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Correlation of the Analysis Results of the Lead Concentration with Results of Nuclide Analysis of the Air around the Facility

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1. Introduction

In the environment, the lead is contained in food, drink, industrial products and air. So, it is naturally faced to the public. However, workers in the lead-related manufacturing or working space with lead components are more likely to be exposed to the lead. The lead is absorbed into the human body through the breathing in the dust or vapor in the air, and is transferred to the respiratory or digestive system through the blood. In the case of nuclear facilities, the lead is mainly used as a shielding material, and exists in the radiation-controlled area as the forms of a lead brick or lead glass. As shown as Figure 1, the natural lead is composed of Pb-208(53%), Pb-207(22%), Pb-206(24%) and Pb-204(< 1%).

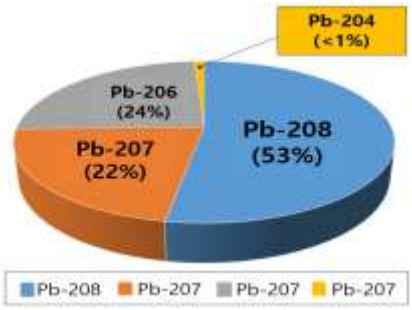

Figure 1. Abundacne of natural lead

Neutron, proton and other heavy charged particles can interact with the substances such as Pb in a normal operation of the nuclear facilities. And that interactions lead to the radio-activation of the air. Therefore, we intend to analyze the air in the proton accelerator, check the lead concentration in the work spaces, and use it as a monitoring data for the working environment.

2. Methods and Results

In order to analyze the lead concentration of air in the building, the dust is collected on the air filter using an air sampler. And then, the air filter is pre-treated before using a lead detection kit (Avotex) to determine the presence or absence of the lead. We analyzed the concentration of the lead and compared it with the limits of the lead exposure concentration for the working space [1], [2].

In addition, the dust was collected on the air filters before and during the proton beam extraction in the target room, and gamma nuclides on these filters were analyzed and compared, each other.

2.1 Measurement

Air dust samples are collected at the radiation-controlled area and at public area in the accelerator building. The sampling points are shown in Table 1.

Table 1. Sampling point in the area

Area	Sample #	Sampling Point
Radiation Controlled Area	1	Stack Monitoring Filter
	2	Target Room Entrance
	3	Beam Target Room
Public Area	4	None Sampling Filter
Radiation Controlled Area	5	Hallway
	6	Lead Block
Public Area	7	Hallway
	8	Outdoor
	9	Table (Surface Rub)

After the air sampling on the filters is completed, the filters are placed in a beaker and is added a vinegar sufficiently. Then, the particles on the filters are allowed to stand for 4 hours in order to elute sufficiently. After 4 hours, the samples are quantified and placed in the glass vial (20ml). We add 2ml of solution liquid (Abotex solution liquid) into the samples and stabilize them for a day. After stabilization, we check the color to determine the lead concentration using the color table presented in the lead detection kit. The concentration value is calculated by reflecting the sampling condition and the calculation formula is as follows.

$$Concentration_{Air-Pb} = \frac{ppm \times V}{T \times R \times E}$$

◦ ppm: Parts per million(mg/L)
◦ T: Sampling time (min)
◦ R: Sampling Flow rate (Liter per min, LPM)
◦ E: Sampling efficiency

In order to check the artificial nuclide, gamma nuclides on these filters were analyzed by using HPGe detector.

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2.2 Results

As the result of confirming the color of the sample solutions, there was a color change in the solutions of the filters which are sampled at the target room and at its entrance. And, there was also a color change in the solutions of the smear paper which is sampled at the lead bricks as the comparison group. The lead bricks are placed in the target room and its entrance. The lead concentration values are calculated in 0.04 mg/m^3 at the target room entrance, 0.07 mg/m^3 at the target and 0.34 mg/m^3 at the lead bricks. The concentration for the filters sampled in other places was found to be below the minimum detection limit. Table 2 summarizes the calculated concentration results.

Table 2. Lead concentration for the sample

No.	Sampling Point	Concentration [mg/m^3]	Exposure limit	LDL
1	Stack Monitoring Filter	< LDL	0.05 [mg/m^3]	0.014 [mg/m^3]
2	Target Room Entrance	0.04		
3	Beam Target Room	0.07		
4	None Sampling Filter	< LDL		
5	Hallway	< LDL		
6	Lead Block	2.5		
7	Hallway	< LDL		
8	Outdoor	< LDL		
9	Table (Surface Rub)	< LDL		

As shown as Figure 1, Pb is mainly present as four stable isotopes within the natural environment: 208Pb (≈52%), 206Pb (≈24%), 207Pb (≈23%) and 204Pb (≈1%). These nuclides interacted with proton produce Bi-205 and Bi-206 as shown in Table 3 [2].

Table 3. Induced nuclear reaction between proton and natural lead

Reaction	Isotope	keV	Ir[%]	$T_{1/2}$
$^{206}Pb(p, n)^{206}Bi$	Bi-206	138.977	15.8	6.243d
		343.51	23.4	
		497.06	15.31	
$^{207}Pb(p,2n)^{206}Bi$		537.45	30.5	
		803.1	99	
		881.01	66.2	
$^{208}Pb(p,3n)^{206}Bi$		895.12	15.66	
		1098.26	13.5	
		1718.7	31.8	
$^{206}Pb(p,2n)^{205}Bi$	Bi-205	703.44	31	15.31d
$^{207}Pb(p,3n)^{205}Bi$		987.62	16.13	
$^{208}Pb(p,4n)^{205}Bi$		1764.36	32.5	

Table 4. Induced nuclear reaction between neutron and natural lead

Reaction	Isotope	keV	Ir[%]	$T_{1/2}$
$^{206}Pb(n,3n)^{204m}Bi$	Bi-204m	53.4	7.6	13ms
		752.1	96.8	
$^{206}Pb(n,\alpha)^{203}Hg$	Hg-203	279.2	81	46.6d
$^{208}Pb(n, p)^{208}Tl$	Tl-208	277.351	6.31	3m
		510.77	22.6	
		583.19	84.5	
		860.56	12.42	
		2614.533	99	

In addition, Hg-203 and Tl-208 could be produced by interacting with neutron generated in (p,n) reaction as shown in Table 4. In the case of Tl-208, it is also a nuclide that can naturally occur through the Rn-222 decay. Therefore, the sampling was performed before and during the proton beam irradiation in the target room to verify the affecting of nuclear reaction.

And we attempted to search the gamma peaks of Bi-206, Bi-205 and Bi-204m, Hg-203, Tl-208 using the HPGe detector. If their peaks are present, we could consider that air activation from lead could be occurred during the beam irradiation. In the search result of the gamma spectrum, Tl-208 was confirmed and two cases of the radioactivity measured of before and during beam irradiation are similar to each other. The gamma peaks of Bi-205, Bi-206, Bi-204m, and Hg-203 were not observed.

3. Conclusions

The air sample inside the building was analyzed, and the lead concentration values were less than LDL except for samples which are sampled at the target room and at its entrance. The reason is that lead bricks are placed in these areas. In the case of entrance, the calculated concentration value was lower than the exposure limit of lead in the working space. As a result of analyzing the gamma spectrum on the filter which is sampled in the target room during the beam irradiation, the Tl-208 was confirmed and two cases of the radioactivity measured of before and during beam irradiation are similar to each other. The shielding door of the target room is usually closed and that the space does not belong to the main working space where workers stay for a long time. However, there is a need to prevent the leakage into the surrounding and to monitor the air activation continuously in order to be the safe of the working environment.

REFERENCES

[1] Lead and Inorganic Compound Exposure Health Care Guidelines, H-134-2013, Korea Occupational Safety and Health Agency

[2] Calculation of Proton Induced Reaction on Lead in Energy Region up to 300MeV, QingBiao Shen, JinFeng Zhou & XiuQuan Sun, 27 Aug 2014