

AIR POLLUTION IN CENTRAL AND SOUTHERN VIETNAM USING MOSS BIOMONITORING TECHNIQUE AND NEUTRON ACTIVATION ANALYSIS

- T.T. Doan Phan, Nha Trang Institute of Technology Research and Application, Vietnam
- H.K. Le, D.Q. Vu, Institute of Physics, Vietnam Academy of Science and Technology
- M.V. Frontasyeva, T.T.M. Trinh, Frank Laboratory of Neutron Physics, JINR, Dubna, Russia

VIETNAM LOCATION AND SOME FEATURES

- Southeast Asia country
- Climate: Sub-tropical in the north and tropical in the south

- Population: 94 millions (2016)
- Land Area: about 325 000 sq km

EXPERIMENT

Sampling

- **Used moss: *Barbula indica***
- **Moss sampling was carried out according to the Monitoring manual 2015 (UNECE ICP Vegetation)**

Analytical technique

- **NAA, in NAA Dept, FLNP-JINR, Dubna, Russia**
- **Factor Analysis was used to explain NAA obtained result**

Thirty-two moss samples used in this investigation were collected in the end of the rainy season of 2015 in 4 cities characterized as below:



HUE:

- ancient capital at coastline,
- tourist & traditional activities inside the city
- agricultural vicinity and mining activities in the surrounding

HOI AN:

- small, ancient, coastal
- tourist & traditional activities, agricultural vicinity

NHA TRANG:

- small, coastal
- tourist

HO CHI MINH CITY:

- large economical city
- light industrial activities
- high traffic

RESULT

- **28 elements (including Cd and Cr),** were determined in the moss *Barbula indica* by ENAA with the error range of **4 to 15%**
- The obtained concentrations of **19 selected elements** with the errors of about from 3% to 10 %, except for Cr and Cd (up to 14%) were **subjected to factor analysis** to reveal possible pollution sources of the studied sites.

These are some main features of pollutants in the studied areas

Hue

- The highest concentration and highest median concentration of Se, Cd, Sb (and high Cl content)
- The highest concentration of Ba found in the site Hu-N4

Hoi An

- The same structure of pollution as in Hue with a smaller size
- The highest median concentration of Zn

Nha Trang

- The cleanest area of four cities with low levels of pollutants

Ho Chi Minh City

- High or highest concentrations of potential contaminants associated with urban and different light industrial sectors (Ti, Cr, Fe, Ni, Co, Zn, Ba)

FACTOR ANALYSIS

Five main factors were extracted using FA with a Varimax rotation, that explained more than 81% of variability

% of expl. variance of the factors					%
Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Cumulative
41.1	14.5	12.9	7.4	5.8	81.8

- Factor 1 (*Sc, Ti, Cr, Fe, Co, As, Ba, La, Ce*) could characterize local soil dust.
- Factor 2 (*Cl, Se, Cd, Sb*) could associate with the fuel combustion process.
- Factor 3 (*Al, Ca, Ti, V, Cr, Sb*) could relate to atmospheric transport.
- Factor 4 (*Mg, Cl, Ca, As*) could relate to water and sea environment.
- Factor 5 (*Zn, Ba*) could be derived from local human activities.

Factor scores

- **Factor score is used to estimate ability or the suggested source in a site; the more involved a factor, the higher the score weight.**
- **In the following slides the possible sources revealed by factor scores will be confront to the real sources presented in the site**

Sites	Factor1	Factor2
Hu_S4	0.68	1.13
Hu_S3	0.14	1.56
Hu_S2	-0.64	1.52
Hu_S1	-0.61	1.58
Hu_N4	1.41	1.18
Hu_N3	-0.17	-0.07
Hu_N2	-0.83	0.94
Hu_N1	0.06	1.42
Hu_E4	0.08	1.14
Hu_E3	-0.34	0.33
Hu_E2	-1.41	-0.56
Hu_E2/	0.12	-0.06
Hu_E1	0.65	0.63
Hu_W4	1.60	1.12
Hu_W3	-1.00	-0.29
Hu_W2	-1.49	0.21
Hu_W1	-1.14	-0.20
HA1	-1.28	-0.57
HA2	-0.94	-0.84
HA3	0.42	0.19
HA4	0.65	0.30
HA7	-0.83	-0.37
HA9	1.74	-0.52
HA10	-0.86	0.27
HCM1	-0.60	-1.00
HCM2	0.88	-1.31
HCM3	1.84	-1.13
HCM4	0.99	-1.39
HCM5	-0.46	-1.46
HCM6	1.91	-0.95
NT1	0.08	-1.12
NT2	-0.65	-1.67

High scores of Factor 1 relate to high population sites, with high traffic ways around in Hue, Hoi An and Ho Chi Minh city

High scores of Factor 2 reflects the routine use of traditional fuel combustion (firewood, charcoal...) in Hue and the vicinity



Sites	Factor 3	Factor 4
Hu_S4	0.43	0.53
Hu_S3	-0.24	0.03
Hu_S2	-0.51	0.44
Hu_S1	-0.65	0.88
Hu_N4	-2.31	-0.89
Hu_N3	-0.11	-0.22
Hu_N2	-0.30	0.13
Hu_N1	1.04	-0.19
Hu_E4	1.33	-0.94
Hu_E3	0.58	-0.07
Hu_E2	0.24	-0.49
Hu_E2/	0.46	-0.18
Hu_E1	1.53	-0.31
Hu_W4	0.50	-0.90
Hu_W3	0.39	-0.98
Hu_W2	-0.35	0.12
Hu_W1	0.08	-0.33
HA1	-0.88	0.85
HA2	-0.55	-0.67
HA3	0.14	-0.50
HA4	-0.18	0.84
HA7	-1.08	-0.22
HA9	0.00	3.95
HA10	-0.99	0.89
HCM1	3.73	0.65
HCM2	-0.56	0.20
HCM3	0.04	-0.12
HCM4	0.02	-1.17
HCM5	-0.43	-1.04
HCM6	-0.33	-1.22
NT1	-0.58	-0.60
NT2	-0.46	1.55

High scores of Factor 3 show that a lot of Hue sites are polluted by atmospheric transport coming from mining activities surrounding.

The highest score corresponds to the peculiar site HCM1 located between several big garages in Ho Chi Minh City



Gold exploitation in Hue



Titanium factory in Hue

High and M in the biggest Bon r



estuary of Thu Bon river

Hoi An locations with the of Thu

Sites	Factor 5
Hu_S4	-1.10
Hu_S3	0.08
Hu_S2	0.27
Hu_S1	-0.21
Hu_N4	3.08
Hu_N3	-0.76
Hu_N2	-0.52
Hu_N1	0.03
Hu_E4	-0.05
Hu_E3	-0.59
Hu_E2	-0.05
Hu_E2/	-1.30
Hu_E1	-1.00
Hu_W4	-1.21
Hu_W3	-0.11
Hu_W2	-0.69
Hu_W1	0.29
HA1	0.31
HA2	-0.20
HA3	0.96
HA4	0.48
HA7	0.31
HA9	-0.09
HA10	0.86
HCM1	2.98
HCM2	0.03
HCM3	-0.39
HCM4	-0.79
HCM5	0.54
SG6	0.66
NT1	-1.06
NT2	-0.78

The anthropogenic Factor 5 associates with Zn and Ba.

- The tire-wear particles have been recognized as a source of Zn to the environment; besides, a composition of Ba and Zn is released from lubricant used in vehicle engines. Consequently, the condense traffic in Vietnamese cities could be one of main sources of Zn and Ba there.



Sites	Factor 5
Hu_S4	-1.10
Hu_S3	0.08
Hu_S2	0.27
Hu_S1	-0.21
Hu_N4	3.08
Hu_N3	-0.76
Hu_N2	-0.52
Hu_N1	0.03
Hu_E4	-0.05
Hu_E3	-0.59
Hu_E2	-0.05
Hu_E2/	-1.30
Hu_E1	-1.00
Hu_W4	-1.21
Hu_W3	-0.11
Hu_W2	-0.69
Hu_W1	0.29
HA1	0.31
HA2	-0.20
HA3	0.96
HA4	0.48
HA7	0.31
HA9	-0.09
HA10	0.86
HCM1	2.98
HCM2	0.03
HCM3	-0.39
HCM4	-0.79
HCM5	0.54
SG6	0.66
NT1	-1.06
NT2	-0.78

• However, the sites with the highest scores of factor 5 could connect to peculiar pollutions such as:

- The site HCM1 in Ho Chi Minh city with the highest concentration of Zn could relate to big garages in the vicinity;
- The site HA3 in Hai An with high concentration of Zn locates



CONCLUSION

- This work demonstrates that the *Barbula indica* moss technique combined with *NAA* method and *Factor Analysis* could reasonably detect main pollution sources presented in the studied areas.
- Hue and Ho Chi Minh city are two high contaminated cities with two different structures of pollution caused by the traditional fuel combustion and by industrial sectors; respectively. Nha Trang is the cleanest one of the four cities.
- The purpose of this work is to study elemental air pollution in different cities in Vietnam and find out their potential sources. Ability to compare this result with the ones using other moss species was not examined.

**THANK YOU FOR
YOUR ATTENTION!**