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Heavy Metals and Radionuclides in Lichens and Mosses in Thrace, Turkey

E. Eğilli (Ölmez), S. Topcuoğlu, D. Kut, Ç. Kırbaşoğlu, N. Esen

Çekmece Nuclear Research and Training Center, Post Office Box 1, Atatürk Airport, 34831, Istanbul, Turkey

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Lichens and mosses have long been used as bioindicators in monitoring surveys of chemical and radioactive pollutions (Ross, 1990; Sawidis et al.,1997). These organisms are the most sensitive markers of air born contaminants. Following the nuclear accident in Chernobyl, the activity levels of fallout radionuclides, especially ^{134}Cs and ^{137}Cs, were investigated in lichens and mosses in Turkey (Topcuoğlu et al.,1992; Topcuoğlu et al., 1993; Köse et al.,1994; Varinlioğlu et al.,1994). At the same time, the natural depuration rate of ^{137}Cs radionuclides in a lichen and moss species were also determined in Turkish terrestrial environment (Topcuoğlu et al.,1995). On the other hand, no data is available on the heavy metal or organic pollutants in lichen and moss species collected from Turkish environment. However, the large number of papers have been published on the metal and organic pollutant concentrations in the plants collected from different countries in the world (Villeneuve et al.,1988; Chettri,et al.,1997; Branquinho, 1999).

The objectives of the present work were as follows: *(i)* to determine understanding of the availability and location of heavy metals in lichen and moss species; (ii) to update of the inventory of ^{137}Cs in lichen and moss species over 12-14 years interval after Chernobyl accident; (iii) to determine the concentration of some natural radionuclides in these plant species.

MATERIALS AND METHODS

Lichen and moss samples have been collected at various locations in Thrace part of Turkey during the period of 1998 – 2000. The sampling locations are indicated on the map (Fig. 1). At each station, samples of the dominant species of lichens and mosses were taken as follows:

a. lichens, *Evernia prunastri* (L.) Ach., *Parmelia sulcata* Taylor, *Pseudevernia furfuracea* (L.) Zopf, *Ramalina farinicea* (L.) Ach., *Xanthoria parietina* (L.) Th.Fr.
b. mosses, *Hpnum ssp., Leucodon ssp., Tortula princeps* De Not.

In the laboratory each plant was first separated from the substrate and other contaminating materials. After homogenizing, 100-150 g of each species was

Correspondence to: S. Topcuoğlu

dried below 85° (to constant weight), and kept away from metallic materials, radioactive materials and dusty conditions to avoid contamination.

About 0.2 g each lichen and moss species was added in 1 cm^3 polyethylene tubes and irradiated for 4 hr at a thermal neutron flux of about 2×10^{13} n cm^{-2} s^{-1} in TR-2 Reactor of Çekmece Nuclear Research and Training Center. IAEA's CRM SL-1 was used as the standard. The gamma spectra of all samples and standards were obtained by using a gamma-ray spectrometer consisting of a 4K analyzer (Canberra, S85) and a high purity Ge detector (Ortec, GMX) which has a resolution of 1.9 keV at 1333 keV of ^{60}Co. Decay periods were 24 hr for short-lived and 3-4 weeks for long-lived isotopes. Counting times varied between 3000 to 80 000 sec.

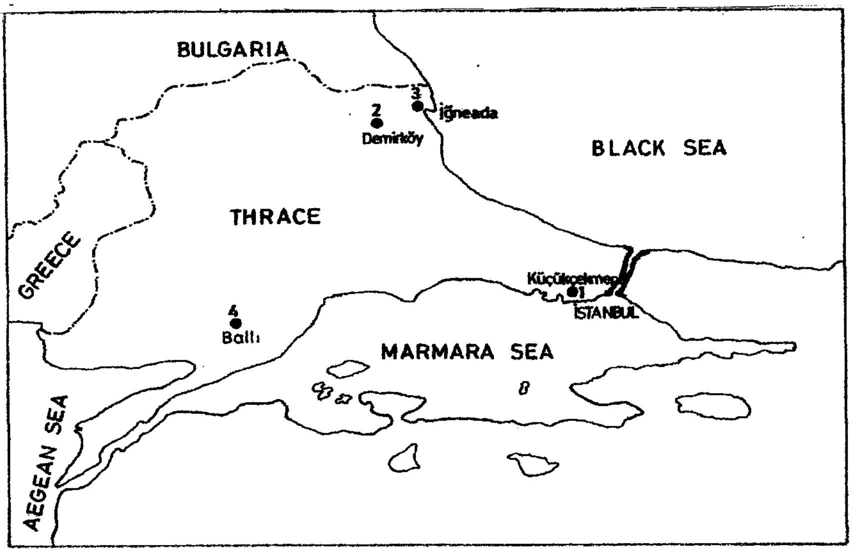

Figure 1. Collection sites of lichen and moss samples in Thrace part of Turkey. –1: Küçükçekmece, 10 m. –2: Demirköy, 1000 m. –3: İğneada, 250 m. –4: Ballı, 550 m.

The gamma isotopic analyses were carried out using the same gamma-ray spectrometer. The properties of the counting system as described above. The sample powder (about 100 g) was pressed by hand into the special cup and it was placed at the distance 10 cm in front of the detector for counting. The energy dependent efficiency calibration were done with a solid nuclide mixture of the Amersham gamma-reference sources containing known activities of ^{109}Cd, ^{57}Co, ^{139}Ce, ^{113}Sn, ^{137}Cs, ^{88}Y and ^{60}Co. Spectrum stabilization was obtained as the counting times were usually long (1-3-5 x 10^5 s).

RESULTS AND DISCUSSION

The heavy metal concentrations in lichen and moss samples are given in Table 1. All heavy metal concentrations, except Hg and Mn, were significantly higher in

Table 1. Heavy metal concentrations (μg g^{-1} dry weight, except Fe) in lichen and moss species. Values are expressed as mean of three analysis for each sample.

Species	Site / Date	Mn	Cr	Fe,%	Co	Zn	As	Hg	Se	Sb
a. Lichens										
E. prunastri	2/ Feb. 98	121±1	31.2±2.2	0.88±0.05	9.6±1.1	276±40	16.9±1.7	0.25±0.21	1.4±0.8	1.64±0.13
P. sulcata	2/ Feb. 98	39±1	8.7±1.7	0.18±0.03	1.2±0.4	91±24	11.5±1.0	-	3.5±2.7	0.26±0.03
P. furfuracea	3/ Feb. 98	101±2	14.5±0.8	0.31±0.02	2.5±0.3	118±16	5.8±0.6	0.18±0.03	1.4±0.9	0.69±0.06
R. farinicea	4/ May.00	41±1	15.9±0.2	0.41±0.01	1.6±0.2	93±10	-	-	-	-
X.parietina	1/ Jan. 98	158±3	147.9±5.6	3.65±1.60	22±1.6	620±79	31.5±3.1	0.10±0.08	21.5±9.2	7.73±0.57
b. Mosses										
Hypnum ssp.	3/ Feb. 98	1088±18	21.7±1.9	0.60±0.04	5.0±0.7	189±23	5.8±0.6	0.11±0.05	2.5±1.1	0.69±0.08
Leucodon ssp.	2/ Feb. 98	146±3	18.6±2.2	0.71±0.05	4.8±0.9	97±20	3.9±0.5	0.16±0.06	6.7±4.4	1.19±0.11
T.princeps	4/ May.00	105±1	12.4±0.2	0.48±0.02	2.6±0.2	472±10	-	-	-	-

- Not tested

the lichen species *X. parietina,* than the other tested lichen and moss species. This species collected from the Istanbul region at a lowest altitude. This result showed that the Küçükçekmece region of the Istanbul city was the most polluted area of the Thrace part of Turkey. This station is located in the urban area of the city. Istanbul, the air pollutants are emitted mainly from industrial processes (Mn, Cr, Sb, etc), fossil fuel combustion (As, Se, Sb) and municipal waste incineration (Zn). It is well known that the metal concentrations in lichens have shown parallelism with the element content of air particulate matter in urban areas (Saeki et al.,1977). The Mn concentration in a moss species *Hypnum ssp.,* collected from the İğneada station is significantly higher than the other tested plants. İğneada station is located on the western part of the Black Sea. In one study, the concentrations of many elements in airborne particles in the western part of the Black Sea higher by a factor of two comparing the concentrations in the eastern part (Hacısalihoğlu et al., 1992). We can say that Europe is the dominant source of anthropogenic metals in the Thrace atmosphere besides the Istanbul city. The Hg concentrations in all tested samples were found to be similar.

In general, the concentrations of Zn, Cr and Mn in *P.sulcata* or other epiphytic and epigeic lichen samples collected from northern Greece agree well with the present results (Chettri,1997). Only our Cr data in *X.parietina* species collected from Küçükçekmece station has the opposite trend noted. The result presented above clearly indicated that Cr concentration is increased in the urban area.

The heavy metal concentrations in two moss species have been determined after collection from Swedish forest sites (Ross, 1990). The average metal contents were given as follows: Mn, 380; Cr 1.7; Fe, 400 and Zn, 42 $\mu g\ g^{-1}$ (dry weight). When these results are compared with the values in Table 1, it shows that Cr and Zn concentrations are significantly higher in moss species collected from the Thrace region. At the same time, Mn concentration in *Hypnum ssp.* is also significantly higher than the Sweden mosses. On the other hand, Mn concentrations in *Leucodon ssp.* and *T.princeps* species collected from the forest sites in Thrace are significantly lower than the Sweden mosses. The Fe concentrations in moss samples collected from Sweden and Thrace region of Turkey were generally found to be at similar level.

Concentrations of ^{137}Cs in lichen and moss samples are given in Table 2. The high level of ^{137}Cs activities were found in *E.prunastri* and *Leucodon ssp.* to be 114 and 139 Bq kg^{-1} among the tested lichen and moss species, respectively. These two plant samples were collected from the same station. The low level of ^{137}Cs concentrations were detected in *R.farinicea* lichen (<3 Bq kg^{-1}) and *T.brinceps* moss (43 Bq kg^{-1}) at the Ballı station. These results showed that moss species take up higher amounts of ^{137}Cs than lichen species in the same sites. On the other hand, the activity values of ^{137}Cs in lichen species were found to be significantly higher than moss species (Sawidis,1988; Topcuoğlu et al.,1993). Moreover, the biological half-life of ^{137}Cs in moss was shorter than in lichen species under Chernobyl conditions (Topcuoğlu et al.,1995). The variations in ^{137}Cs

Table 2. Radionuclide concentrations (Bq kg^{-1} dry weight) in lichen and moss species (uncertainties = $\pm 1\sigma$).

Species	Site	Collection Date	Counting Date	^{137}Cs	^{238}U	^{232}Th	^{40}K
a. Lichens							
E. prunastri	2	Feb. 98	May.00	114±21	<13	<7	<170
P. sulcata	2	Feb. 98	May.00	92±15	<13	<7	<170
P. furfuracea	3	Feb. 98	May.00	22±17	311±44	<7	<170
R. farinicea	4	May.00	Jul. 00	<3	583±109	<7	710±283
X. parietina	1	Jan. 98	May.00	51±25	126±55	<7	<170
b. Mosses							
Hypnum ssp.	3	Feb. 98	May.00	92±34	940±78	277±95	<170
Leucodon ssp.	2	Feb. 98	May.00	139±25	130±74	<7	<170
T.princeps	4	May.00	Jul. 00	43±34	531±89	<7	1471±611

concentration between non-vascular plants suggests that, unless biokinetic experiments are performed along with biomonitoring investigations, no reliable result can be achieved.

The natural radionuclide concentrations of ^{238}U, ^{232}Th and ^{40}K were also determined in the tested plants samples (Table 2). The ^{40}K was only detectable in lichen and moss species collected from the Ballı station. The ^{232}Th was found only in a moss sample *Hypnum ssp.,* collected from İğneada station. At the same time, the high ^{238}U concentration also detected in this moss sample. The higher ^{238}U concentration was found in *R. farinicea* among the tested lichen species. It is remarkable that ^{238}U, ^{232}Th and ^{40}K were not detectable in lichen samples collected in the Demirköy station. Details of these bioaccumulation conditions can be determined after having more reliable values.

These nonvascular plants appear to be valuable potential bioindicators for atmospheric pollution by heavy metals or radionuclides. The present study supported the fact that the heavy metal concentrations in lichen and moss species could be significant indicators to determine pollution level of urban area along with the forest environment. At the same time, the ^{137}Cs concentrations in the present work showed that the lichen and moss species could be valuable indicators to determine the lasting effect of the radionuclide.

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