Lebanese Atomic Energy Commission CNRS

INTERNATIONAL CONFERENCE ON
ACCELERATORS FOR RESEARCH AND SUSTAINABLE DEVELOPMENT
From good practices towards socioeconomic impact

Elemental Characterization of PM$_{2.5}$ Aerosol Samples in Four Mid-Eastern Cities and Source Apportionment Investigation

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IAEA Headquarters, Vienna, Austria

Outline

➢ Background

➢ Aerosol Regional projects

➢ Tools & IBA techniques

➢ Analysis and Results

➢ Summary

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Background

- The Mediterranean basin is considered one of the most controversial regions for aerosol transportation due to its location at the intersection of air masses circulating among the three continents

- Eastern Mediterranean region shows higher levels of air particulate matter than in other regions, even when compared to the Western Mediterranean

- Air quality in Beirut city: high density population, geographic location, traffic, structural layout, lack of rules and regulations

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Background II

- ARASIA region: Lack of enough data and studies dealing with air pollution in the region

- An ambitious IAEA-ARASIA project: study of air pollution in regional and national contexts and investigate the elemental composition of fine and coarse atmospheric particulate matter

- Atmospheric Particulate Matter (PM2.5 and PM10) represent a special interest for air pollution studies

- Ion Beam Analysis techniques should contribute effectively to evaluate and map the PM levels and conclude source apportionment: PIXE, PIGE, EBS, PESA

ARASIA region

Participating Members are:

- Iraq
- Jordan
- Lebanon
- Syria
- United Arab Emirates
- Yemen
- Kuwait
- Qatar

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Morning haze over Beirut

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Sandstorm in Baghdad

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Image of a dust storm in the Middle East captured by the Moderare Resolution Imaging Spectroradiometer (MODIS) instrument on board the Aqua satellite on 8 September 2015. © NASA
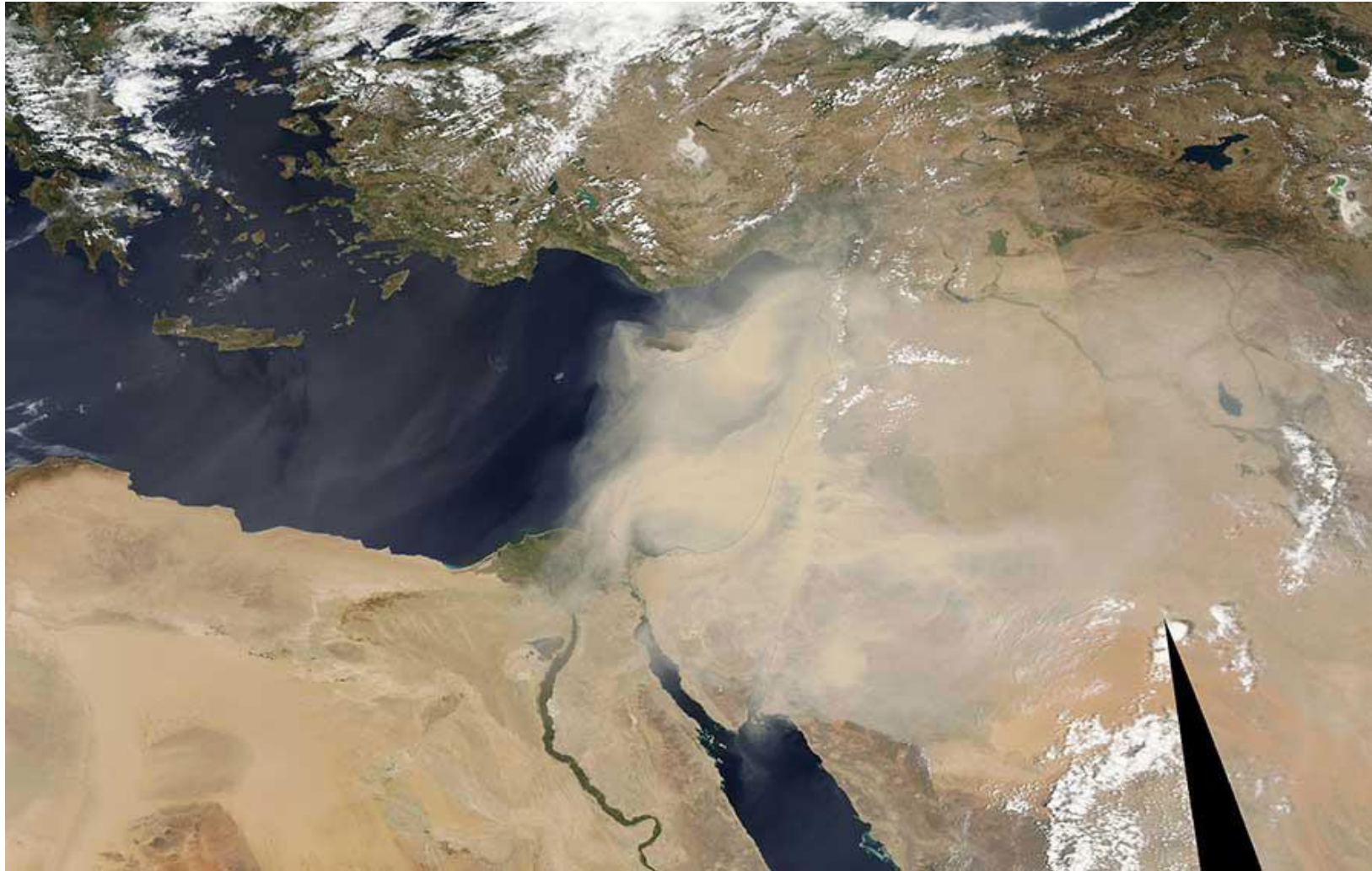
Sandstorm in September 2015 at the Ramlet Al-Bayda public beach

PROJECTS

IAEA-RAS0072 (2014-2015)

IAEA-RAS0076 (2016-2018)

IAEA- RAS0078 (2019-2021)

Studying Characterization, Source Apportionment and Long-Range Transport of Air Pollution within the Regional Network

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OBJECTIVES

Foster cooperation between ARASIA Member States on air pollution studies using nuclear analytical and complementary techniques

Increase awareness of air pollution and to initiate/improve air quality monitoring in ARASIA Member States

Build the necessary human capacity and infrastructure

Create a local team and a regional network

Establish a database of elemental composition of PM2.5 using nuclear analytical techniques (IBA and XRF)

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RAS0078 Strategy

consolidate the database of air pollution based on coarse and fine particulate matter in each country and at the regional level

continue to build human capacities, expertise and have the necessary equipment to undertake such a program

identify source fingerprints and their contributions to pollutants

provide advise to decision makers who issue regulations controlling air pollution sources and emissions

Procedures and tools

➢ Sampling using low volume air sampler

➢ Common protocol for sampling and analysis

➢ Suggest synchronized sampling

➢ Determination of total mass of $PM_{2.5}$, elemental composition and black carbon contents

➢ Use of Ion Beam Analysis techniques IBA and XRF (preference is given to PIXE technique) for elemental composition

Low volume air Samplers

Microprocessor Controlled Aerosol Sampling device **ISAP** 1050e with combined inlet for PM10 and PM2.5

Meteorological sensor installed for certified onsite temperature, atmospheric pressure, and humidity measurements

Sven Leckel Aerosol Sampler (PM10 or PM2.5)

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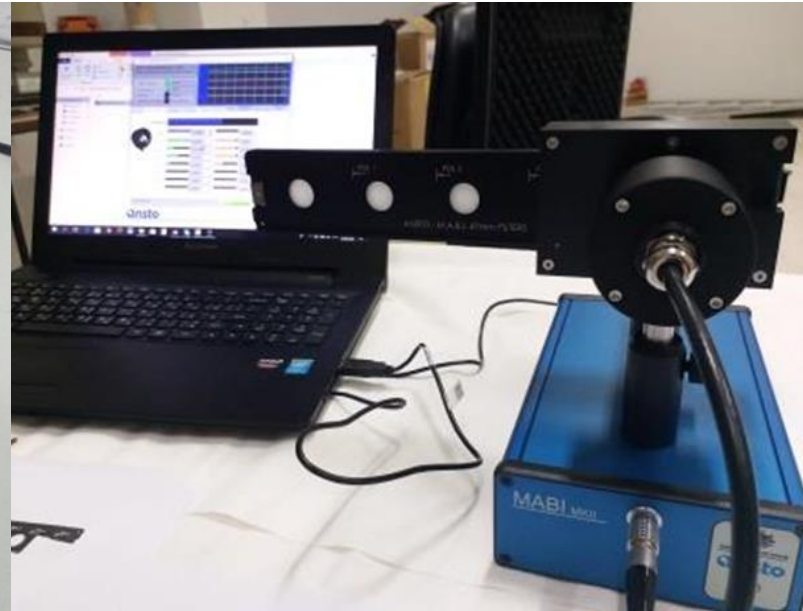**Accelerators for Research and Sustainable Development**
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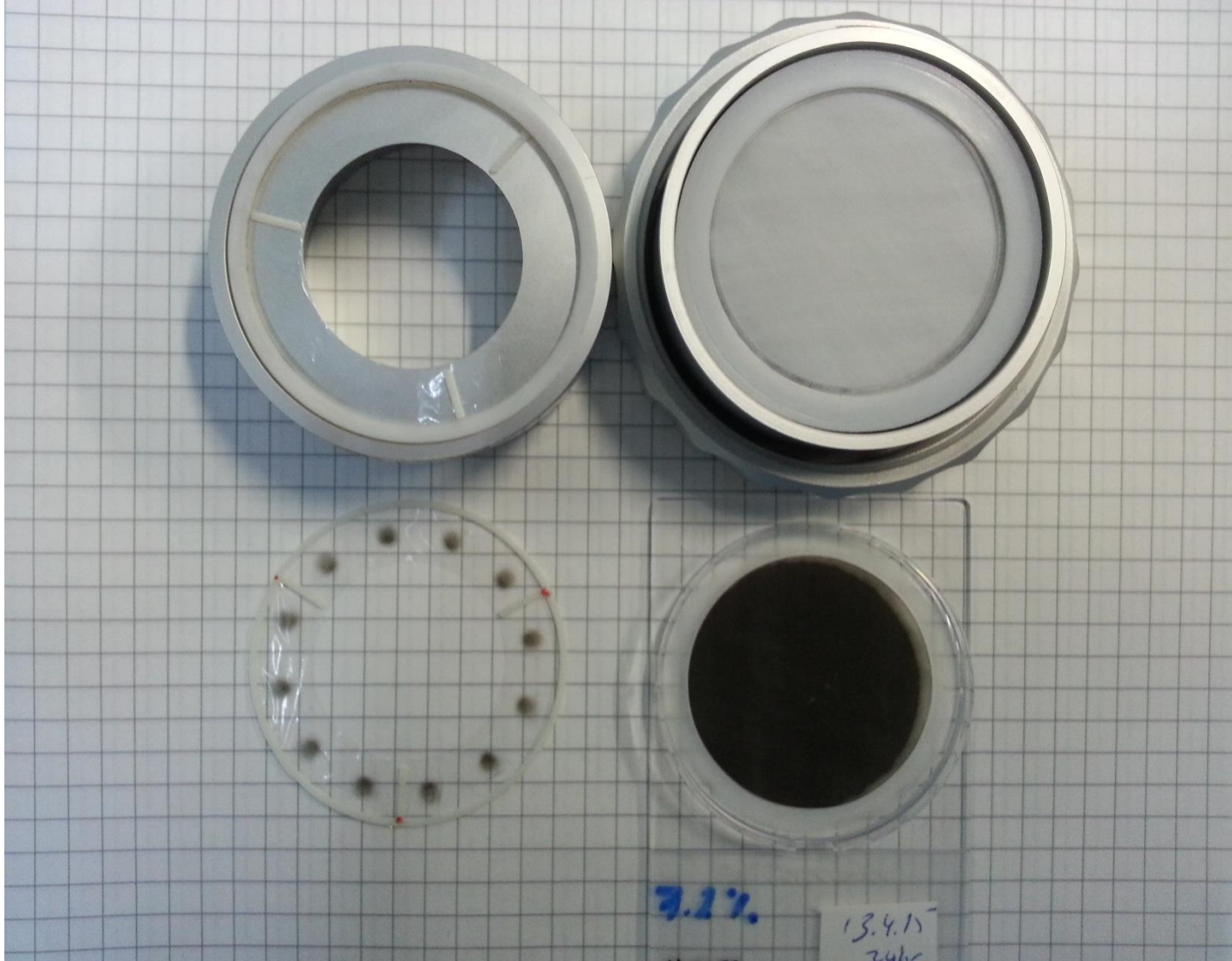
Before sampling

After sampling

PM10-2.5   PM2.5

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Others
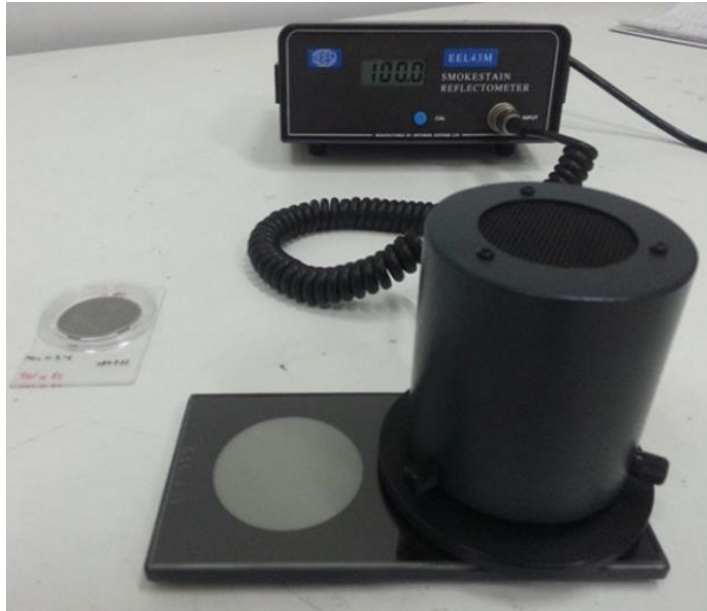
Smokestain Reflectometer for Black Carbon

Multi-wavelength Absorption Black Carbon (MABI)
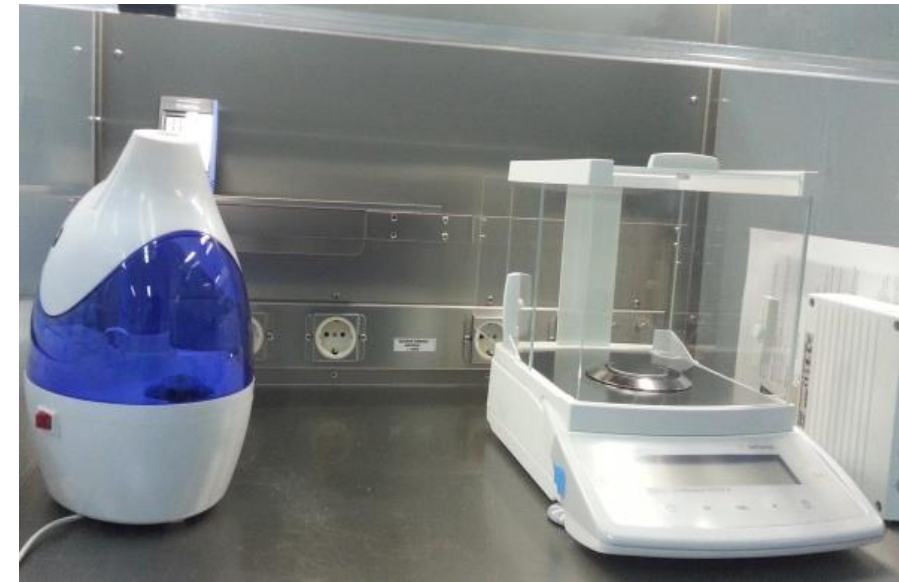
Gravimetric: Micro- Balance

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Why PIXE

- Since air filters contain very small particle deposit, preference is given to methods that **are:**
    - multi-elemental
    - can accommodate small sample sizes
    - and that require little or no sample preparation
    - short operator time after the samples are loaded into the analyzer
    - sensitivity to ng/cm2 for most elements
    - Possibility to combine simultaneously with other IBA techniques (PIGE, RBS, PESA)
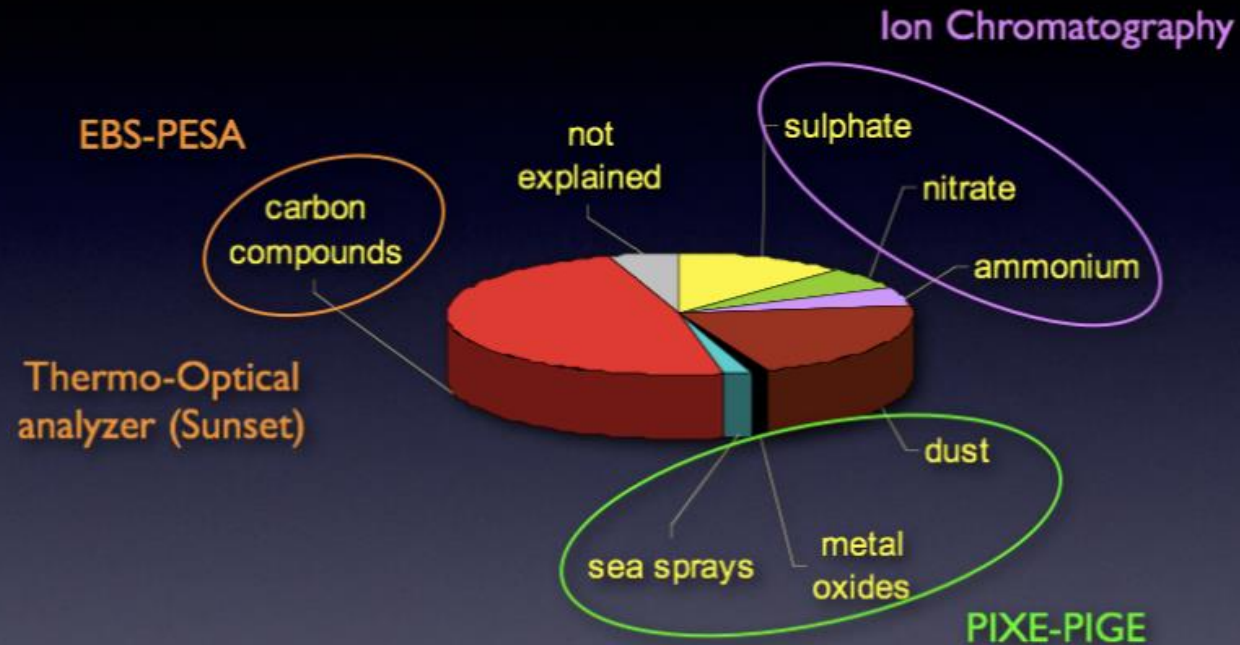
- Availability of IBA techniques
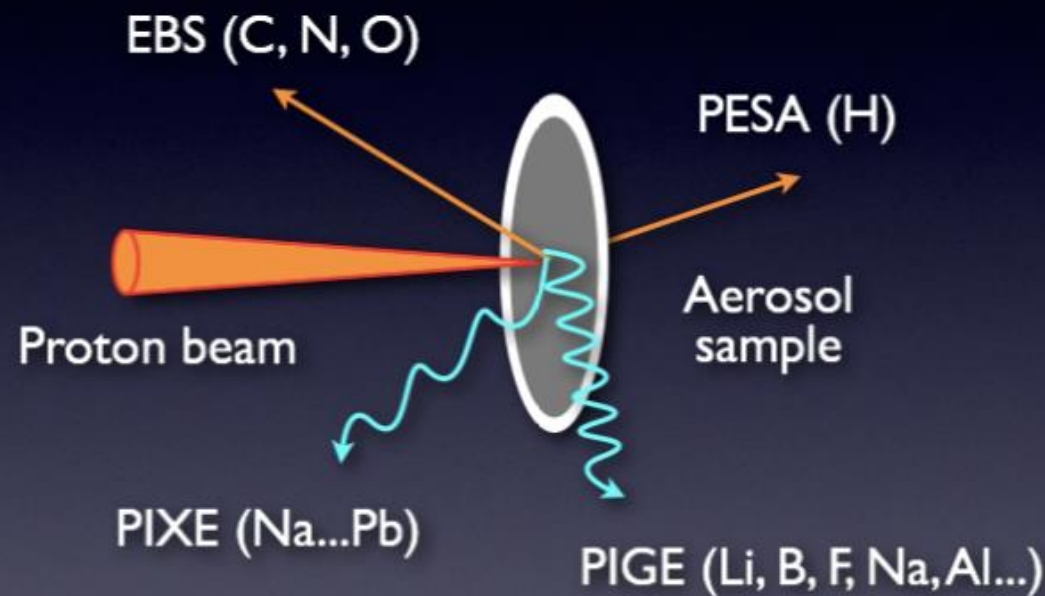
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Experimental setup & Analytical Techniques

5SDH Pelletron Tandem Accelerator of 1.7 MV from NEC

"First Accelerator Based Ion Beam Analysis Facility in Lebanon: Development and Applications",

M. Roumié, & al, *Nuclear Inst. and Methods in Physics Research B* 219-220 (2004) 389.

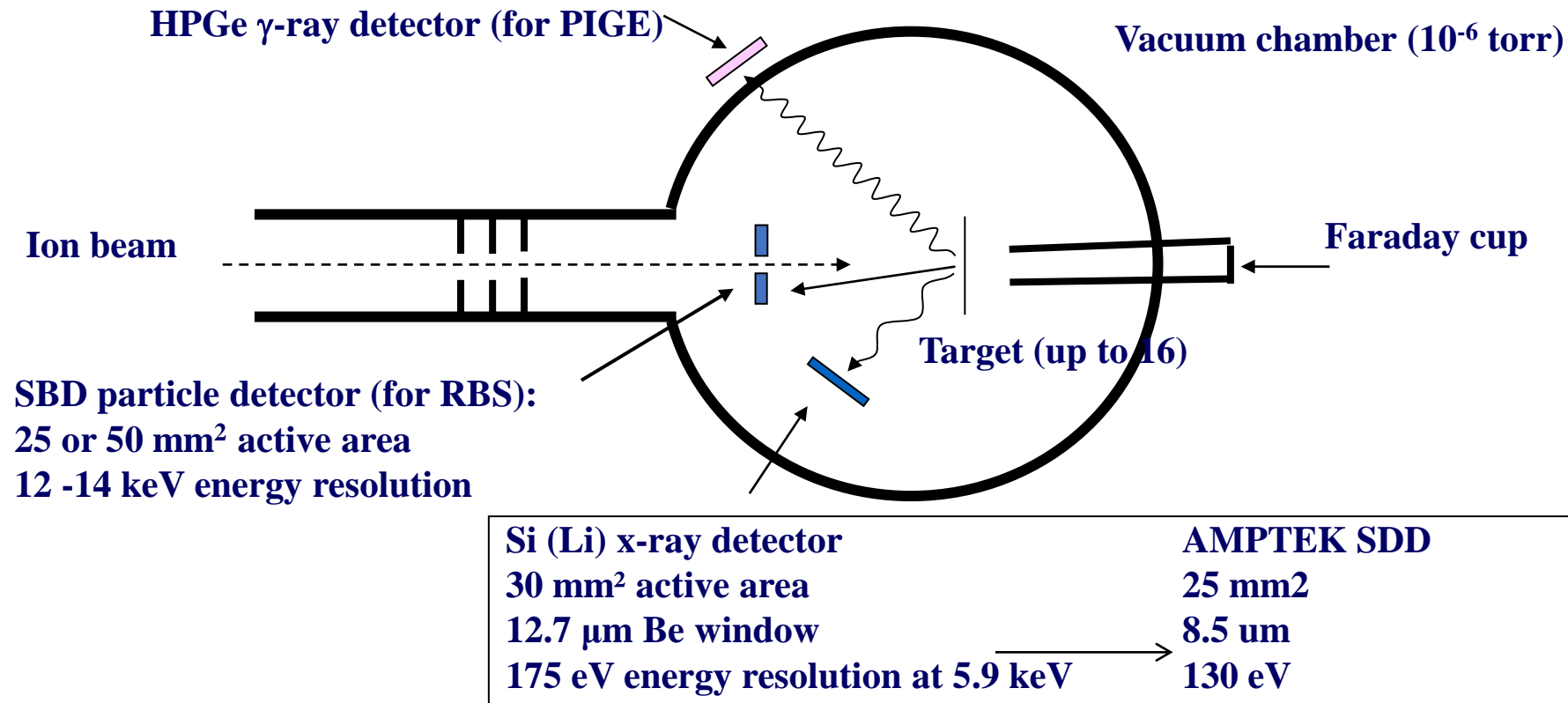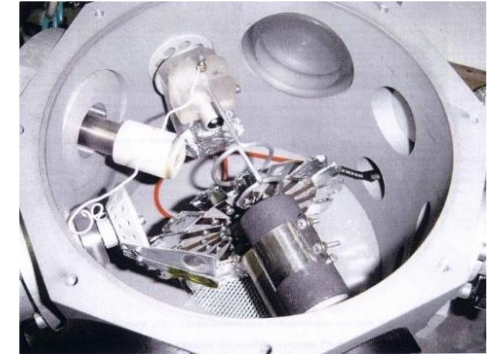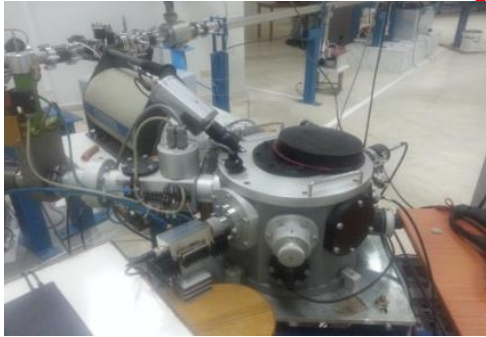Protons beam:

0.3-3.4 MeV

1-200 nA

Alpha-particles beam:

0.5-5.1 MeV

1-100 nA

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CONVENTIONAL EXPERIMENTAL SETUP

HPGe γ-ray detector (for PIGE)

Vacuum chamber (10⁻⁶ torr)

Ion beam

Faraday cup

SBD particle detector (for RBS):
25 or 50 mm² active area
12 -14 keV energy resolution

Target (up to 16)

Si (Li) x-ray detector	AMPTEK SDD
30 mm² active area	25 mm2
12.7 μm Be window	8.5 um
175 eV energy resolution at 5.9 keV	130 eV

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Some development

Designing a special and suitable Aerosol sample holder to fit the under vacuum analysis chamber (up to 12 half filters)

An AMPTEK SDD X-ray detector is used for PIXE analysis

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PERFORMED ION BEAM ANALYSIS TECHNIQUES IBA

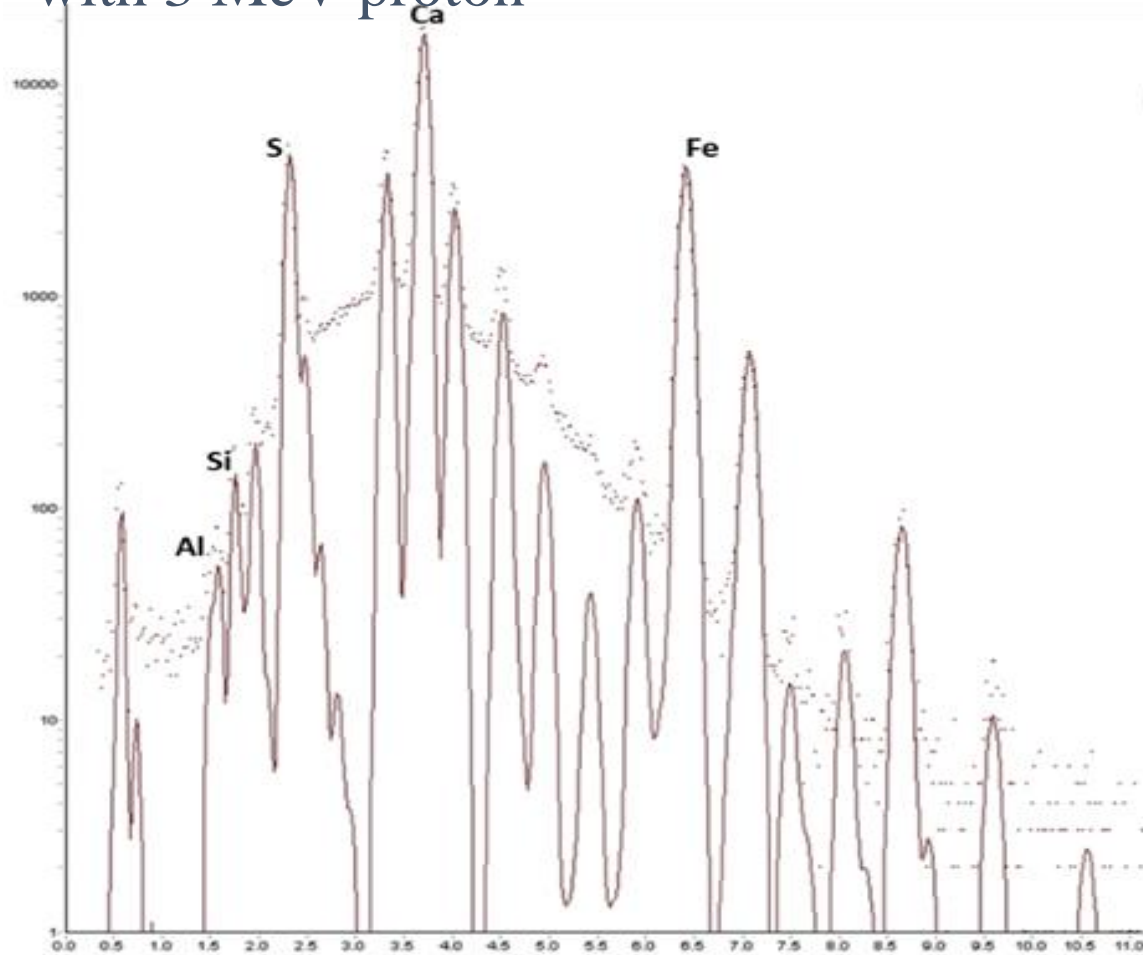| TECHNIQUE	ACRONYM	PARTICLE/RADIATION MEASURED
Particle-Induced X-ray Emission	PIXE	Characteristic X-rays
Elastic Back-scattering Spectrometry	EBS	Elastically scattered ions in backward angles
Nuclear Reaction Analysis	NRA	Prompt product particles or gamma-rays (PIGE)

Calibration and Validation

- The ratio of the experimental concentration over the certified one, for 30 elements from Na to Pb (Na, Mg, Al, Si, S, Cl, K, Ca, Sc, Cr, Mn, Fe, Co, Ni, Cu, Br, Rb, Sr, Y, Mo, Sn, Ba, W, Pb), using the Micromatter thin film standards, as a function of the atomic number. A proton beam at 3 MeV and 128 µm kapton filter (between detector and sample) are used.
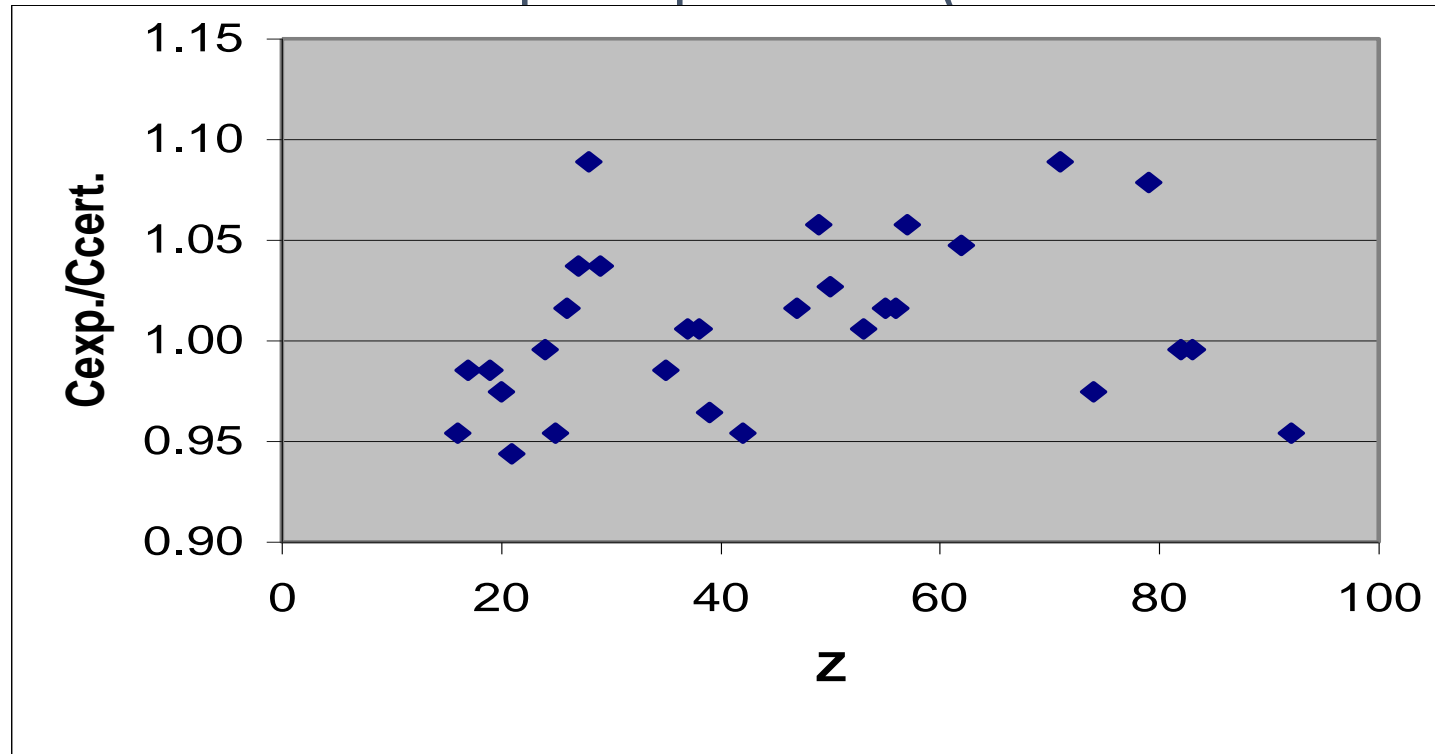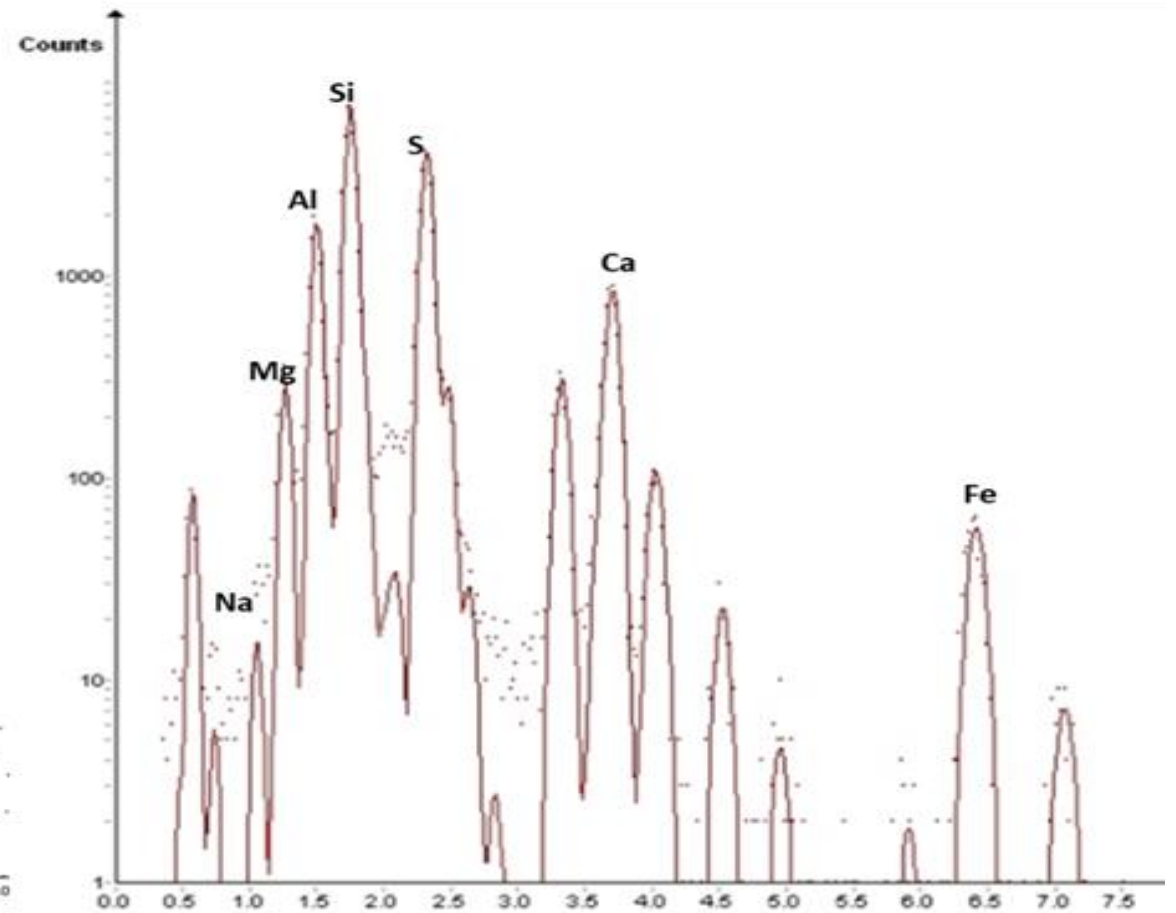

- **NIST SRM#2788, IAEA-PT, UC Davis**

PIXE spectrum of PM2.5 sample measured with 3 MeV proton

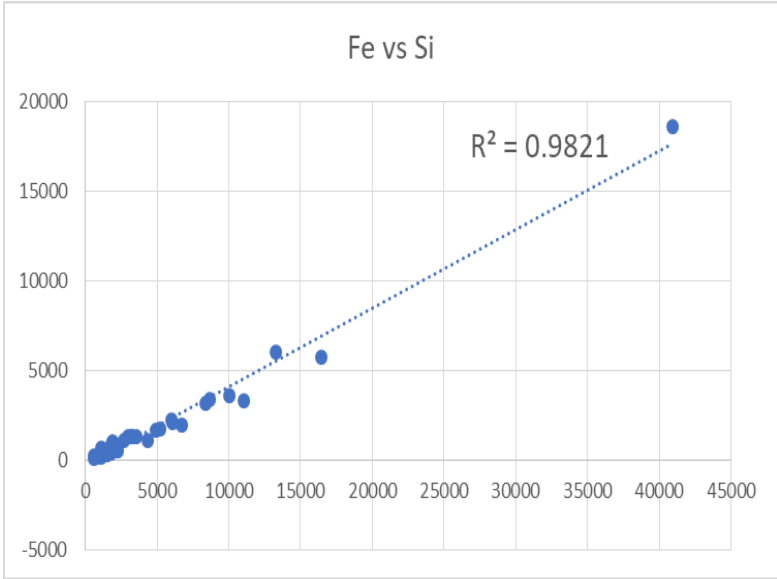PIXE spectrum of PM2.5 sample measured with 1 MeV proton

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Analysis and Results (Baghdad)

	Avg	Max	Min
Si	38997	91609	9877
S	7579	14011	2811
Cl	1480	3715	174
K	5948	16105	1233
Ca	40848	128167	9245
Ti	1222	4013	238
V	77	323	11
Cr	49	172	6
Mn	274	898	53
Fe	14914	53710	2845
Ni	70	214	8
Cu	51	180	4
Zn	167	907	51
Br	46	91	14
Sr	167	553	14
Pb	142	951	11

Ca vs Si — $R^2 = 0.9593$

Ti vs Si — $R^2 = 0.9622$

Fe vs Si — $R^2 = 0.9313$
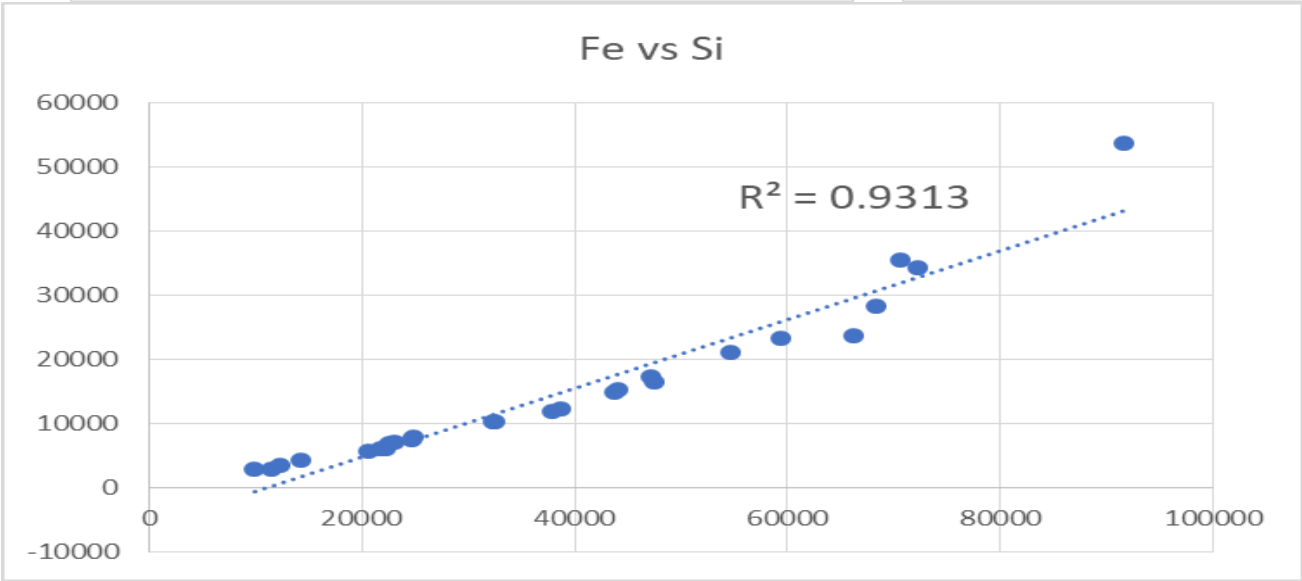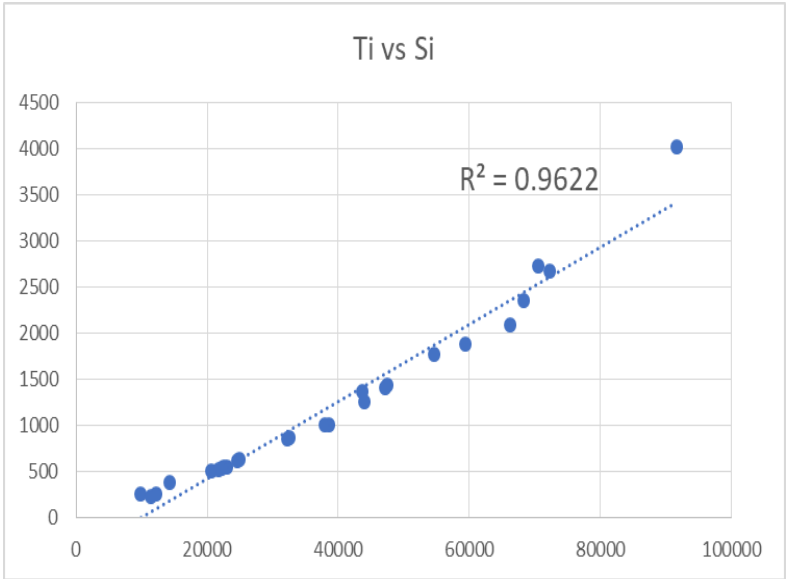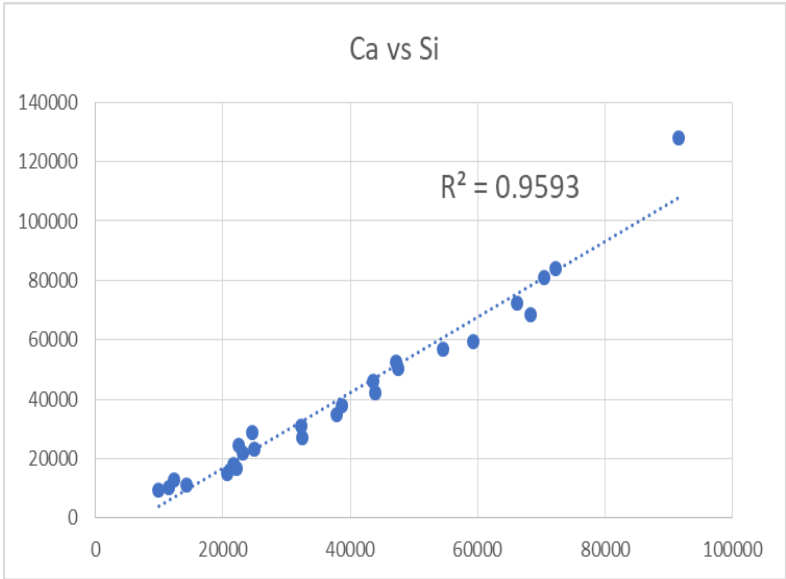
Analysis and Results (Kuwait City)

	TEF#47	with TEF#47			without TEF#47		
		AVG	MAX	MIN	AVG	MAX	MIN
Al	8235	1789	14798	96	1628	14798	96
Si	93047	6906	93047	620	4752	40927	620
S	2522	10518	25433	2323	10718	25433	2323
Cl	614	91	1073	11	78	1073	11
K	29610	1606	29610	292	905	5729	292
Ca	23066	4641	48179	180	4180	48179	180
Ti	1100	191	1701	11	168	1701	11
V	505	51	505	8	39	103	8
Cr	97	12	97	4	10	55	4
Mn	109	42	330	5	41	330	5
Fe	4962	1874	18592	130	1797	18592	130
Ni	56	20	56	5	19	41	5
Cu	65	30	264	8	29	264	8
Zn	107318	2769	107318	26	155	556	26
Br	273	32	273	8	26	71	8

K vs Si

$R^2 = 0.9421$

Ca vs Si

$R^2 = 0.9528$

Fe vs Si

$R^2 = 0.9821$

Analysis and Results (Beirut)

PM$_{2.5}$ values in µg/m^3 between February and November of

2015. The WHO established a daily PM threshold of 15 µg/m^3.
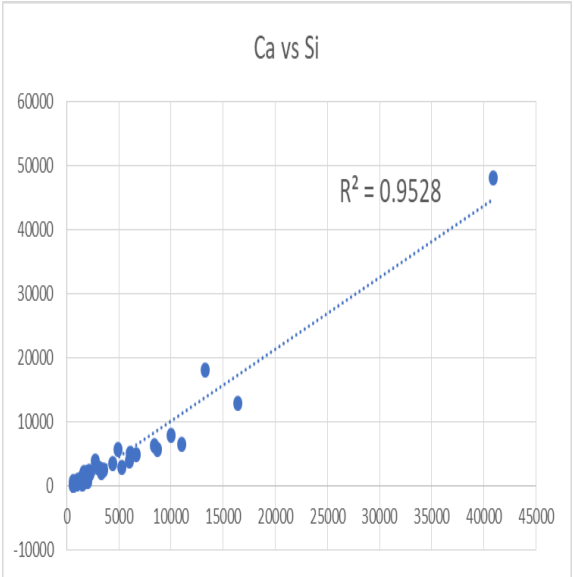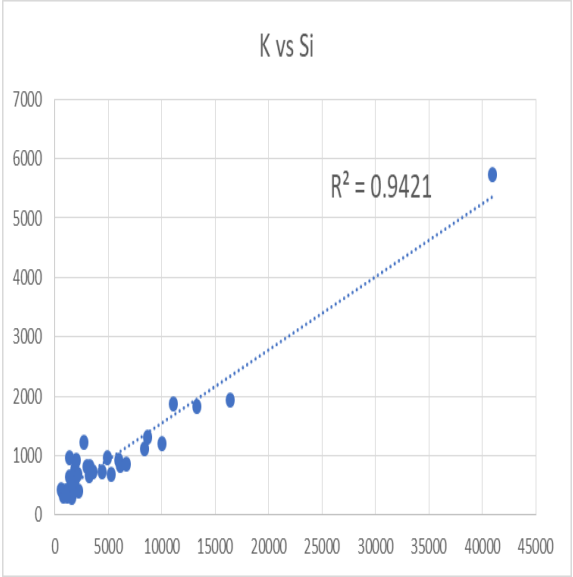
Changes in mineral dust

	NDs + DDs	NDs	DDs
	Value $_{(maximal\ value\ -\ minimal\ value)}$ (µg/m^3)		
PM	35.74 $_{(311.33\ -\ 4.88)}$	23.33 $_{(53.60\ -\ 4.88)}$	200.30 $_{(311.33\ -\ 91.78)}$
Sulfates	5.60 $_{(13.67\ -\ 0.35)}$	5.39 $_{(13.67\ -\ 0.35)}$	8.31 $_{(12.79\ -\ 5.71)}$
Mineral Dust (Ca)	10.82 $_{(178.89\ -\ 0.07)}$	3.84 $_{(18.34\ -\ 0.07)}$	103.33 $_{(178.89\ -\ 43.58)}$

- **PIXE, Gravimetric Measurements and BC (LAEC)**
- **PESA and PMF: 180 samples (LABEC)**

PM - Run 6

Factor Contribution > 0.05 %
- anthropic = 8.32870 (42.8 %)
- sea spray = 1.09470 (5.6 %)
- sulphate = 4.43450 (22.8 %)
- mineral dust = 5.61550 (28.8 %)

Summary

- Comparing to WHO standards, there are high values of PM2.5 and PM10 total masses

- Crustal elements are increased significantly with dust storms

- Transfer of knowledge and technology related to fine particle air pollution to all MSs

- Effective and continuous APM sampling performed by the regional network

- Contribute to a regional and national databases of elemental composition of APM using PIXE technique, as well as on source apportionment

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Beirut Seaport Blast on August 4th 2020: Air quality??

Thank you

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Mr. Roman Padilla-Alvarez and IAEA staff

ARASIA project counterparts

Mr. Massimo Chiari, LABEC

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