^{137}Cs activity concentrations in lichen and moss collected in Malaysia and Korea

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1. Introduction

There is a long history of lichens and mosses being used as bio-indicators of air pollution. Lichens are a type of fungus, that were the first organisms to be used as bio-monitors because they are sensitive enough to react to changes in the quality of the environment [1], [3~6]. Due to these criteria, Lichens are often selected as bio-indicators due to their ability to procure and rivet air pollutants elements and trace elements [1]. Lichen has slow growth rate, which allows the accumulation to a higher degree of various pollutants properties, so they were selected as a universal indicator for bio-monitoring purposes [1], [3]. Mosses are the simple type of plant (rudimentary root system) that have no true roots, shoot or vascular system and all the nutrients are assumed that received from the atmosphere and influence by environment. This advantage of the simplicity and easily influence by geographical areas and tolerate environment, makes mosses are well known globally as bio-indicators among researchers.

Nuclear weapons testing in the atmosphere in 1950~60's and nuclear reactor accidents such as the Chernobyl accident in 1986 and the Fukushima accident in 2011 caused the ^{137}Cs contamination in the terrestrial environment of the globe because of the long-range travel due to highly volatile properties [2~5]. The ^{137}Cs can be considered as one of the most hazardous radionuclides in the environment because of its high fission yield, long half- life (30.1 years) and high solubility [2].

A number of studies have demonstrated that lichens and mosses can accumulate high amounts of radioactivity. In spite of the growing research of lichens and mosses, there have been no prior studies in Malaysia on radionuclides bio-monitoring by lichen moss species. Thus, as a first step, a comparison of ^{137}Cs activity concentrations in lichens and mosses regardless of the species in Malaysia and other countries were carried out in this study.

2. Materials and Methods

2.1 Sampling

Malaysian lichen samples were collected from 10 locations in 2012, at 2 different locations in the State of Kelantan, 4 different locations in the State of Terengganu and 4 different locations in the State of Negeri Sembilan. The coordinates of sampling areas were shown in Table 1. Kelantan and Terengganu both situated at the East of Peninsular Malaysia while Negeri Sembilan situated at the West of Peninsular Malaysia, consist of urban area, suburban area and industrial area.

Malaysian moss samples were collected from 8 locations along to the West of Peninsular Malaysia during July and August in 2019.

Table 1: Sampling locations and their respective coordinates

No	Location	Coordinate	Area characteristic
1	Tanah Merah, Kelantan	N 05º 48.61' E 102º 8.0'	Sub-urban
2	Kota Bahru, Kelantan	N 06º 13.02' E 102º 17.79'	Urban
3	Kuala, Terengganu	N 05º 18.72' E 103º 7.66'	Urban
4	Paka, Terengganu	N 04º 36.02' E 103º 26.16'	Industrial
5	Kerteh, Terengganu	N 04º 28.10' E 103º 6.47'	Industrial
6	Chukai, Terengganu	N 04º 12.30' E 103º 26.19'	Sub-urban
7	Nilai, Negeri Sembilan	N 02º 50.61' E 101º 47.79'	Sub-urban
8	Seremban, Negeri Sembilan	N 02º 46.50' E 101º 58.45'	Sub-urban
9	Port Dickson, Negeri Sembilan	N 02º 31.45' E 101º 49.0'	Industrial
10	Telok Kemang, Negeri Sembilan	N 02º 27.29' E 101º 51.6'	Urban

Korean moss samples were collected a location of Ulleungdo and 2 locations of Gyeryong Mountains and 3 locations of the hill of urban-area park in Daejeon city.

About 200~300 g fresh weight of each moss sample were collected from the bark of old trees at height of 1~2 m above the ground using a knife and disposable gloves, as shown Fig. 1.

Fig. 1. Moss sampling from the bark of tree in Korea

All of the samples were unwashed and each sample was carefully cleaned with sharp-end toothpick or wooden chopsticks to remove pieces of bark and other impurities such as small insects. All samples were air-dried at room temperature for a few days. In case of Korean moss samples, dried again in an oven at 97 ℃ approximately for 48 hours. Malaysian lichen samples then were grinded using marble agate and mortar while samples were submerged in liquid nitrogen inside fume hood. And then the grinded samples were transferred to petri dish for overnight drying. The Korean dried moss samples were subsequently grinded to powder with the use of a lab blender, homogenized by passing through a 500 μm mesh sieve. After each homogenized sample was weight, the samples were enclosed in 130 ml plastic containers (KINS-D6H4) which were of the same geometry as containers to which the detector was calibrated using a multi-radioisotope standard sources for gamma-ray peak efficiency calibrations.

2.1 Analytical procedures

The radioactivity concentration of ^{137}Cs in lichen moss samples were measured by gamma ray spectrometry using high purity germanium (HPGe) detector and multichannel analyzer. The detector was shielded by a cylindrical lead shield of 10 cm thickness with copper liner. Gamma spectra were measured for 54,000 s (15 hours) in case of lichen sample of about 6 g and 80,000 s (about 22.3 hours) in case of moss sample of about 30 g. The peak area corresponding to the ^{137}Cs gamma ray energy of 661.6 keV was calculated by spectrum analysis software (Gennie 2000, CANBERRA). The HPGe detector was calibrated with the mixed radionuclides solution which was prepared by spiking of standard solutions and filled in the same geometry plastic container. The activity values were given as Bq·kg^{-1} in dried weight.

3. Results and Discussions

The results of ^{137}Cs activity concentration in lichen samples collected from Malaysia are presented in Table 2. The ^{137}Cs of 7 locations are not detected as the yields are less than the detection limit. For 3 other locations, which is 6, 7 and 10, are sub-urban and urban area with activity concentration level of 2.0, 2.6 and 2.2 Bq·kg^{-1}, respectively. The Malaysian moss samples are under radioactivity measurement at the present.

Table 2: Results of ^{137}Cs radioactivity concentration in lichen samples

Sample Locations	Radioactivity (Bq/kg)
1	ND
2	ND
3	ND
4	ND
5	ND
6	2.0 ± 0.23
7	2.6 ± 0.30
8	ND
9	ND
10	2.2 ± 0.26

Note) ND means less than detection limit.

The results of ^{137}Cs radionuclide activity concentration in moss samples collected from Korea are presented in Table 3. The activity concentrations of ^{137}Cs in Korean mosses were founded to be in the range of less than minimum detectable concentration (MDC) ~ 31.63 Bq·kg^{-1} in dried weight.

Table 3. Results of ^{137}Cs radioactivity concentration in moss samples

Sample Locations	Collection Date	Radioactivity (Bq/kg)
Urban* Park Hill #1	2019/05/18	1.89 ± 0.26
Urban Park Hill #2	2019/05/19	< 2.64
Urban Park Hill #3	2019/07/06	<5.51
Ulleungdo	2019/05/23	31.63 ± 0.91
Gyeryong Mt. #1	2019/07/05	1.98 ± 0.30
Gyeryong Mt. #2	2019/07/05	6.23 ± 0.48

Note) * : Daejeon city in Korea
< : less than MDC

4. Conclusions

The behavior of ^{137}Cs in the atmosphere is strongly related to its chemical form as it may be released in the atmosphere in gaseous form or adsorbed onto particles. ^{137}Cs contamination level in the terrestrial environment due to atmospheric fallout varies with geographic location and rainfall [2]. Although the activity concentrations of ^{137}Cs in Malaysia were probably low compared to other country's monitoring studies conducted in the northern hemisphere such as Korea, Norway, Greece, Turkey and Iran. This could be due to different factors such as geographical location, meteorological condition, and sampling species of lichen or moss. On the other hand, Malaysia may be influenced by ^{137}Cs fallout resulted from nuclear

weapon tests and/or Chernobyl and Fukushima nuclear reactor accidents lower than northern countries. Therefore, we need further investigations of our territory. The results of this study will provide a reference level to trigger overseas nuclear accidents in a future.

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