (Table 1) and the second water sample was taken only from RSPCS inlet on Nov. 27 because it is the most active sample (Table 2). From LSC measurement, it is available to get the gross alpha and gross beta activity (Bq/L) of each water sample. According to the measurement results, every gross alpha activity is lower than 0.38 Bq/L, so it is obvious that there are almost no alpha emitters in every water sample. In addition, for gross beta activity, there is such a significant difference between RSPCS and HWL inlet and outlet. Therefore, we were able to confirm that the filters in RSPCS and HWL circuits are working well.

Table 1: Gross alpha and beta activity of OPAL water samples measured by LSC

Measurement	Sample	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
1st	RSPCS Inlet	<0.38	77753
	RSPCS Outlet	<0.38	7
	HWL Inlet	<0.38	25830
	HWL Outlet	<0.38	6
2nd	RSPCS Inlet	<0.32	56476
	RSPCS Outlet	<0.32	5
	HWL Inlet	<0.32	18885
	HWL Outlet	<0.32	4
3rd	RSPCS Inlet	<0.34	42197
	RSPCS Outlet	<0.34	3
	HWL Inlet	<0.34	14146
	HWL Outlet	<0.34	4

Table 2: Gross alpha and beta activity of water sample from RSPCS inlet measured by LSC

Measurement	Sample	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
1st	RSPCS Inlet	<0.37	848453
2nd		<0.36	637019
3rd		<0.34	440058

Table 3 is a list of gamma emitting radionuclides and their activities of RSPCS water samples measured by GSS. In GSS, by analyzing the gamma spectrum and its energy peaks, it is available to identify and quantify what radionuclides are present in an unknown sample.

Table 3: List of gamma emitting radionuclides and their activities of RSPCS water samples measured by GSS

RSPCS Inlet		RSPCS Outlet	
Radionuclides	Activity (Bq/kg)	Radionuclides	Activity (Bq/kg)
Co-60	2.53	Cd-115	1.10
Ce-144	137.7	I-124	1.72
Y-85	181.3	Nb-95	0.90
Ru-103	6.40	Hf-181	0.67
Na-24	25.7	Xe-133	16.31
Nb-95	18.0		
La-140	2.03		
Zr-95	15.1		
Am-241	71.8		
Cd-115	9753.5		
Cr-51	185.9		
Hf-181	116.0		
Ta-183	36.8		
Ta-182	8.89		
Cd-115M	3463.4		
Mo-99	6.98		
Cd-109	188.3		

There are big differences between RSPCS inlet and outlet results. Almost every radionuclide was removed by the filter in the water circuit and even though there were some radionuclides remaining in the sample, their activities were very low so that we didn't have to consider them.

Table 4: List of gamma emitting radionuclides and their activities of HWL water samples measured by GSS

HWL Inlet		HWL Outlet	
Radionuclides	Activity (Bq/kg)	Radionuclides	Activity (Bq/kg)
Cr-51	57.1	Ce-144	2.79
Hf-181	13.7	Nb-95	1.15
Nb-95	9.83		
La-140	1.12		
Zr-95	6.38		
Cd-115	1645.1		
Cd-109	53.1		
Na-24	1.04		
Cd-115M	1216.9		

Table 4 is a list of gamma emitting radionuclides and their activities of HWL water samples. There are also huge differences between HWL inlet and outlet results like RSPCS results.

4. Conclusions

We could evaluate the efficiency of filters in RSPCS and HWL in OPAL research reactor. Through the measurements of radioactivity using GSS and LSC, we could conclude that there is likely to be no alpha emitter in water samples, and for beta and gamma activity, there are very big differences between inlet and outlet results, so every filter is working efficiently to remove the radioactive substance.

REFERENCES

[1] D. Delacroix, J. P. Guerre, P. Leblac, C. Hickman, Radionuclide and Radiation Protection Data Handbook, 2002.
[2] ANSTO Document, Activation of the internal components of the reactor pool (Document Number: RRRP-0057-2BEIN-020-A)
[3] SUNGFOONG KIM, The OPAL (Open Pool Australian Light-water reactor in Australia), 2005.
[4] ANSTO, OPAL shines with its first water, News on nuclear sciences, Atomical, 2006.

[5] A. S. Murray, M. J. Aitken, Analysis of low-level natural radioactivity in small mineral samples for use in thermoluminescence dating, using high-resolution gamma spectrometry, 145-147, 1988.
[6] T.M. Semkow, P.P. Parekh, Low-background gamma spectrometry for environmental radioactivity, Applied Radiation and Isotopes 57, 213-223, 2002.
[7] H. Al-Ghamdi, A. Al-Muqrin, A. El-Sharkawy, Assessment of natural radioactivity and ^{137}Cs in some coastal areas of the Suidi Arabian gulf, Marin Pollution Bulletin, 2016.
[8] G. F. Knoll, Radiation Detection and Measurement, 3rd ed., John Wiley & Sons, Inc., New York, 1999.
[9] Quanta Smart for Tri-Carb Liquid Scintillation Analyzers Getting Started Guide
[10] D.M. Brizel, T.H. Wasserman, M. Henke, V. Strnad, V. Rudat, A. Monnier, F. Eschwege, J. Zhang, L. Russell, W. Oster and R. Sauer, Simultaneous determination of beta nuclides by liquid scintillation spectrometry, Advances in Liquid Scintillation Spectrometry, 2008.
[11] M. S. Patterson , R. C. Greene, Measurement of low energy beta-emitters in aqueous solution by liquid scintillation counting of emulsions, Analytical Chemistry 37 (7), 854–857 , 1965.