Department of Neutron Activation Analysis & Applied Research
Division of Nuclear Physics
Frank Laboratory of Neutron Physics
Joint Institute for Nuclear Research

NEUTRON ACTIVATION ANALYSIS FOR AIR POLLUTION STUDIES

Marina Vladimirovna Frontasyeva

marina@nf.jinr.ru

Ostrava, Czech Republic, September 2017,

International Intergovernmental Organization

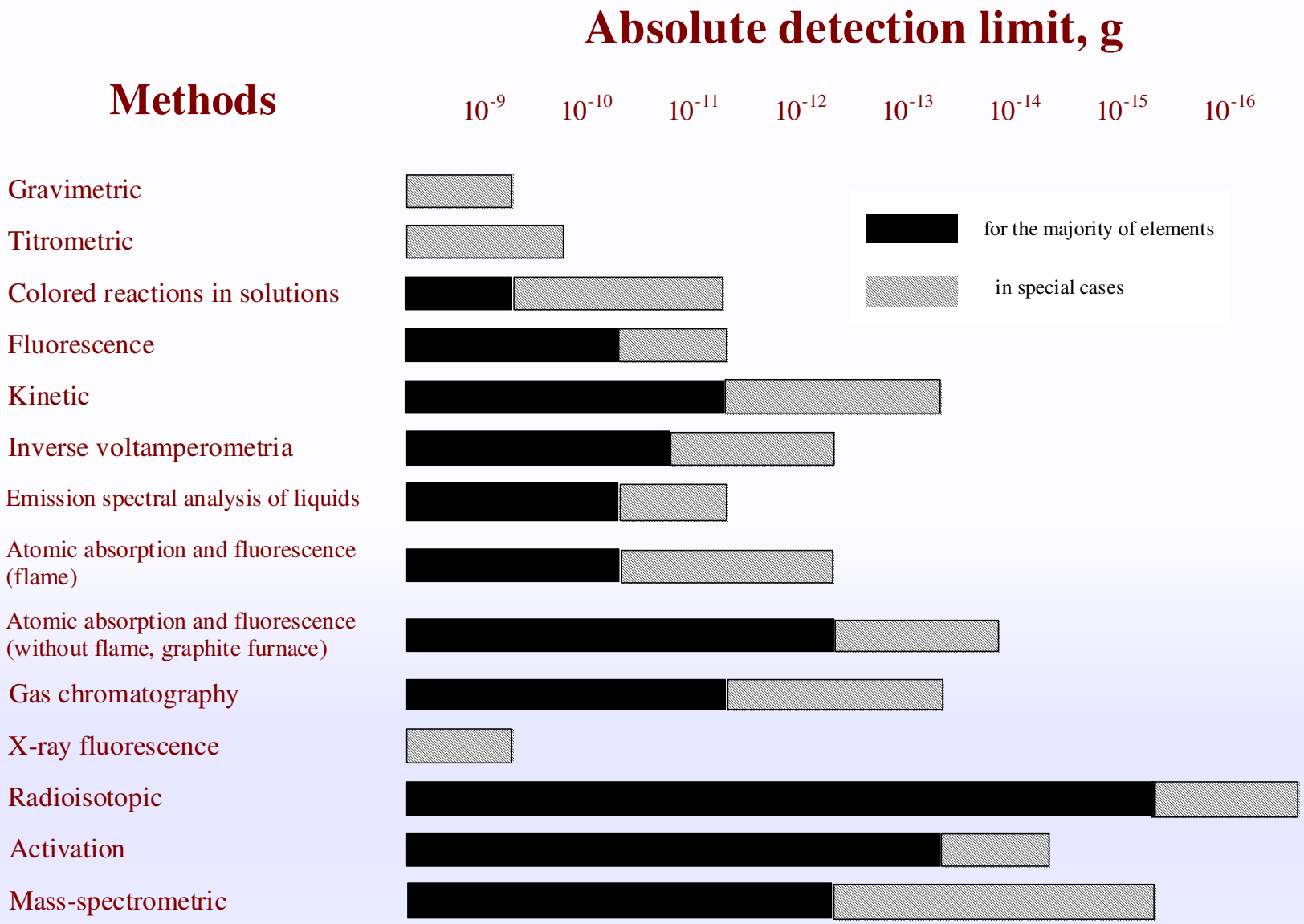
Armenia
Azerbaijan
Belarus
Bulgaria
Cuba
Czech Republic
Georgia
Kazakhstan
D. P. Republic of Korea
Moldova
Mongolia
Poland
Romania
Russian Federation
Slovakia
Ukraine
Uzbekistan
Vietnam

Participation of Egypt, Germany, Hungary, Italy, the Republic of South Africa and Serbia in JINR activities is based on bilateral agreements signed on the governmental level.

Neutron activation analysis is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content

P. Bode, J. J. M. de Goeij, '***Activation Analysis***', Encyclopedia of Environmental Analysis and Remediation, J. Wiley & Sons, New York, **1998**, ISBN 0-471-11708-0, pp 68–84

The method is based upon the conversion of stable atomic nuclei into radioactive nuclei by irradiation with neutrons and the subsequent detection of the gamma radiation emitted during the decay of these radioactive nuclei. Activation by neutrons may result in radionuclides from all elements (that have radioactive daughter products) present in the sample, with sometimes strongly different production rates


Absolute detection limit, g
Methods
10-9
10-10
10-11
10-12
10-13
10-14
10-15
10-16
Gravimetric
Titrometric
Colored reactions in solutions
Fluorescence
Kinetic
Inverse voltamperometria
Emission spectral analysis of liquids
Atomic absorption and fluorescence (flame)
Atomic absorption and fluorescence (without flame, graphite furnace)
Gas chromatography
X-ray fluorescence
Radioisotopic
Activation
Mass-spectrometric
for the majority of elements
in special cases

Metrology in Chemistry
63, No. 10 1

2007

CHIMIA **2009**,

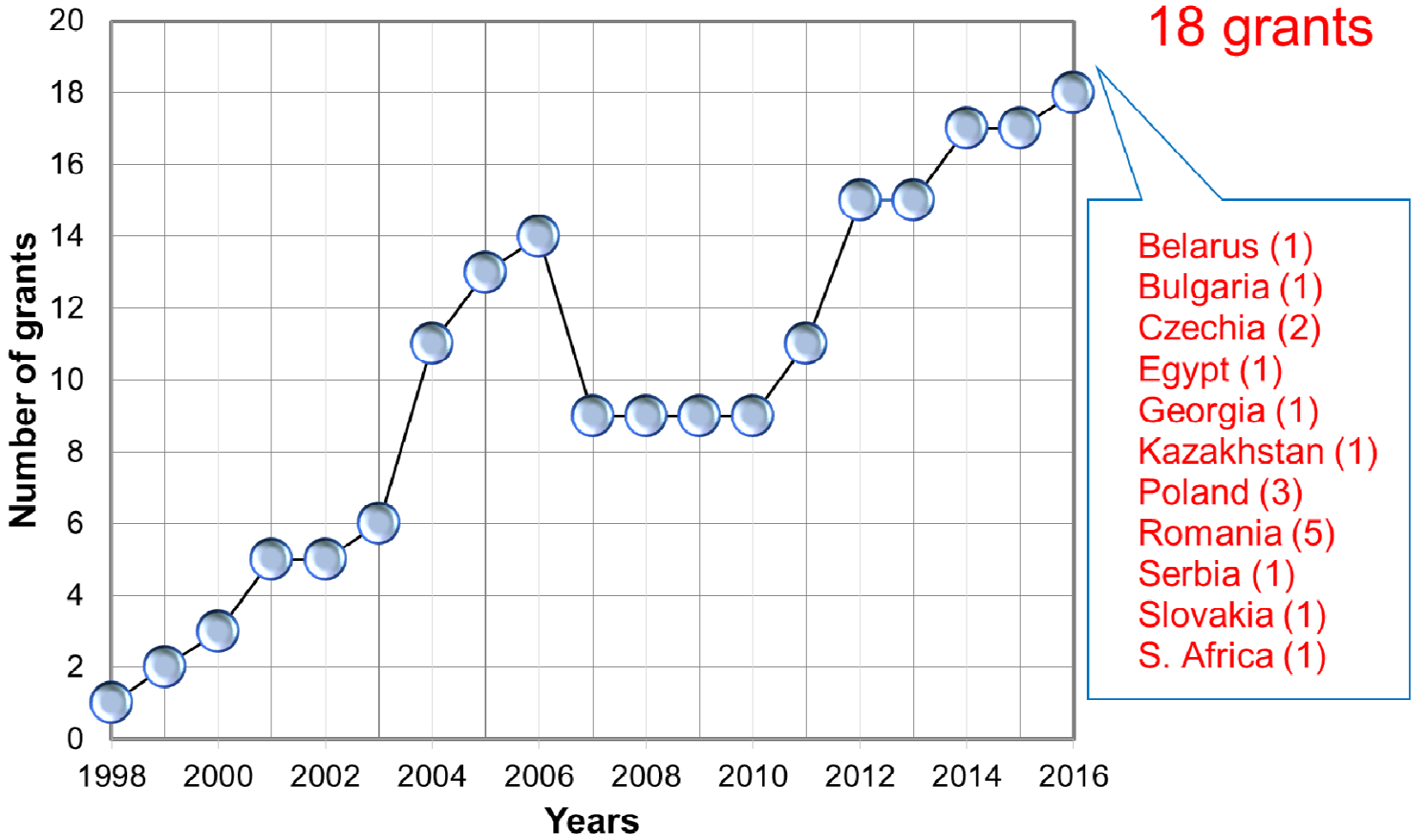
Neutron Activation Analysis: A Primary (Ratio) Method to Determine SI-Traceable Values of Element Content in Complex Samples

Peter BODE
Delft University of Technology
The Netherlands

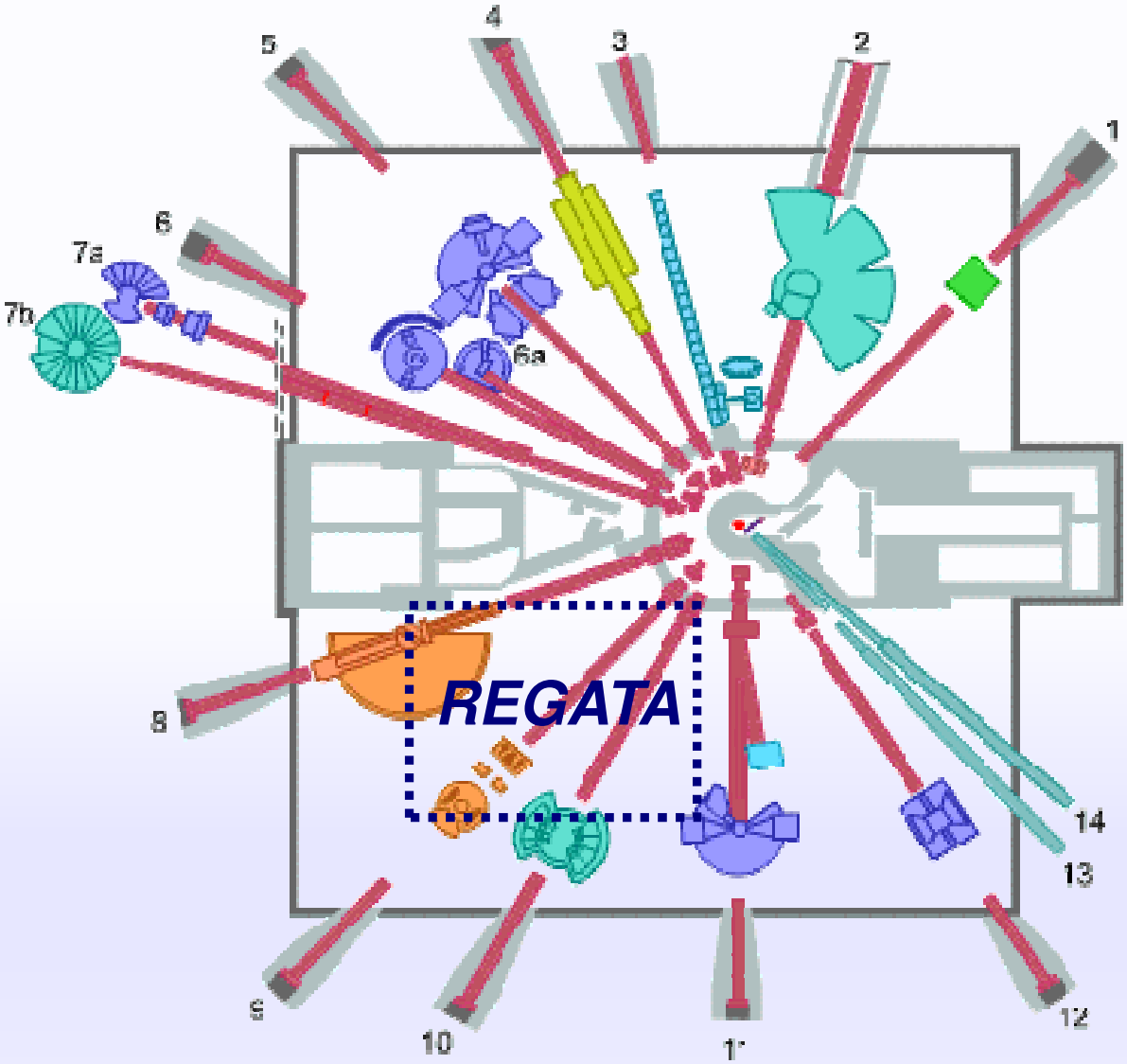
Robert GREENBERG
National Institute of Standards and Technology, NIST
USA

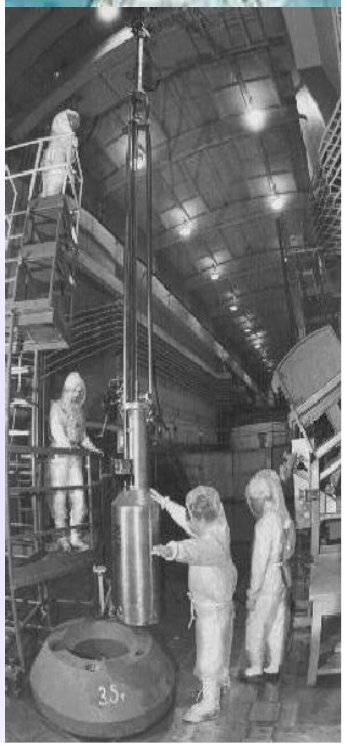
Elisabete FERNANDES
Univer. de Sao Paulo Centro de Energia Nuclear na Agricultura
Brazil

Grants of Plenipotentiaries of JINR member-states

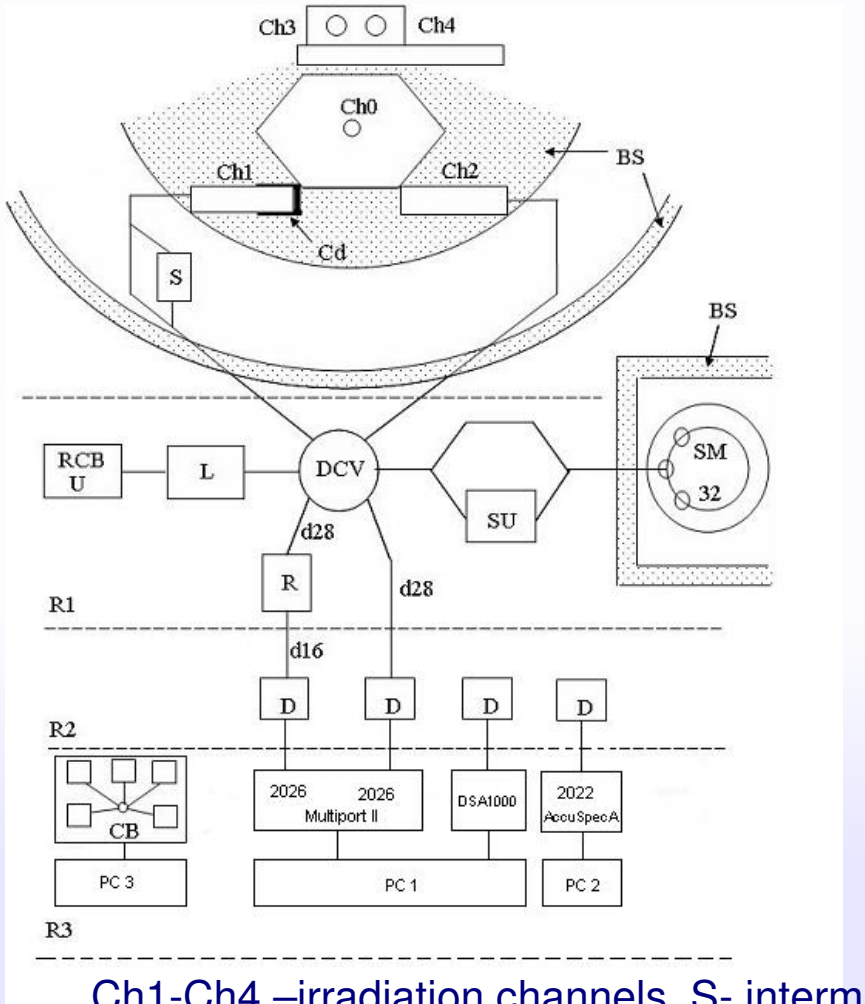


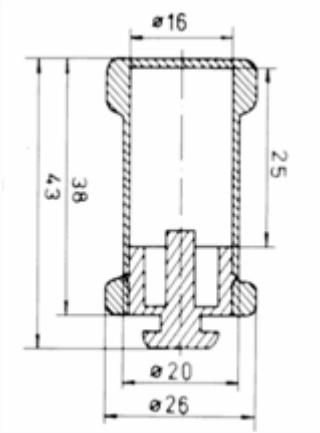
IBR-2 Pulsed Fast Reactor and Radioanalytical complex REGATA





Experimental facility REGATA at IBR-2 reactor

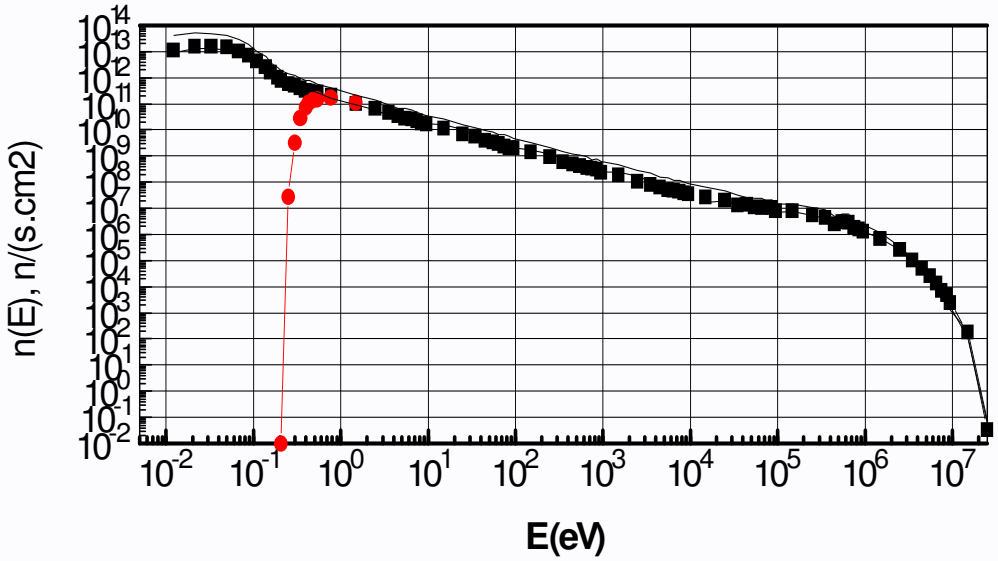




Transport capsules for irradiation

Ch1-Ch4 –irradiation channels, S- intermediate storage, DCV- directional control valves, L- loading unit, RCB- radiochemical glove-cell, U- unloading unit, SU- separate unit, SM- storage magazine, R- repacking unit, D- detector, CB- control board, R1-R3- the rooms where the system is located.

Neutron energy spectra and irradiation channels



Neutron energy spectra in irradiation channels CH1(■) and CH2 (curve)

The main characteristics of the irradiation channels at 1.5 MW

Irradiation site	Neutron flux density (n/cm^2 s) 10^{12}			T ^{0}C	Channel diam., mm	Channel length, mm
	Thermal	Resonance	Fast			
Ch1	Cd-coated	3.31	4.32	70	28	260
Ch2	1.23	2.96	4.1	60	28	260
Ch3	Gd-coated	7.5	7.7	30-40	30	400
Ch4	4.2	7.6	7.7	30-40	30	400

NAA + AAS

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	*Cu*	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	*Cd*	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	*Pb*	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs

*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw

NAA ~ 55 elements

~ 55 elements

IAEA
International Atomic Energy Agency

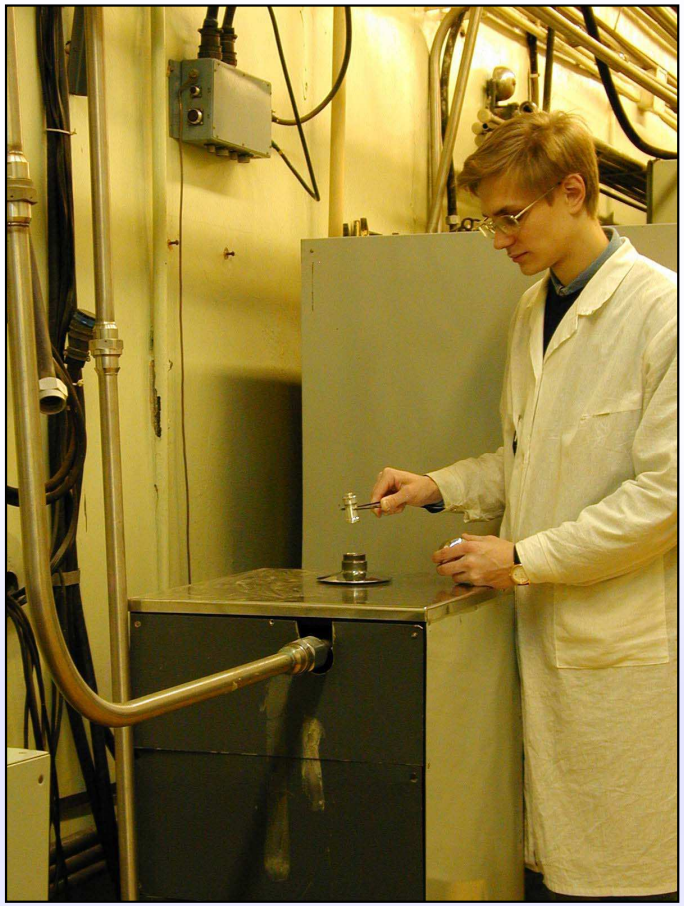
TITLE OF RESEARCH CONTRACT:

Automation of Reactor Neutron Activation Analysis

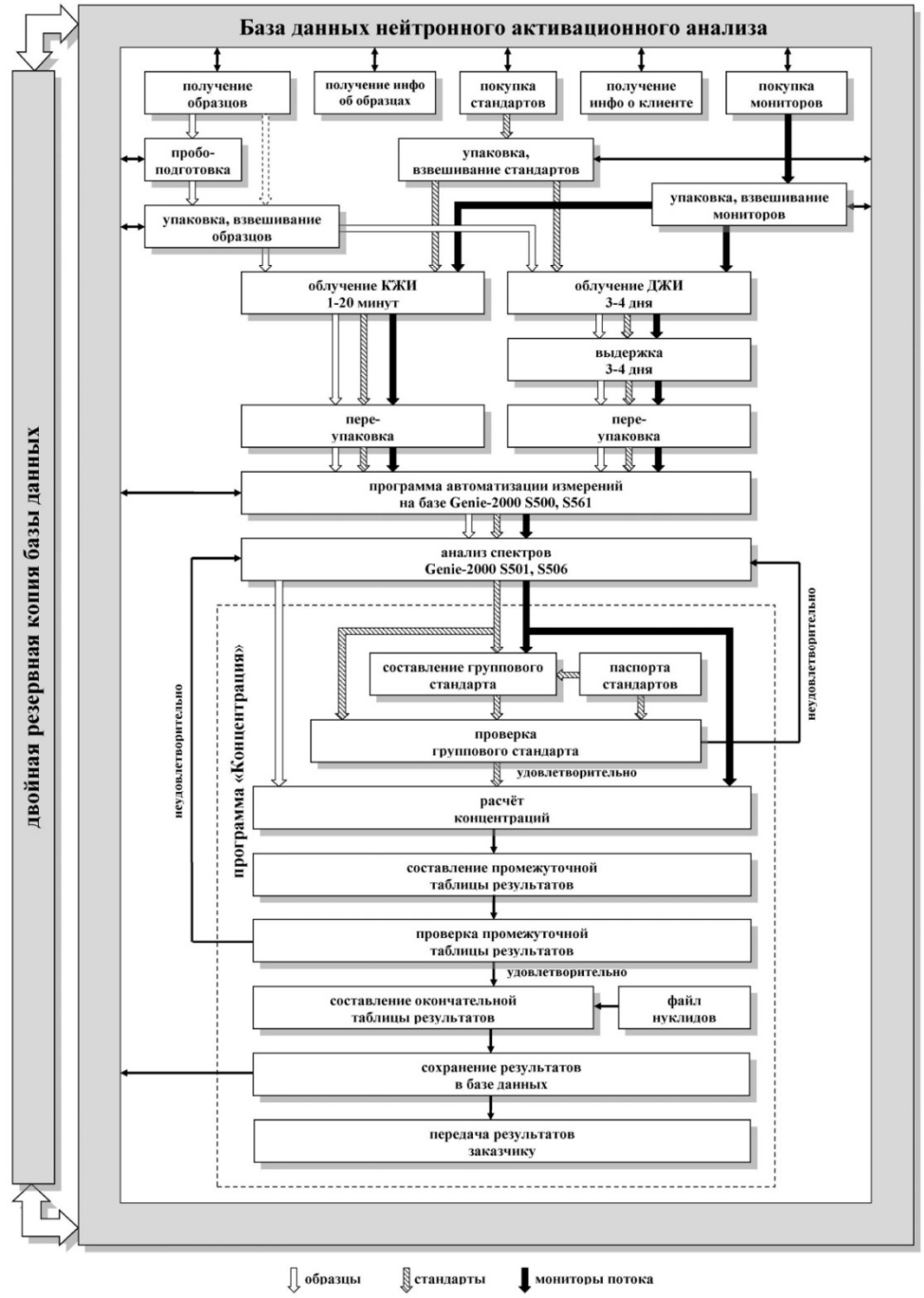
Part of the IAEA's Coordinated Research Project (CRP):

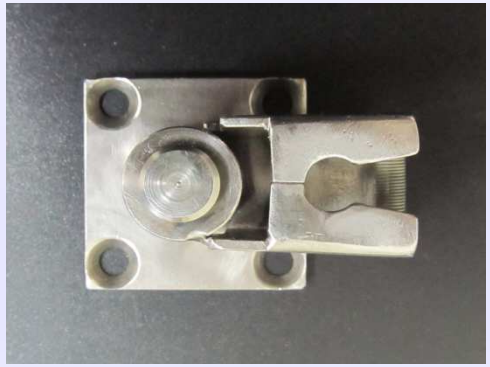
Development of an Integrated Approach to Routine Automation of Neutron Activation Analysis
(Ref. F1.20.25 / CRP1888)

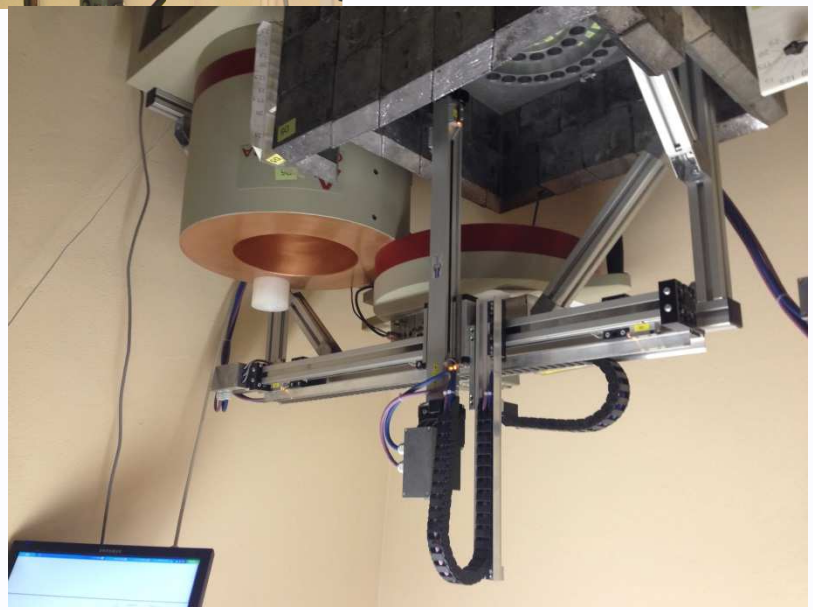
Hot-cells and loading of containers with samples for irradiation

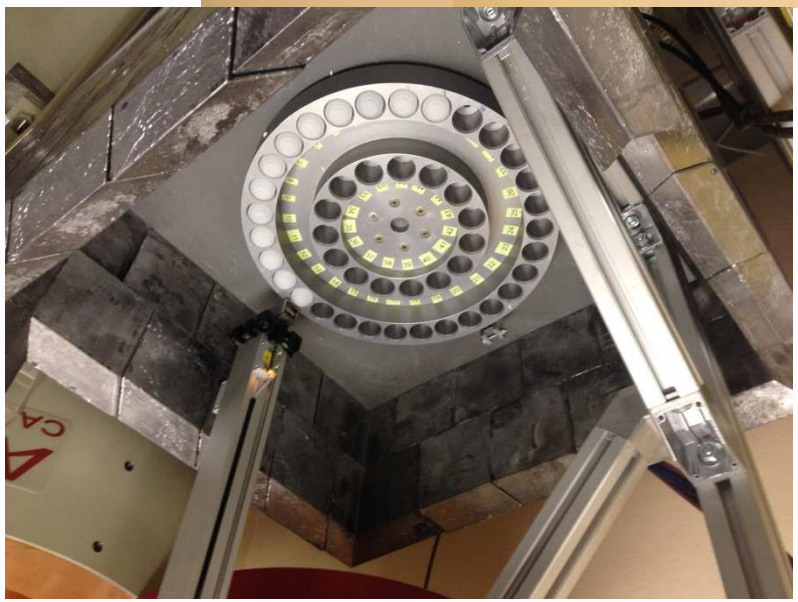


NAA DATABASE



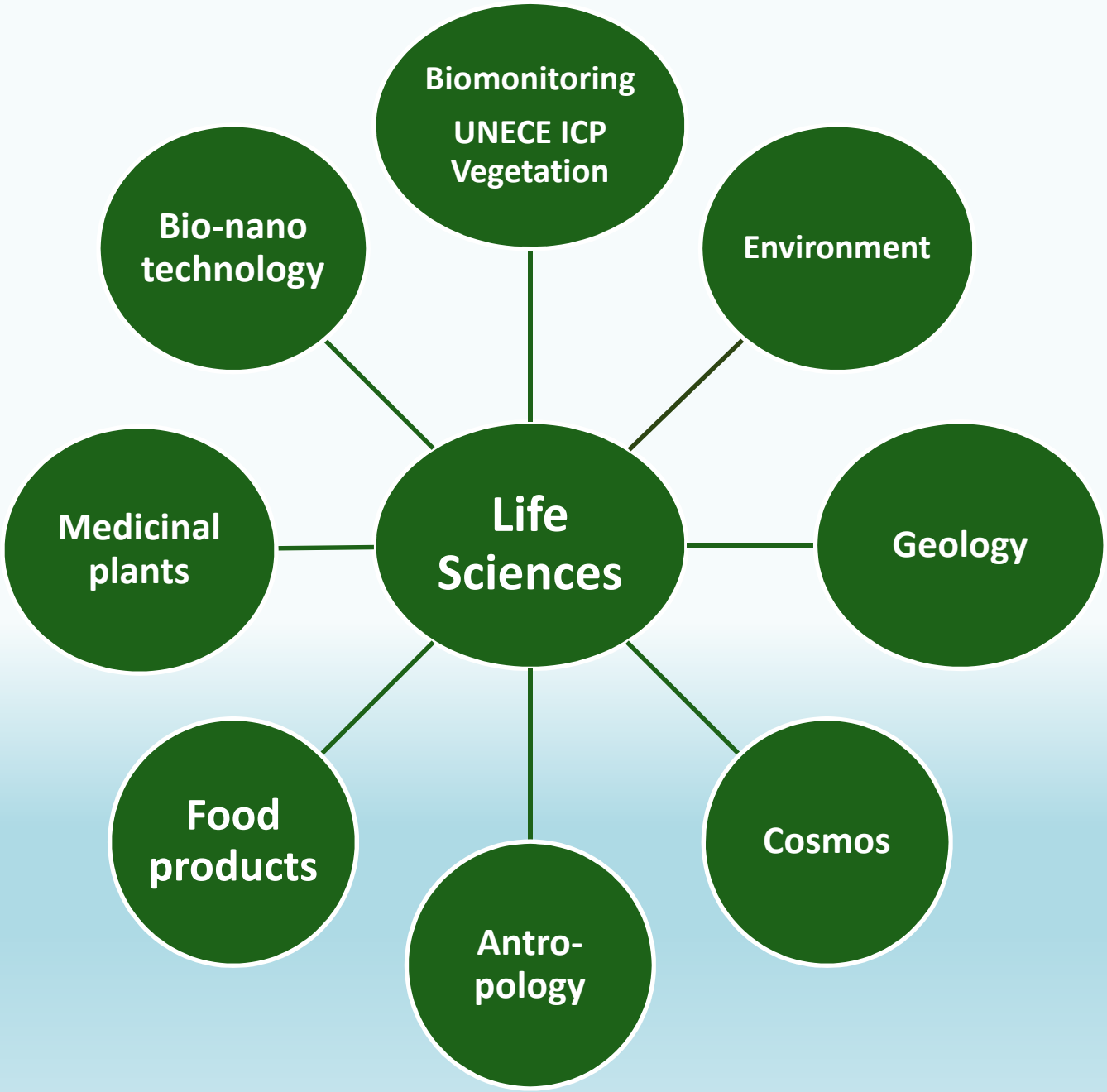






Chemical laboratory of Dept. NAA & Applied Research

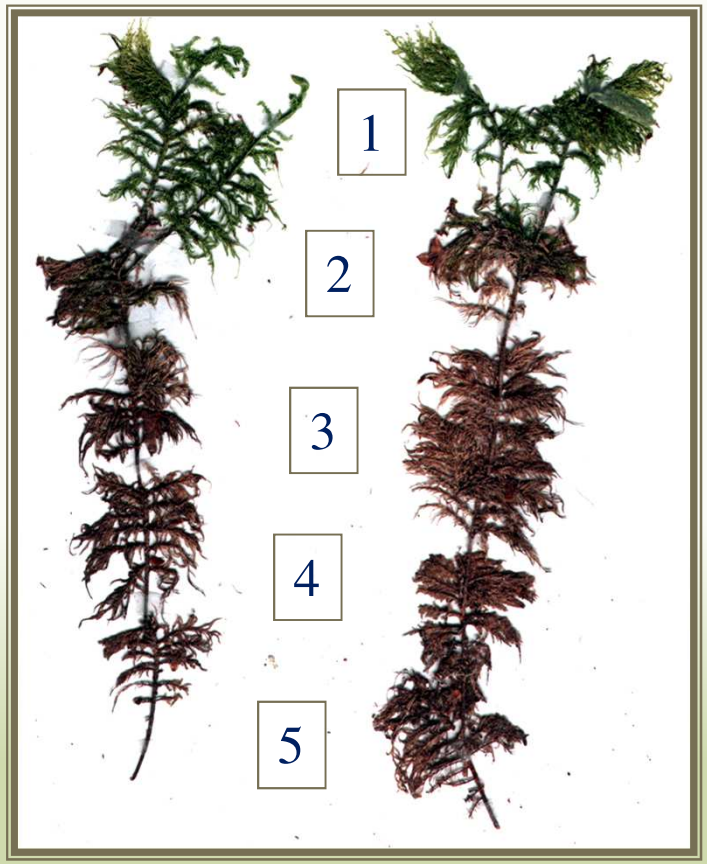
and some equipment for sample preparation


Biomonitoring
UNECE ICP Vegetation
Bio-nano technology
Environment
Medicinal plants
Life Sciences
Geology
Food products
Antro-pology
Cosmos

Air pollution studies

based on moss analysis

Moss biomonitor



Annual segments

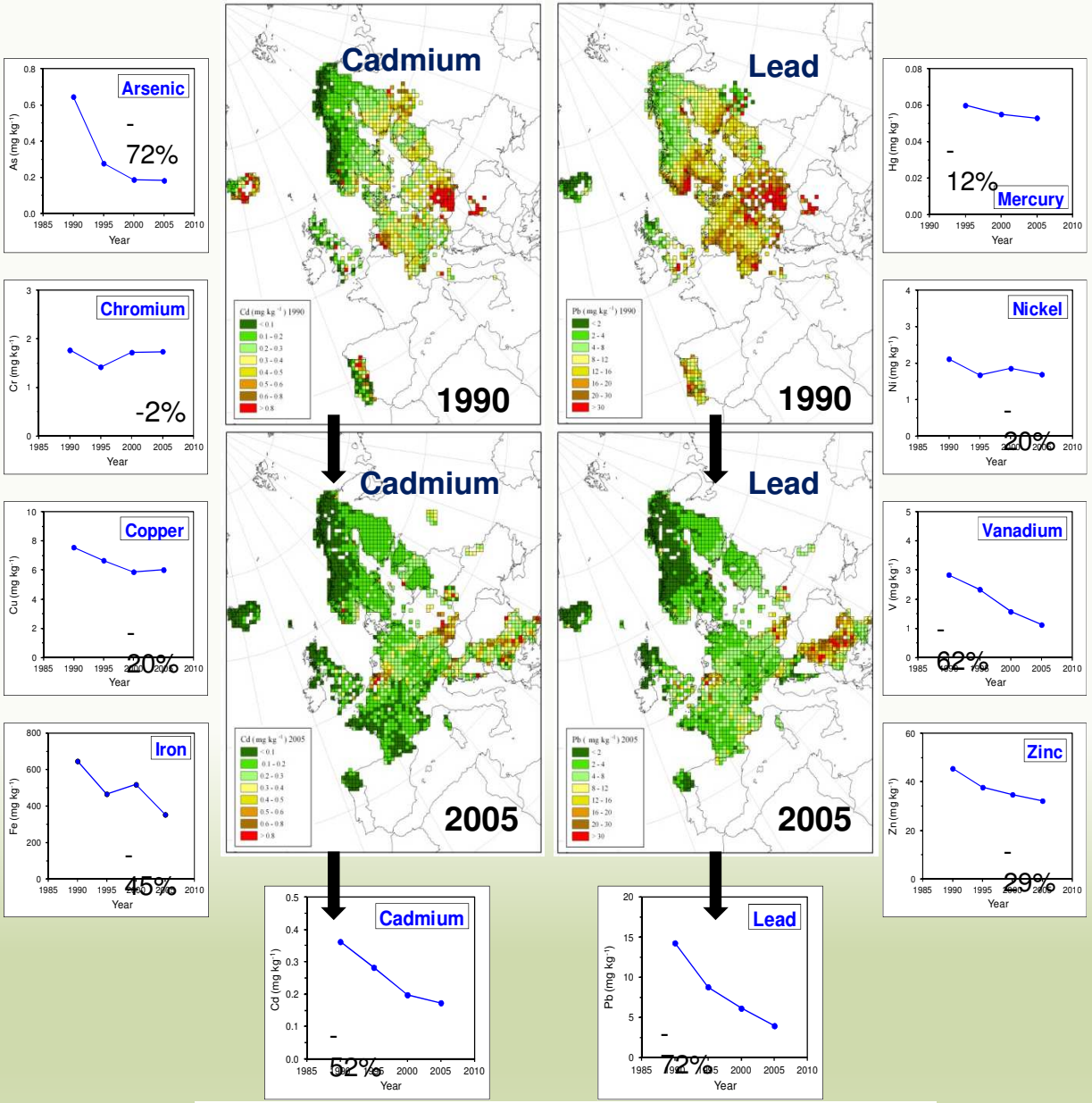
Inna Vikhrova, teacher of physics,
Livceum No. 8, Tikhvin,
Leningradskaya Region

UNECE

United Nations Economic Commission for Europe

International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops

Working **G**roup on **E**ffects - 1981



ICP Vegetation Programme Coordination Centre

Mosses provide a complementary method to assess **spatial patterns** and **temporal trends** of atmospheric heavy metal deposition:

- Carpet forming mosses receive trace elements and nutrients mainly from the atmosphere.
- In recent years, the lowest concentrations of heavy metals in mosses were found generally in northern Europe and the highest concentrations in Belgium and eastern Europe .
- Europe-wide the concentration in mosses of **arsenic, cadmium, lead and vanadium has declined** the most between 1990 and 2010, with hardly any reduction being observed for **chromium and mercury.**
- Temporal trends were country-specific.
- Spatial patterns and temporal trends for cadmium and lead agree quite well with those modelled by the **European Monitoring and Evaluation Programme (EMEP)**.

wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

HM – N – POPs – RN – CD

- Heavy Metals (~1970)
- Nitrogen (1980-…)
- Persistent Organic Pollutants (2010)
- Radionuclides (1980 - 2015)
- Cosmic Dust (?)

Project REGATA

(1995-2000-2005-2010-2015-2020)

Title

Heavy metal atmospheric deposition study in selected European and Asian countries using nuclear and related analytical techniques

Participating countries:

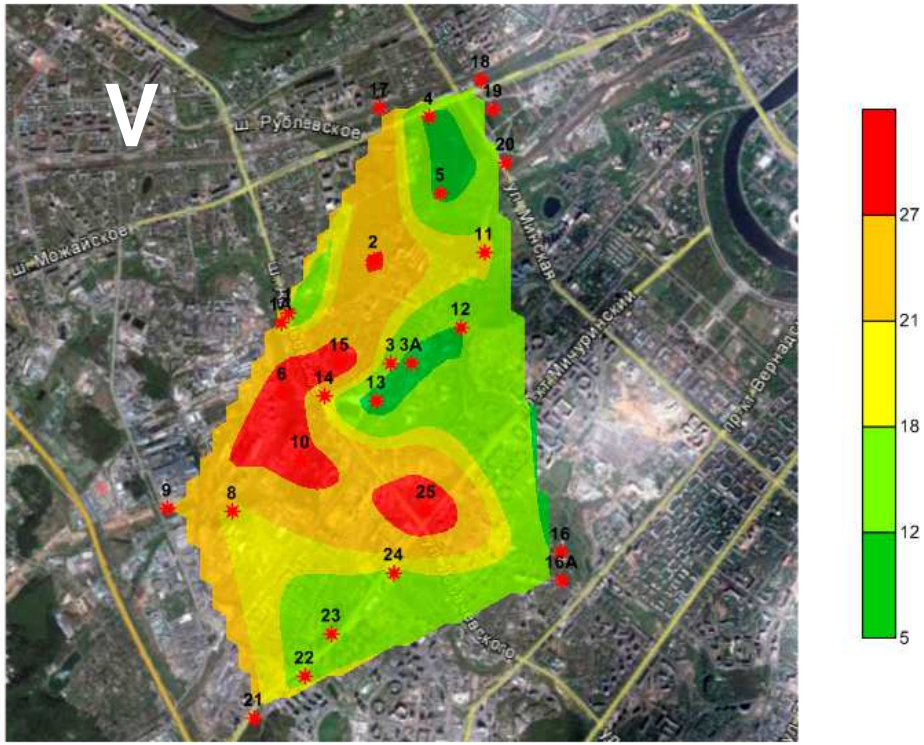
Russia, Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Georgia, Poland, Romania, Slovakia, Greece, Kazakhstan, Macedonia, Moldova, Serbia, Croatia, Albania, Turkey, Mongolia, Vietnam, South Korea, Thailand

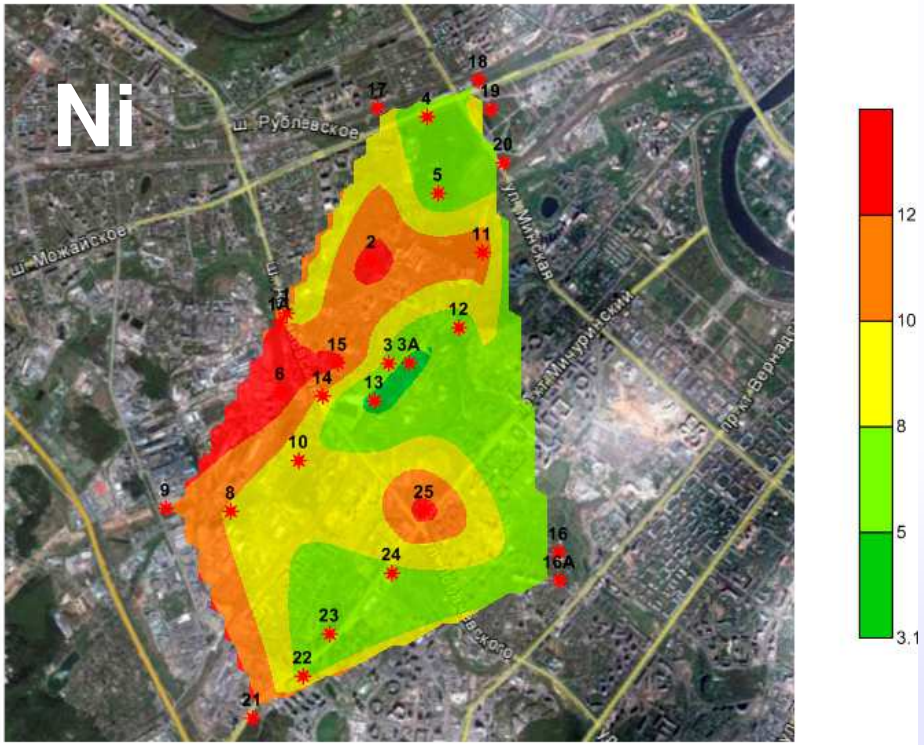
Химкинское водохранилище
Красногорск
Одинцово
Люберцы
Москва
Москва
Звенигородское ш.
Щелковское ш.
ш. Энтузиастов
Волгоградский просп.
Севастопольский просп.
Люблинская ул.
Варшавское ш.
Мира просп.
МКАД Внутренняя Сторона
Боровское ш.
A106
M9
A105
M1
M3
M7
P105
A102
17
19
18
4
20
11
5
11A
1
1A
6
3
3A
12
14
2
7
8
9
13
25
10
16
22
24
16A
21
23
27
Image © 2012 GeoEye
© 2012 GIS Innovatsia
Google earth
Дата съемки: 7.5.2010
55°43'29.03" С 37°36'20.71" В Высота над уровнем моря: 133 м
Высота камеры над уровнем моря: 41.08 км

Thermal power plant in Moscow

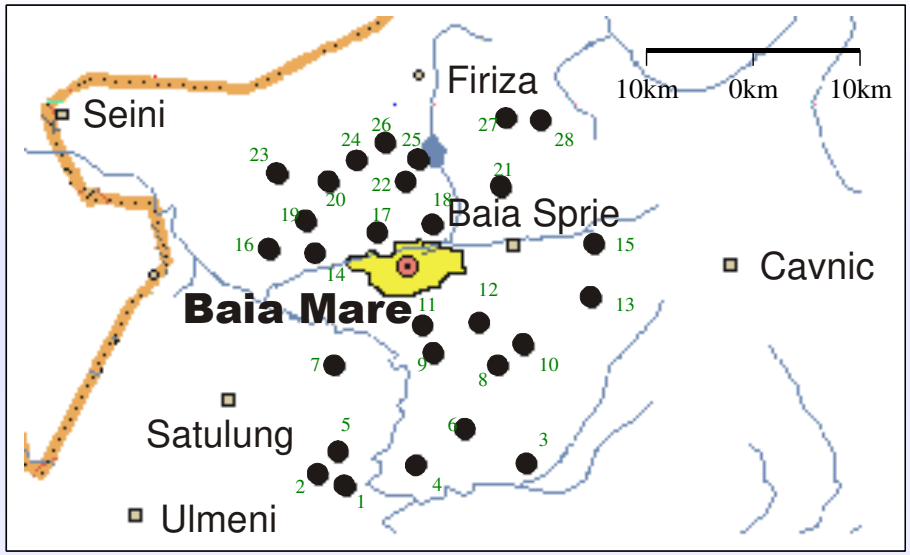
Olga Kapturova and Alexandra Volokhova, school No. 814, Moscow

Thermal power plant in Moscow

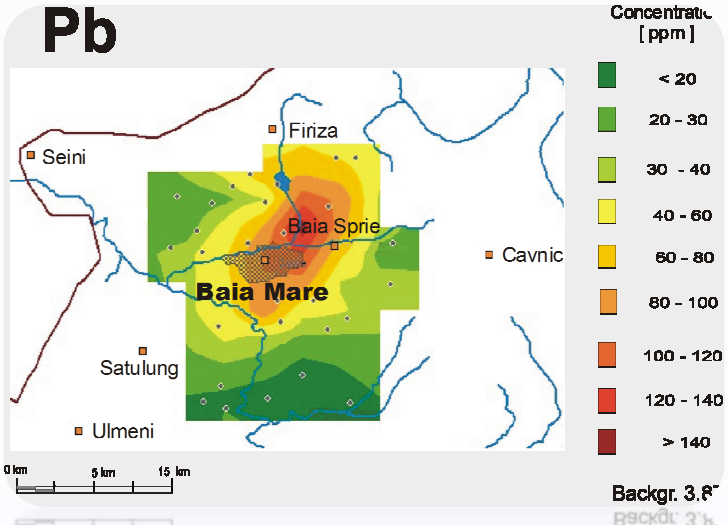


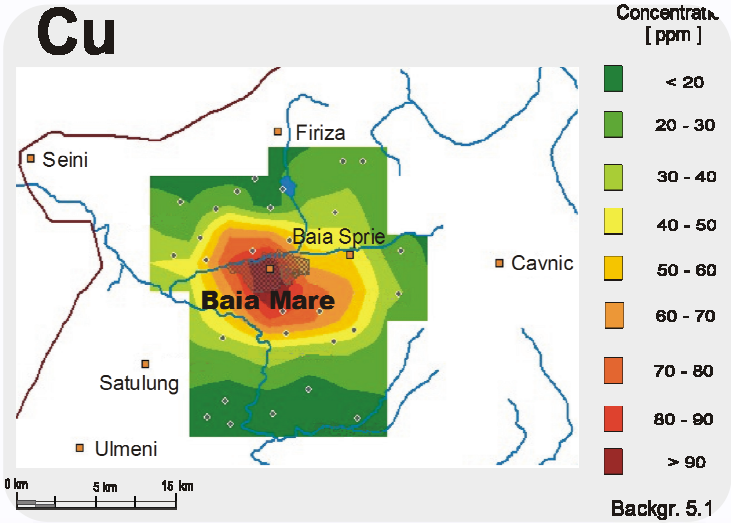


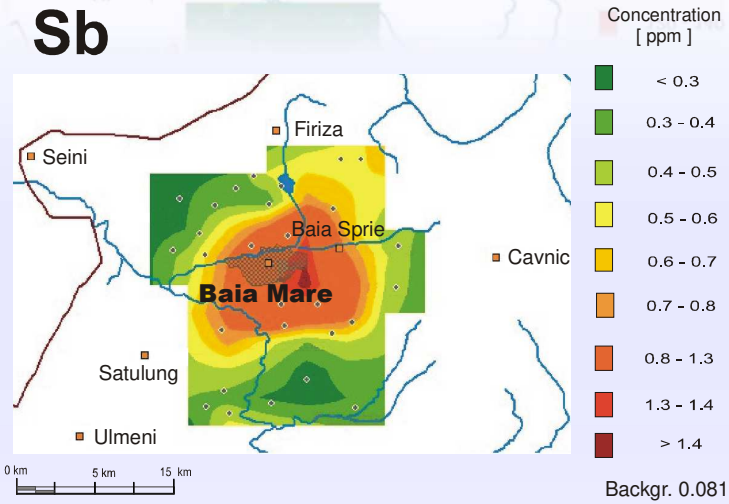
Pb-Zn smelters: Baia Mare (RO)

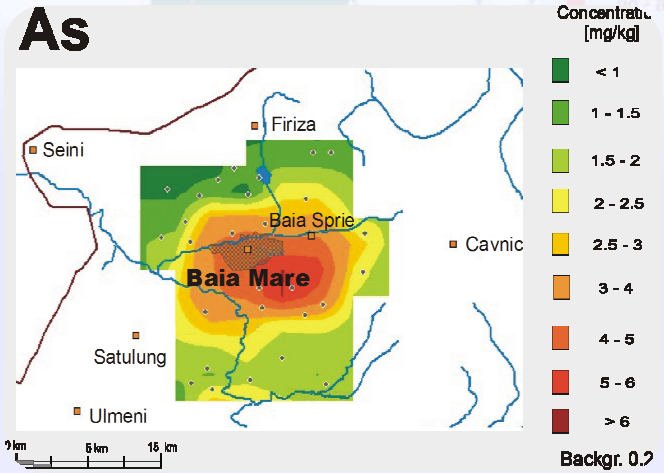


Zn-Pb smelter: Baia Mare (RO)

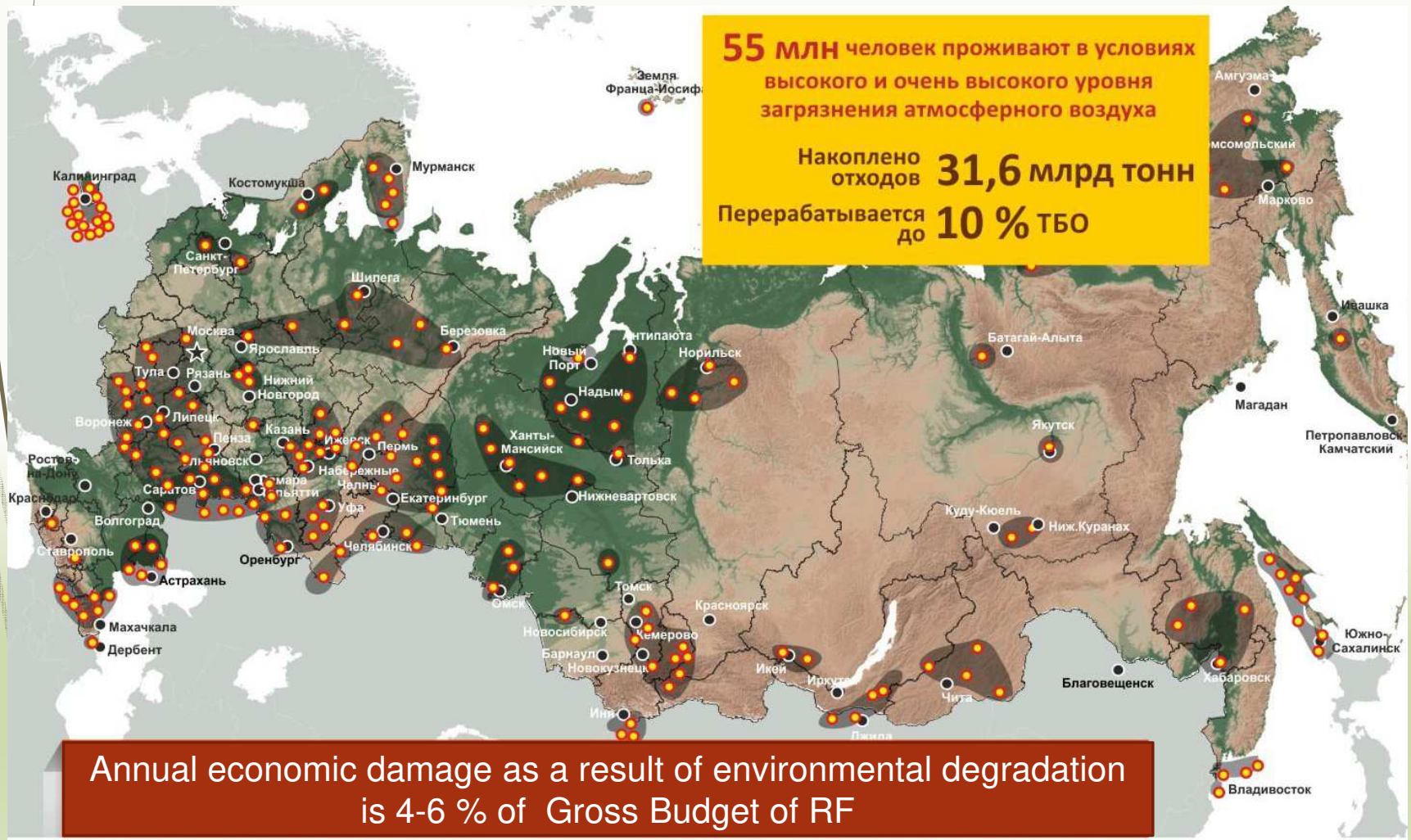








From the State Program of the Russian Federation "Protection of the Environment" for 2012-2020

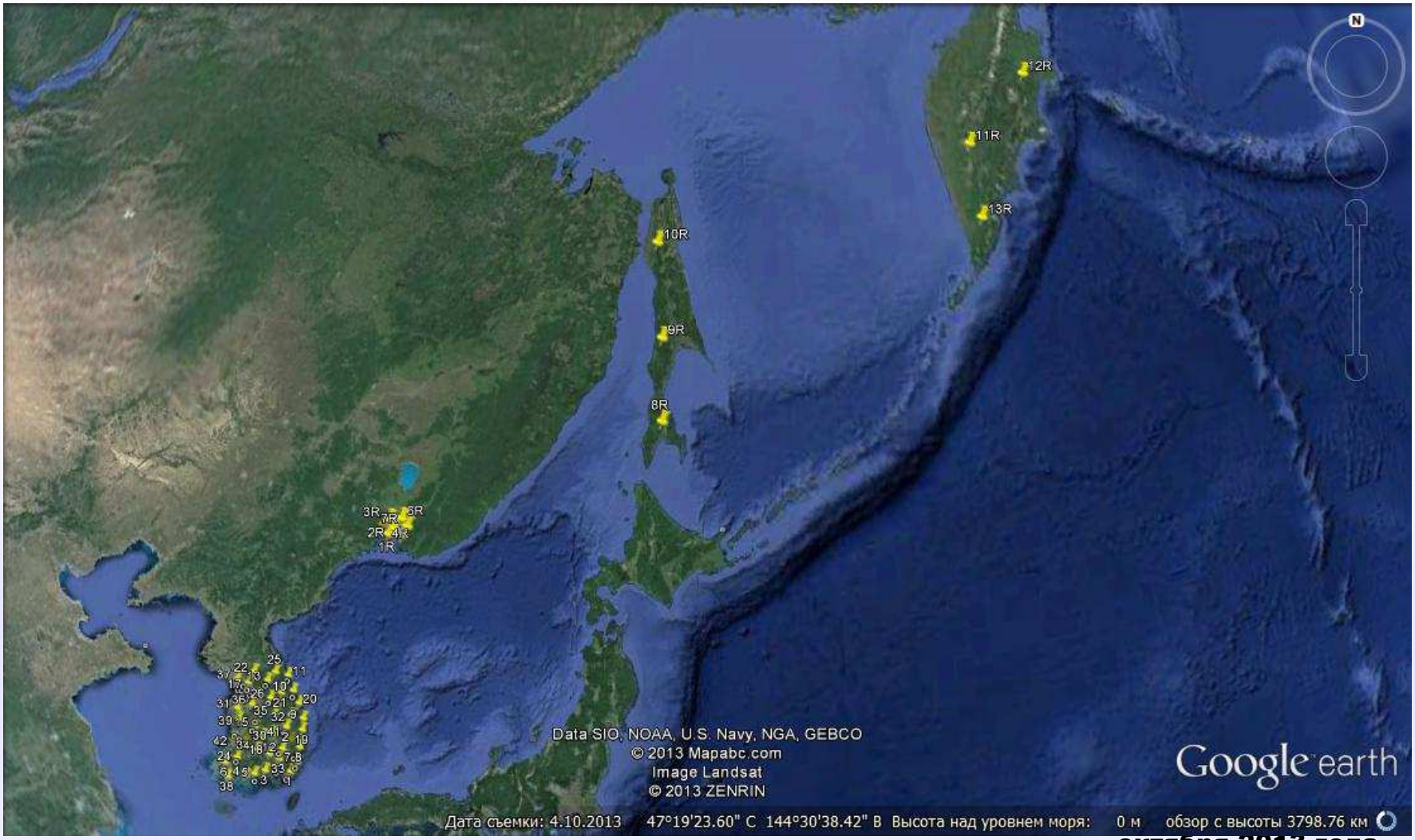


Russian Federation

Long-lived radionuclides in the Far East of RF and South Korea

The moss technique is supposed to be used for assessing sequences of the Fukushima disaster in the Far East of the Russian Federation and entire territory of South Korea

Long-lived radionuclides in the Far East of RF and South Korea



октября 2013 года

International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops

http://icpvegetation.ceh.ac.uk/

http://icpvegetation.ceh.ac.uk/publications/documents/Finalmossreportwithmaps_110708_proofedits_180708_highquality.pdf

http://icpvegetation.ceh.ac.uk/research/heavy_metals.html

Moss survey protocol

http://icpvegetation.ceh.ac.uk/manuals/moss_survey.html

Presentations by Marina V. Frontasyeva:

http://icpvegetation.ceh.ac.uk/events/documents/Frontasyeva.pdf

http://icpvegetation.ceh.ac.uk/events/documents/Frontasyeva_000.pdf

WEEKLY CYCLES OF ELEMENT POLLUTANTS IN AIR OF THE GREATER CAIRO AREA (EGYPT) STUDIED BY NEUTRON ACTIVATION ANALYSIS

Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia
National Center for Nuclear Safety and Radiation Control, Cairo, Egypt

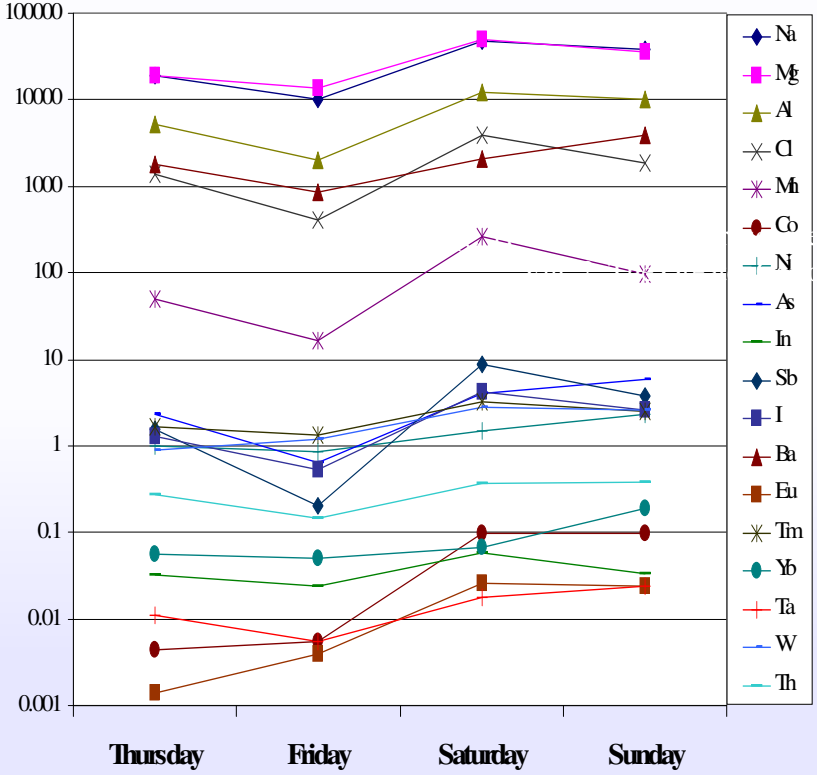


Fig. 1. Irregularity of aerosol elemental content the South of the Greater Cairo Area

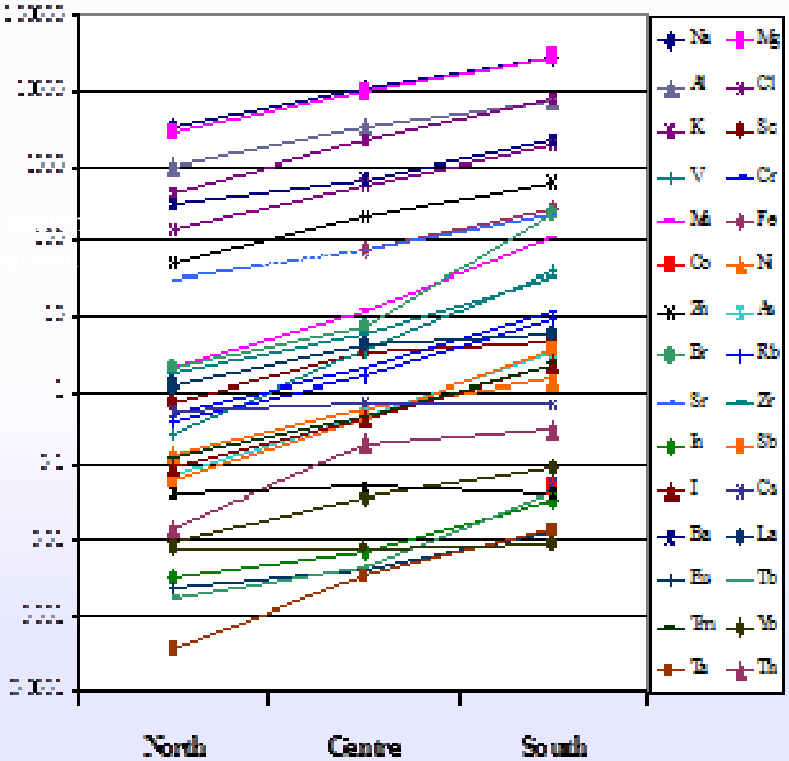


Fig. 2. The Greater Cairo Area aerosolof elemental content.

Contents lists available at ScienceDirect

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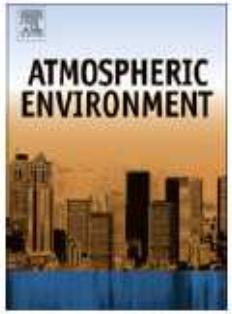
journal homepage: www.elsevier.com/locate/atmosenv



42 (2008) 8079–8085

Evaluation of elemental content in air-borne particulate matter in low-level atmosphere of Bratislava

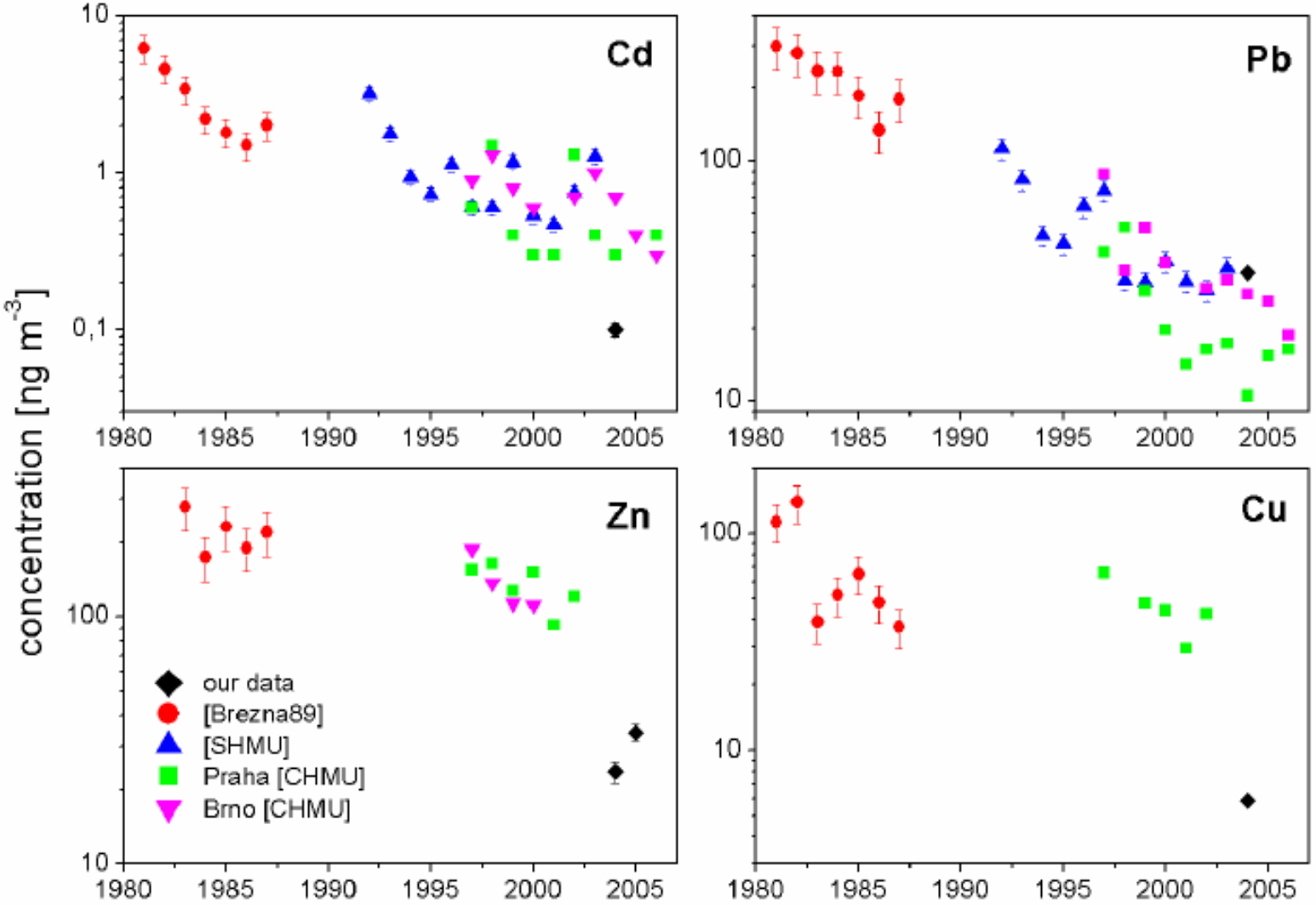
J. Merešová [a,*], M. Florek [a], K. Holý [a], M. Ješkovský [a], I. Sýkora [a], M.V. Frontasyeva [b], S.S. Pavlov [b], M. Bujdoš [c]

[a] Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University, Mlynská dolina, 842 48 Bratislava, Slovakia
[b] Department of Neutron Activation Analysis, Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Street Joliot-Curie 6, 141980 Dubna, Moscow Region, Russia
[c] Institute of Geology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 842 48 Bratislava, Slovakia

Overview on elements determined in air filter samples by INAA

Element determined	Radionuclide	Half-life	Energy [keV]	Measurement[a]	Accuracy [%]
Na	^{24}Na	14.91 h	1368.5	B	10
Al	^{28}Al	2.241 m	1778.9	A	6
Cl	^{38}Cl	37.24 m	2167.7	B	29
K	^{42}K	12.36 h	1524.7	B	19
Ca	^{49}Ca	8.718 m	3084.0	A	14
Sc	^{46}Sc	83.83 d	889.0	D	32
Ti	^{51}Ti	5.76 m	320.0	A	34
V	^{52}V	3.743 m	1434.4	A	18
Cr	^{51}Cr	27.7 d	320.0	D	36
Mn	^{56}Mn	2.578 h	1810.7	B	5
Fe	^{59}Fe	44.5 d	1099.1	D	23
Ga	^{72}Ga	14.1 h	629.9	C	14
As	^{76}As	1.097 d	559.1	C	5
Se	^{75}Se	119.8 d	264.1	D	58
Br	^{80}Br	17.7 m	617.0	B	13
In	^{116m}In	54.1 m	1294.0	B	25
Sb	^{122}Sb	2.7 d	564.2	C	51
I	^{128}I	24.99 m	442.7	A	7
Cs	^{134}Cs	2.062 y	795.8	D	65
Ba	^{139}Ba	83.1 m	165.8	B	45
La	^{140}La	1.678 d	1596.2	C	52
Sm	^{153}Sm	46.7 h	103.2	C	40
Dy	^{165}Dy	2.334 h	94.7	B	40
Tm	^{170}Tm	128.6 d	84.3	D	79
W	^{187}W	23.9 h	685.7	C	60
Au	^{198}Au	2.694 d	411.8	C	49
Hg	^{203}Hg	46.6 d	279.0	D	64
Th	^{233}Pa	27 d	312.0	D	40
U	^{239}U	23.5 m	74.7	B	27

[a] A: conventional NAA, short irradiation, first measurement; B: conventional NAA, short irradiation, second measurement; C: epithermal NAA, long irradiation, first measurement; D: epithermal NAA, long irradiation, second measurement.



Temporal variation of atmospheric concentrations of Cd, Pb, Zn, and Cu in Bratislava

Circle – our data; **diamond** – (Brezna´ and Za´vodsky´, 1989);
triangle – (SHMU). For comparison are shown also elemental concentrations in Prague (**square**) and Brno (**reverse triangle**) (CHMU).

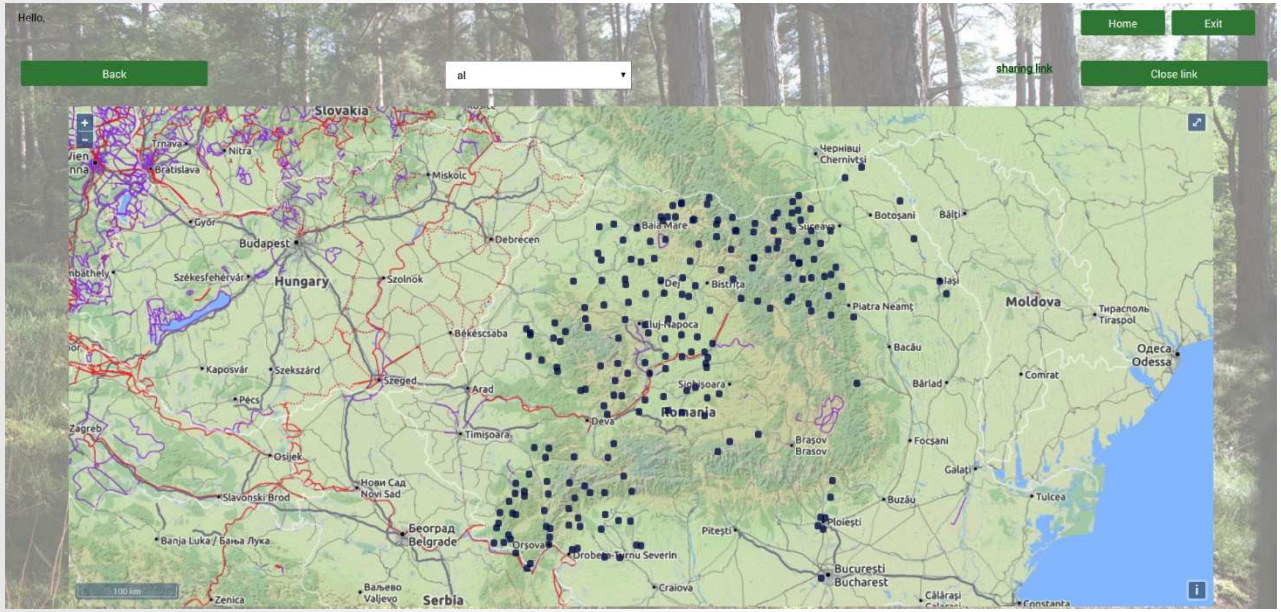
DATA MANAGEMENT SYSTEM OF THE UNECE ICP VEGETATION

Alexander Uzhinskiy[1], Gennady Ososkov[1],
Marina Frontasyeva[2]

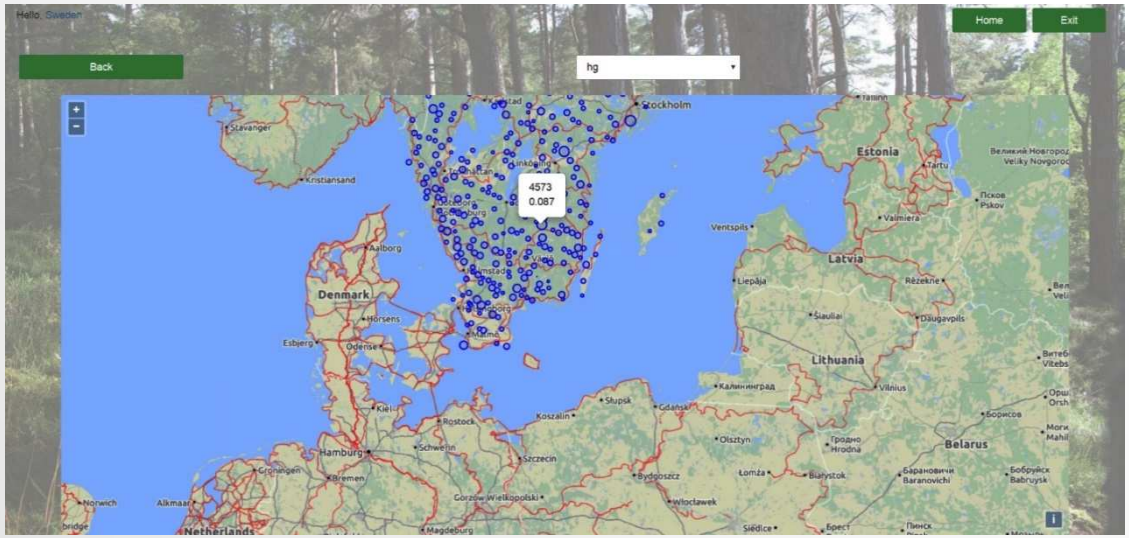
[1]Laboratory of Information Technologies,
[2]Frank Laboratory of Neutron Physics,
Joint Institute for Nuclear Research, 6, Joliot-Curie, str. ,
141980, Dubna, Moscow Region, Russian Federation

E-mail: uzinskiy@jinr.ru, ososkov@jinr.ru,
marina@nf.jinr.ru

WEB-PORTAL (MOSS.JINR.RU) PARTICIPANT

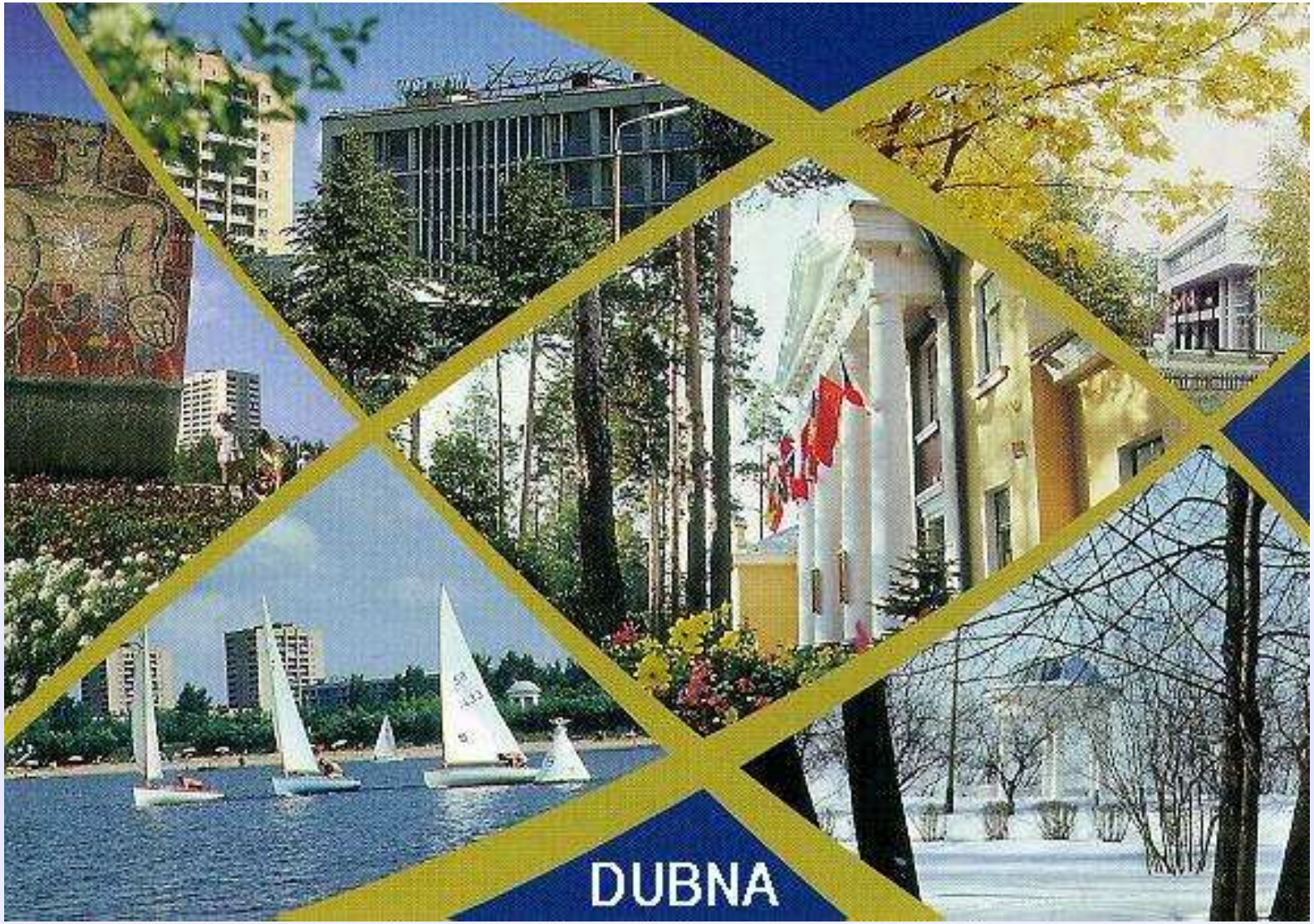


Sampling map



Graduated symbol map

WEB-PORTAL (MOSS.JINR.RU) SUPERVISOR

Sampling map (summarized information)

Welcome to Dubna!