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Using Factor Analysis To Find Source Atmospheric Pollution By Moss Technique

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Abstract: The aim of this investigation was to apply the moss biomonitoring technique using *Barbula indica* moss and factor analysis to evaluate the possible sources of atmospheric pollution in Thua Thien Hue province. The *Barbula Indica* moss samples were collected at sixteen sites in the areas of Thua Thien Hue province - the Central Vietnam. The concentrations of thirty elements in the collected *Barbula indica* moss samples were determined by neutron activation analysis at the reactor IBR-2 at the Joint Institute for Nuclear Research (JINR) in Dubna, Russian Federation. Factor analysis has been applied to the concentration of chemical elements in the moss samples to reveal the possible pollution sources. Rotated factor loadings suggested three factors, that could explained more than 84% of variability. Three factors are speculated for three main pollution sources in the study area: soil dust (F1), traffic (F2) and burning of traditional fuels (F3). Additionally, factor scores were calculated, that confirmed the presence of pollution sources in the corresponding sites.

Keyword: *Barbula Indica, factor analysis, atmospheric pollution*.

I. INTRODUCTION

In Vietnam, the environmental quality has been gradually degraded by unplanned economic development, which is increasing industrialization, urbanization, construction, traffic, as well as agricultural development. For a long time, environmental quality monitoring has been often neglected in the country. While several studies assessing metal pollution in aquatic environments have been carried out, metal atmospheric environment monitoring data have remained limited and often focused on large cities such as Ho Chi Minh and Hanoi [1, 2].

The moss technique firstly introduced in Scandinavia has proved to be feasible for studying atmospheric deposition of heavy metals as well as other trace elements [3]. Heavy metals accumulate in moss due to their morphological and physiological characteristics. Moss leaves are highly permeable for ions of trace elements and mineral salts. Ions found in moss come from atmospheric precipitation and dry deposition through simple processes of ion exchange, while the uptake from substratum is negligible [4].

Generally, *Hypnum* moss is hardly found in Vietnam, which is using as a bio-

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indicator for monitoring the air pollution in Europe [5]. Our group found another moss and compared the absorption ability of chemical elements, popularity between *Hypnum* and *Barbula*. *Barbula* moss is a suitable bio-indicator for monitoring air pollution Vietnam [6]. The initial research works using *Barbula Indica* moss to monitor metal atmospheric deposition in the North of Vietnam has shown the effectiveness of this method and it is possible to implement it in other provinces [7, 8]. In this study, chemical elements air polution in Thua Thien Hue province has been investigated by moss technique and factor analysis to conjecture the air pollution sources.

II. MATERIALS AND METHODS

A. Sampling area

The sampling area was Thua Thien Hue (16.30^0N, 107.35^0E), a province in central Vietnam. It is located along the seashore, with an area of about 5,048 km^2. The region features a coastal narrow strip land, leaning against the Truong Son Mountains. The Hue area holds a tropical monsoon climate. There are two seasons (dry and rainy) and the rainy season usually starts from August of one year to January of the next year. The moss collection was carried out at the end of the rainy season. Sixteen locations for moss sampling are shown in Fig.1. At each site 3 to 4 moss sub-samples were collected.

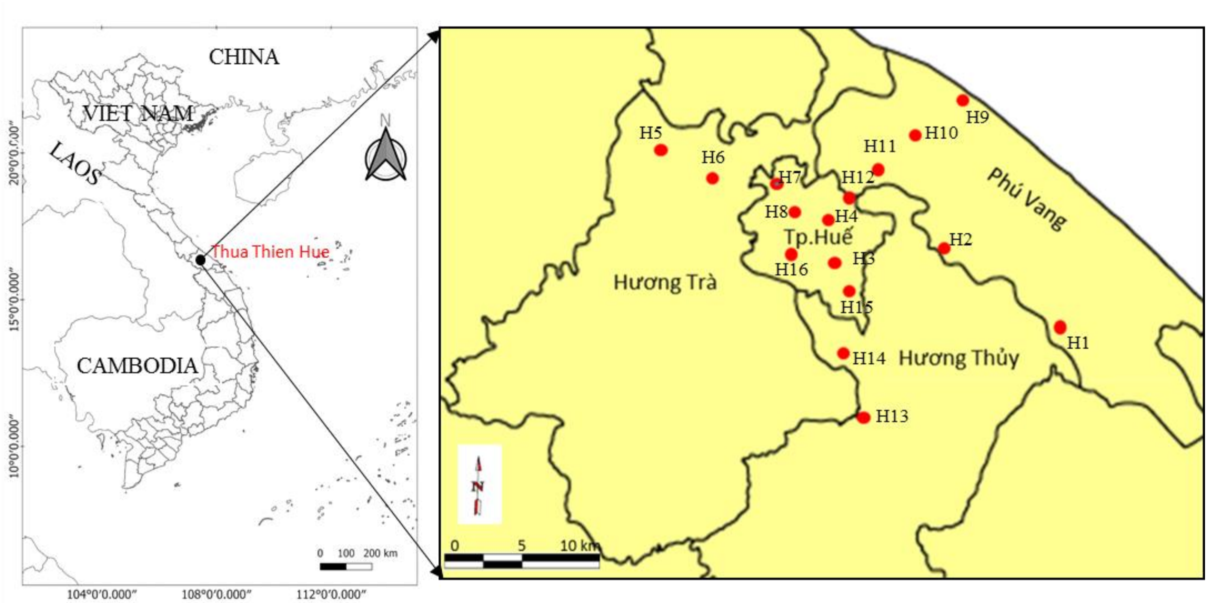

Fig. 1. The locations of moss sample collection in Thua Thien Hue province

B. Moss sampling

To minimize the influence of substrate, moss was picked out from the tree trunk at the height at least 1.5 m from the ground and only the top of the moss plant is taken (Fig. 2a) and the picture of the collected moss is shown in the Fig.2b. Normally, the length of *Babula* moss is only from 2 to 3 cm and rarely up to 5 cm. Leaves are ovate to ovate-lanceolate and plant is green to brownish-green.

The sampling was mainly carried out in accordance with the strategy of MONITORING MANUAL of the UNECE ICP 2015. All sampling sites were located at least 200m from main roads and 50m from local roads. Moss were cut out from its carpets by plastic tools and put in polyethylene zip-lock bags, both tool and bag were made from materials with low impurity level. However, due to the characteristics of the cities of Vietnam, moss was usually covered with soil dust so that in laboratory, the moss samples were thoroughly washed by distilled water and cleaned from extraneous materials (large soil particles, leaves, dust, etc.). The top part of the mosses (living, green) was separated from the lower part (brown, dead), and only the top part was used for analysis. In the last stage, each moss sample was dried until its weight remained unchanged [5].

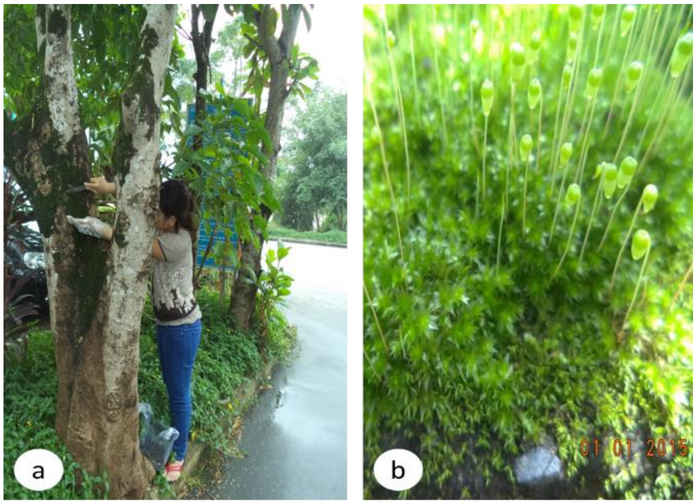

Fig. 2. Picture of the Barbula Indica moss

C. Analytical method

The instrumental neutron activation analysis (INAA) was carried out at the Department of Neutron Activation Analysis of the Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research in Dubna, Russian Federation. The main parameters of irradiation of moss samples at the IBR-2 reactor are shown in Table I.

Each moss sample weighed about 300 mg of dry moss and was wrapped in polyethylene paper for short exposure or aluminum foil for long exposure as shown in Fig. 3.

Fig. 3. The pictures showing moss samples packed in PE paper (lower line) and aluminum foild (top line)

Table I. The main parameters of irradiation of moss samples at the IBR-2 reactor [3]

Irradiation type	Neutron flux density ($x10^{12} n.cm^{-2}s^{-1}$)	Time		
		Irradiation	Decay	Measurement
Short-term (Channel 2)	1.23	3 min	3 min	15 min
Long-term (Channel 1)	3.31 (Cd-coated)	3 - 4 day	4 day	30 min
			20 day	90 min

D. Statistical analysis

In environmental science, factor analysis is a well-known method for statistical data analysis and has been used extensively in order to simplify a set of multidimensional original data and make it easier to interpret. By using this technique, several new latent variables (factors) will be created and each original variable can be expressed as a linear combination of these factors, plus a residual term that reflects the extent to which the variable is independent of the other variables. In our work, factor analysis was used in order to identify and characterize different pollution sources using STATISTICA-12 software.

III. RESULTS AND DISCUSSIONS

Concentration of thirty elements including Na, Mg, Al, Cl, K,Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Sr, Cd, Sb, Cs, Ba, La, Ce, Sm,Tb, Ta, Th, and U of sixteen samples were determined by INAA (Table II) with the relative errors ranging from 3 to 10 percent, except for Cr (14%). Only 13 elements including Al, Cl, K, Sc, Ti, Cr, Ni, Co, Zn, As, Se, Ba and La were chosen for factor analysis (FA). This is due to the fact that the number of sampling locations were only sixteen. Reducing the number of variables will increase the accuracy of the analysis results by factor analysis.

Table II. The concentration (mg/kg) of chemical elements in the moss samples

	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16
Na	594	557	669	797	1280	570	600	769	1080	471	298	695	1110	329	618	336
Mg	1786	1365	1794	1927	1239	1526	1552	1649	1103	1630	1483	1603	1031	829	1554	1566
Al	8760	5820	2980	3010	1010	6000	3640	7480	8650	7160	2670	12700	9450	4260	1840	3330
Cl	3590	2400	3000	3510	1170	1280	2530	1260	1880	1580	827	2080	1250	572	2320	552
K	26200	15700	24800	25700	16400	14500	17500	13200	17000	12200	9670	16300	9440	6480	12400	8340
Ca	9710	10100	11100	12000	4920	9710	9740	15500	9900	13100	14800	11900	10200	14600	11000	15300
Sc	1.85	1.26	0.67	0.58	1.42	1.02	0.59	1.09	1.55	1.19	0.38	1.88	2.12	0.65	0.24	0.55
Ti	543	324	173	170	166	271	226	552	741	412	132	694	470	193	129	150
V	16.6	9.8	5.3	5.5	2.6	8.1	7.9	14.3	15.1	12.2	8.2	19.5	13.5	14.5	12.4	7.3
Cr	20.7	2.1	11.0	8.2	16.8	10.1	6.3	21.7	17.3	8.8	18.2	21.2	14.9	5.6	2.5	7.6
Mn	87.9	57.6	58.2	54.4	64.7	121	64	97.9	99.4	99.4	50.1	114	114	82.3	41.2	74.4
Fe	5690	4460	3150	2520	5830	3070	2140	3720	5990	3730	1410	7030	6630	1990	1120	2100
Ni	5.84	4.89	4.82	4.23	4.34	2.98	3.67	6.15	8.14	3.72	2.08	9.58	5.61	2.67	1.09	3.64
Co	1.84	1.40	1.01	0.75	1.83	1.10	0.81	1.43	1.56	1.58	0.56	2.17	2.10	0.87	0.32	0.80
Zn	110	271	219	167	456	90	95	172	206	110	114	126	113	145	84	203
As	2.67	2.77	2.28	2.03	3.33	2.23	2.18	3.01	3.3	2.52	1.54	3.00	2.74	1.85	0.99	1.89
Se	1.60	1.99	2.06	1.85	1.90	1.17	1.80	2.22	1.42	1.20	1.04	0.84	1.46	1.16	1.07	0.96
Br	8.5	13.3	9.4	8.0	11.5	11.7	9.3	12.0	13.9	19.9	8.9	9.2	10.4	14.3	7.9	13.8
Sr	43.9	65.9	45.2	41.6	59.3	58.2	33.3	50.0	60.4	69.4	45.9	40.5	31.6	44.4	45.8	67.5
Cd	2.25	2.42	3.38	3.39	2.03	1.65	3.00	2.41	2.51	2.15	2.33	3.15	3.34	2.00	3.77	2.49

Sb	1.13	1.91	1.65	1.58	1.52	0.99	1.29	2.06	2.03	1.54	0.93	1.34	1.48	1.27	0.74	1.41
Ba	75.6	65.3	48.3	41.3	340	67.2	36.8	62.3	69.6	50.3	25.4	93.8	104	38.6	23.3	40.1
Cs	1.40	1.16	2.06	1.43	1.58	0.89	1.89	0.77	2.67	2.21	2.05	2.61	1.84	0.71	1.16	1.17
La	3.89	3.56	1.91	2.13	3.87	2.95	1.59	3.52	3.07	3.16	1.18	5.06	7.68	2.32	0.95	1.82
Ce	8.37	7.32	4.46	3.77	8.26	6.63	3.57	7.98	6.22	5.53	2.25	10.8	18.3	4.08	2.35	3.91
Sm	0.75	0.56	0.32	0.34	0.65	0.48	0.27	0.59	0.54	0.51	0.16	0.72	1.01	0.32	0.13	0.25
Tb	0.10	0.10	0.06	0.07	0.11	0.07	0.05	0.1	0.26	0.22	0.07	0.15	0.53	0.05	0.03	0.1
Ta	0.14	0.11	0.05	0.06	0.16	0.08	0.05	0.09	0.13	0.09	0.03	0.15	0.17	0.06	0.03	0.05
Th	2.67	2.21	1.04	1.55	2.81	1.78	0.90	2.40	2.00	1.39	0.44	2.37	3.25	1.01	0.45	0.81
U	0.66	0.72	0.29	0.4	0.94	0.42	0.26	0.60	0.62	0.76	0.2	0.92	0.96	0.63	0.36	0.63

Extracted factors and possible pollution sources

The result of factor analysis of thirteen elements was extract three factors (FAx), that could explained more than eighty-four percent of the variability showed in Table III. Factor loading value characterizes the correlation of element with the related factor. Based on the obtained factor loadings, the main air pollution sources are suggested as follows.

Table III. Factor loading and the percentages, cumulative of the factors

Element	FA1	FA2	FA3
Al	**0.92**	-0.16	-0.02
Cl	0.04	-0.19	**0.94**
K	0.10	0.07	**0.95**
Sc	**0.94**	0.18	0.02
Ti	**0.92**	-0.2	0.09
Cr	**0.69**	0.13	0.03
Ni	**0.88**	0.05	0.26
Co	**0.93**	0.30	0.00
Zn	-0.01	**0.94**	0.08
As	**0.79**	**0.51**	0.17
Se	-0.02	**0.51**	**0.65**
Ba	0.26	**0.89**	-0.08
La	**0.83**	0.19	-0.14
% of expl.variance	48.8	19.5	16.5
% Cumulative	48.8	68.3	84.8

- Factor 1 (Al, Sc, Ti, Cr, Co, As, La) explains 48.8% of the total variance with factor loadings range from 0.69 to 0.94 has a typical crustal composition; it could be characterized local soil dust.

- Factor 2 (As, Se, Zn, Ba) explains 19.5% of the total variance with loadings range from 0.51 to 0.88 could be derived from vehicle emission and waste industry [9]. In Viet Nam in general and in Thua Thien Hue in particular, densed traffic in the cities could be one of main sources of Zn and Ba. The tire-wear particles have been recognized as a source of Zn to the environment [10]. Moreover, Ba and Zn could be released from lubricant used in vehicle engine[11].

- Factor 3 (Cl, Se, K) explains 16.5% of the total variance with factor loadings range from 0.65 to 0.95. This factor contains elements normally associated with the fuel combustion process, especially in the burned area containing a lot of chlorine [12]. The appearance of the element As in both factor 1 and factor 2 has also been confirmed in the previous work on the threat of arsenic pollution in Vietnam [13].

Checking suggested sources with pollution sources in the sampling locations

A factor score (FS) is a numerical value that indicates the contribution of corresponding sampling location on a latent factor. The obtained factor scores of sixteen sampling locations were listed in Table IV.

The sampling locations with high score of F1 (soil dust factor) are H1 (1.03), H9 (1.16), H12 (1.98) and H14 (1.43). These locations are situated in areas of many people and with high traffic ways around. Evidently, soil dust would be the dominant pollution source in these sites.

• High loadings of anthropogenic factor 2 are related to Zn and Ba. These two elements are mainly released in the air from different industrial sectors as confirmed by many previous studies. From Table IV that FS2 of H5 location in Hue has the highest factor score (3.43). This site is located inside Tu Ha – Huong Van industrial area where paper, plastic packaging and construction materials (cement, brick) are produced. Especially, there is the big Portland cement factory Luks operating for over twenty years in this area. These industrial activities should be the sources of high-level accumulation of the non-volatile metal Ba in the site [14].

• High scores of combustion factor 3 related to H1, H3, H4 locations in periphery city area. As reported by the local government in 2015, there are many households using traditional fuels as firewood, charcoal... for cooking and daily activities in this area. These activities should be the emission sources of Cl, K and Se.

Table IV. Factor score

	FS1	FS2	FS3
H1	**1.03**	-0.55	**1.49**
H2	-0.07	0.62	0.56
H3	-0.68	0.32	**1.60**
H4	-0.83	-0.17	**1.74**
H5	-0.07	**3.43**	-0.33
H6	-0.17	-0.43	-0.55
H7	-0.75	-0.4	0.75
H8	0.67	0.27	0.10
H9	**1.16**	-0.12	0.25
H10	0.26	-0.48	-0.53
H11	-0.94	-0.50	-1.03
H12	**1.98**	-0.76	-0.24
H13	**1.43**	0.01	-1.02
H14	-0.71	-0.24	-1.33
H15	-1.53	-0.95	-0.18
H16	-0.79	-0.03	-1.27

IV. CONCLUSION

This work demonstrates that the *Barbula* moss technique combined with INAA method and factor analysis could reasonably detect principal pollution sources and provide data to confront them with the present sources at the studied sites. By the study results, dominant pollution features of these sites in Thua Thien Hue from dust, the traditional fuel combustion, and the vehicle emission.

The purpose of this work is to study elemental atmospheric deposition in different sites in Thua Thien Hue Province of Vietnam and find out their potential sources; confirmed again the high potency of the methods to monitor atmospheric deposition in the area study.

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