



## **Investigation of Air Pollution Using Non-Destructive Techniques:**

# **Particulate Matter Research in the UAE**

**Nasser Hamdan**

**American University of Sharjah**

**And**

**NXFL**

# Talk Outline

- Overview of AQM stations in the UAE
- Analytical capacity at AUS/UoS
- Sampling methods
- Few examples : TSP, size resolved elemental analysis
- **Tomorrow:** PM<sub>10</sub>/PM<sub>2.5</sub> elemental and chemical speciation

# Online Monitoring in the UAE

- 7 Emirates: Abu Dhabi, Dubai, Sharjah, Ajman, Um-Al-Qwain, Fujairah and Ras Al-Khaimah
- All Emirates have monitoring stations for various pollutants including  $PM_{10}$  and  $PM_{2.5}$ .

# Online Monitoring in the UAE

- NCMS has station in all Emirates
- All stations will be connected to a single network and report their data to the NCMS by the end of the year.

# Northern Emirates

## Ambient Air Quality Monitoring Network Managed by NCMS

No.	Station Name	Station ID	Entity ID	Location Type
<b>Ras Al Khaimah</b>				
1	Aljeer	1	2	Suburban
2	Al Burairat	2	2	Suburban
3	Al Qasimiyah	3	2	Urban
4	Ghalilah	5	2	Suburban
<b>Ajman</b>				
5	Rashidiyah	7	2	Urban
6	Elderly House	6	2	Urban
<b>Sharjah</b>				
7	Al Hamriyah	4	2	Industrial
8	Kalba	8	2	Urban



# Environmental Agency Abu-Dhabi (EAD)

Abu Dhabi: 20 fixed and 2 mobile stations that measure:

- SO<sub>2</sub>, NO<sub>x</sub>, O<sub>3</sub>, H<sub>2</sub>S, CO, PM<sub>10</sub>, PM<sub>2.5</sub>, CH<sub>4</sub>, BTEX,
- Noise, wind speed, wind direction, and temperature

EAD'S AIR QUALITY STANDARDIZATION UNIT

**ISO 17025 ACCREDITATION**

## MEASUREMENT SITE CLASSIFICATIONS

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- The Environment Agency – Abu Dhabi monitoring programme used the EU's classification of areas:

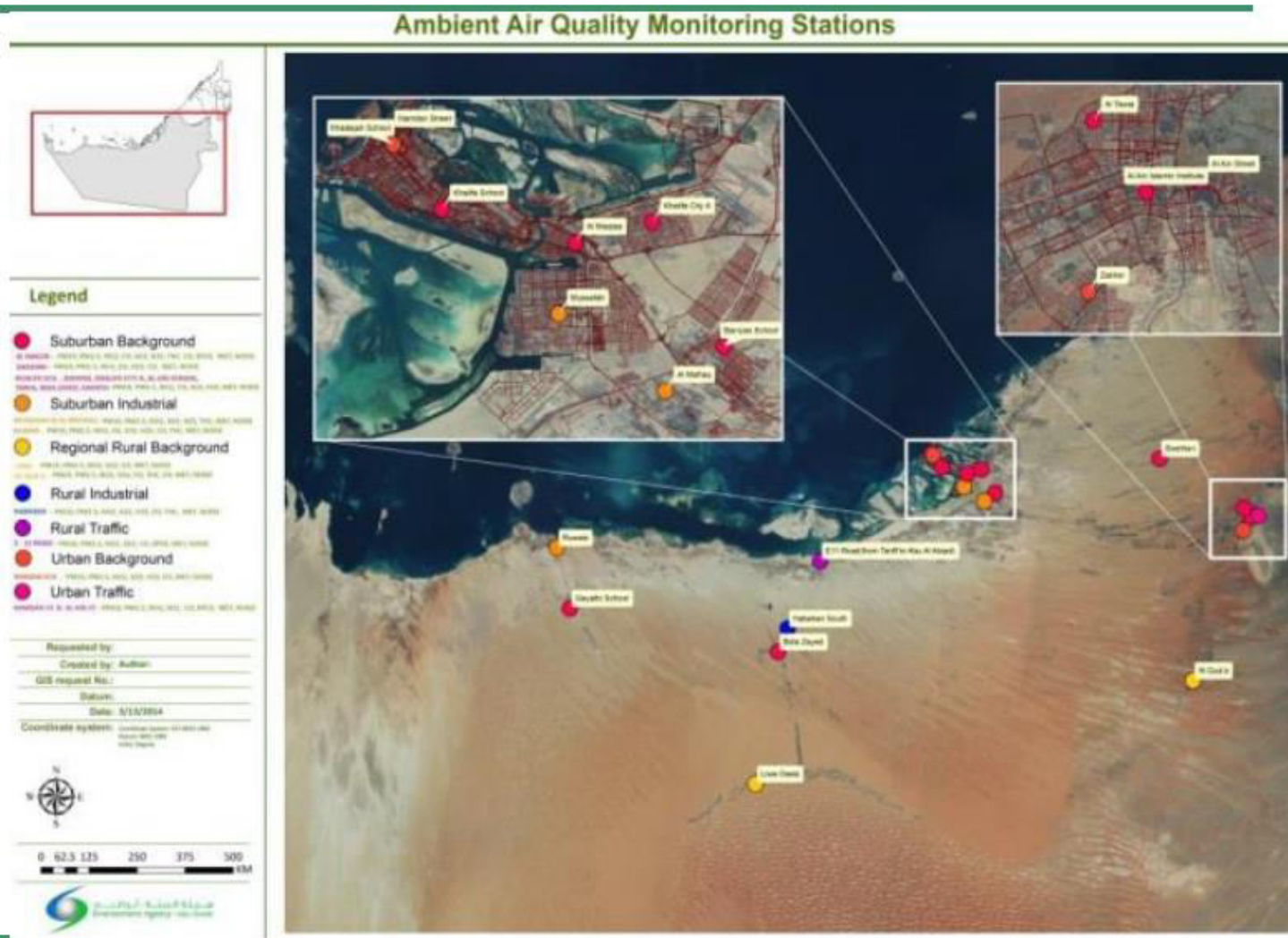
Type of Zone	Type of Station
Urban (U)	Traffic (T)
Suburban (S)	Industrial (I)
Rural (R)	Background (B) Near City – Regional – Remote

- The stations can be a combination of zones and station types such as Urban Traffic (UT), or Suburban Background (SB) etc.



# EAD'S AMBIENT AIR QUALITY MONITORING NETWORK

- 20 stations covering the Emirate of Abu Dhabi
- 10 stations in operation since 2007 and another 10 stations were added in 2012/2013





## AMBIENT AIR QUALITY NETWORKS IN ABU DHABI

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Main networks in Abu Dhabi Emirate:

	OWNER		# of Stations
1	EAD	Environment Agency, Abu Dhabi	20
2	ADNOC	Abu Dhabi National Oil Company	7
3	ADWEA	Abu Dhabi Water and Electricity Authority	3
4	ZC/IDB	Industrial Development Bureau	4
5	TDIC	Tourism Development and Investment Company	1
6	ADPC	Abu Dhabi Ports Company	2
7	ADM	Abu Dhabi Municipality	4
8	ALDAR	Beach Development Project	1
9	EMAL	Emirates Aluminium	1
10	DOT	Department of Transport (Planned)	5
11	UPC	Urban Planning Council (Planned)	5

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# MEASUREMENT METHODS

Component	Measurement method	Reference to standard
<b>NO, NO<sub>x</sub>, NO<sub>2</sub></b>	Automatic Chemiluminescence	CEN/EN142111, Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence.
<b>SO<sub>2</sub></b>	Automatic Ultraviolet fluorescence	CEN/EN14212, Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence.
<b>H<sub>2</sub>S</b>	Automatic Ultraviolet fluorescence	NA
<b>CO</b>	Automatic Non-dispersive infrared spectroscopy	CEN/EN14626, Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy.
<b>O<sub>3</sub></b>	Automatic Ultraviolet photometry	CEN/EN14625, Standard method for the measurement of the concentration of ozone by ultraviolet photometry.
<b>TNMHC</b>	FID	NA
<b>CH<sub>4</sub></b>	Automatic Non-dispersive infrared spectroscopy	NA
<b>BTX</b>	Automatic, GC w/PID	CEN/EN14662, Ambient air quality - Reference method for measurement of benzene concentrations.
<b>PM<sub>10</sub></b>	Automatic Beta gauge	CEN/EN12341, Determination of the PM 10 fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods.  Adapted to CEN/EN12341 for automatic methods.

## ANNUAL AVERAGE CONCENTRATION OF PM<sub>10</sub> (2007-2013)

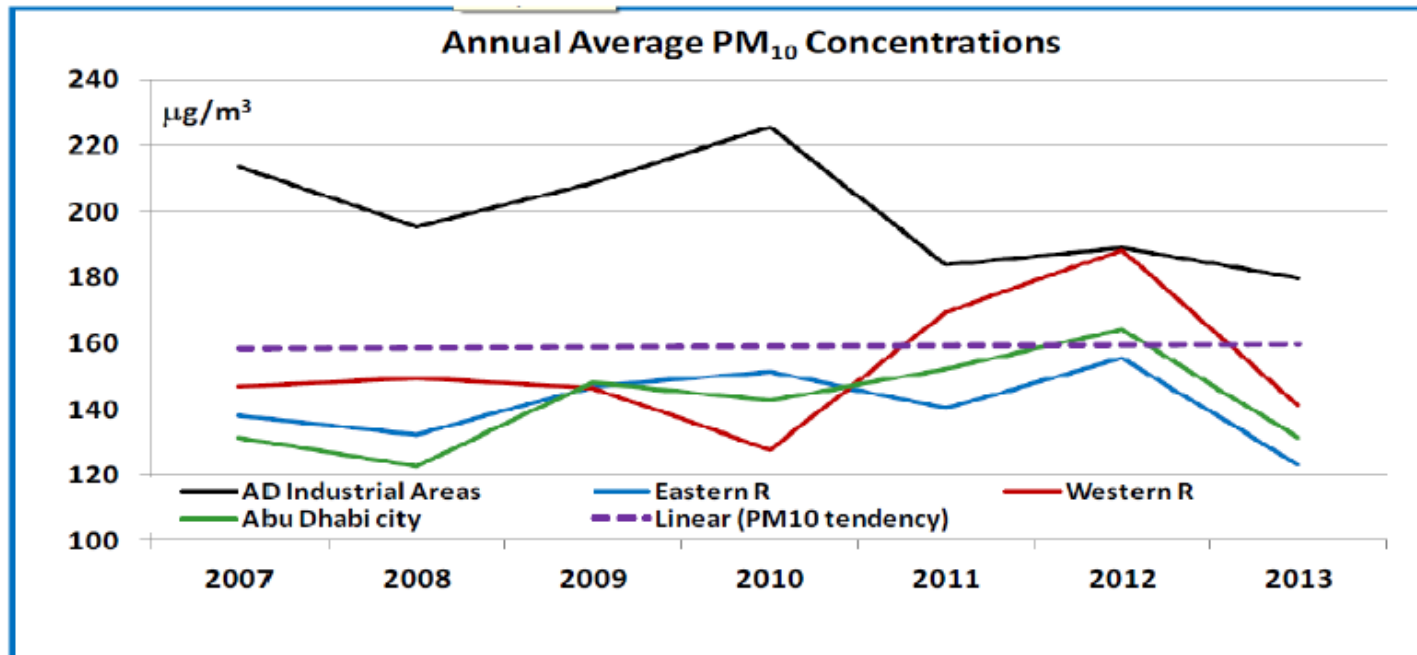


Figure 23: Annual average concentrations for PM<sub>10</sub> given for the sites in the Western Region, Eastern Region, Greater Abu Dhabi, Abu Dhabi Industrial Areas and Abu Dhabi Emirate PM<sub>10</sub> linear regression from 2007 to 2013.

# DUBAI MUNICIPALITY AMBIENT AIR QUALITY NETWORK

No.	Station Name	Station ID	Entity Code	Area Type
Default Units				
1	Deira	UB-1	DM-1	Urban Background
2	Karama	UB-2	DM-2	Urban Background
3	Zabeel Park	UB-3	DM-3	Urban Background
4	Safa Park	UB-4	DM-4	Urban Background
5	Jebel Ali Village	UB-5	DM-5	Urban Background
6	Emirates Hills	UB-6	DM-6	Urban Background
7	Dubai Airport	UB-7	DM-7	Urban Background
8	Mushrif	NCB-8	DM-8	Near City Background
9	Hatta	NCB-9	DM-9	Near City Background
10	Jebel Ali Port	I-10	DM-10	Industrial
11	Al Aweer	I-11	DM-11	Industrial
12	Shk. Zayed Road	T-12	DM-12	Traffic
13	Sheikh Mohd. Bin Zayed Rd.	T-13	DM-13	Traffic

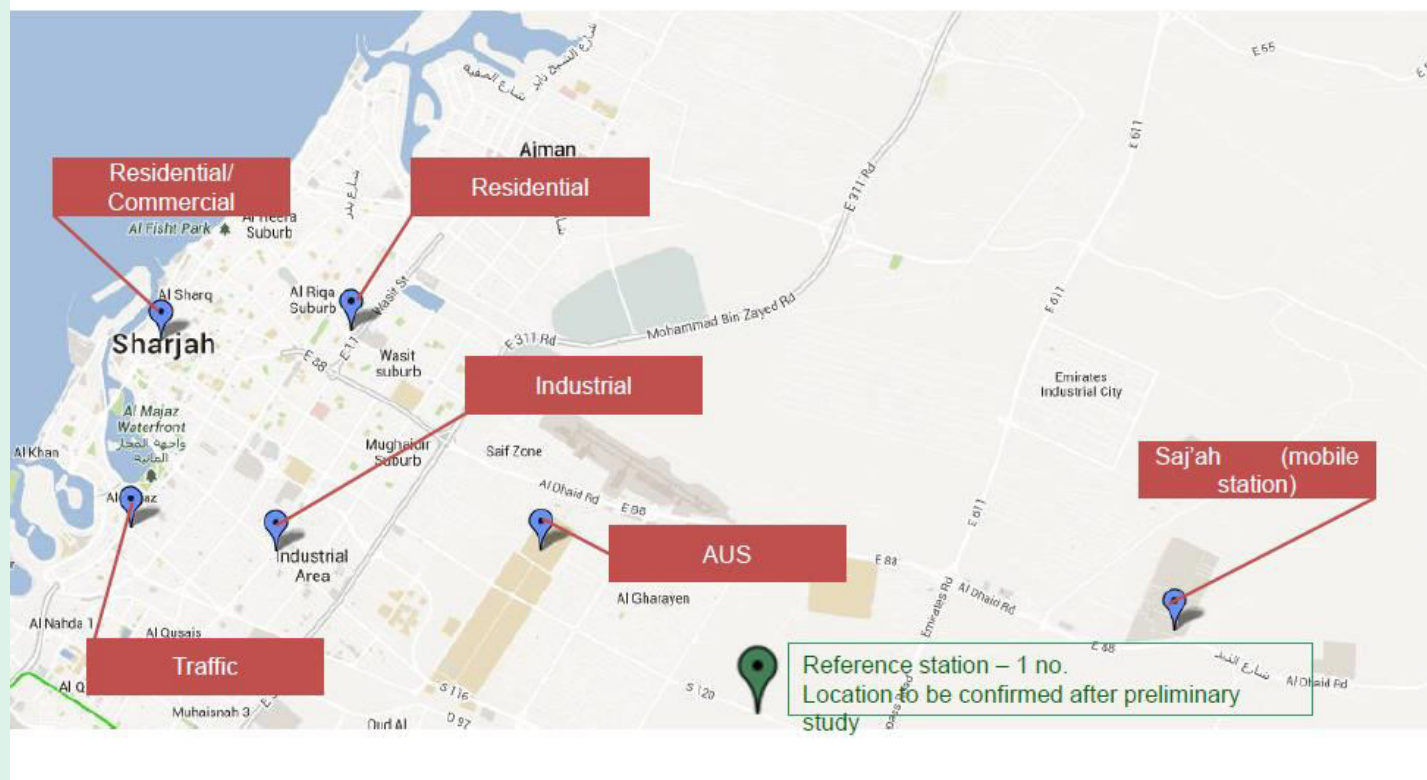




# Emirate of Sharjah: Bee'ah stations

Will be installed by the end of 2015

## Monitoring Locations (Tentative)



# Emirate of Sharjah

## Parameters to be Monitored

Residential/ Commercial	Industrial	Traffic/ Roadside	Sub-urban (AUS)	Background	Mobile Station
NO <sub>x</sub> , SO <sub>2</sub> , CO, O <sub>3</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	NO <sub>x</sub> , SO <sub>2</sub> /H <sub>2</sub> S, CO, O <sub>3</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , BTEX (VOC)	NO <sub>x</sub> , SO <sub>2</sub> , CO, O <sub>3</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , BTEX (VOC)	NO <sub>x</sub> , SO <sub>2</sub> , CO, O <sub>3</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	NO <sub>x</sub> , SO <sub>2</sub> , CO, O <sub>3</sub> , PM <sub>10</sub> , PM <sub>2.5</sub>	NO <sub>x</sub> , SO <sub>2</sub> /H <sub>2</sub> S, CO, O <sub>3</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , BTEX VOC), TRS, NH <sub>3</sub> , THC/CH <sub>4</sub> / nMHC, EMF

# National X-ray Florescence Laboratory (NXFL)

- Established by four physicists/material scientists at the **American University of Sharjah and University of Sharjah** (2007-2014)
- IAEA funding through UAE national Projects
- To be used in applied research mainly cultural heritage and environmental research.
- We collaborate with archaeologists, restorers, museums, historians, environmental agencies ...
- Basic Research in Physics and material Science



# The Team



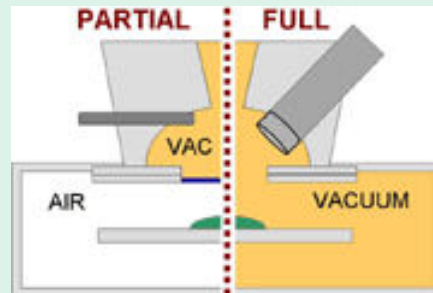
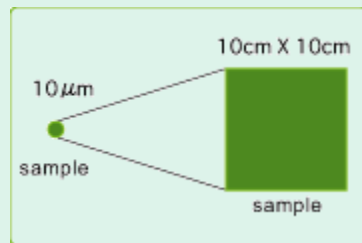
**NXFL executive team (from right to left): Dr. Hussain Alawadhi, Dr. Najeh Jisrawi, Dr. Nasser Hamdan.**

# Major Equipment Available includes

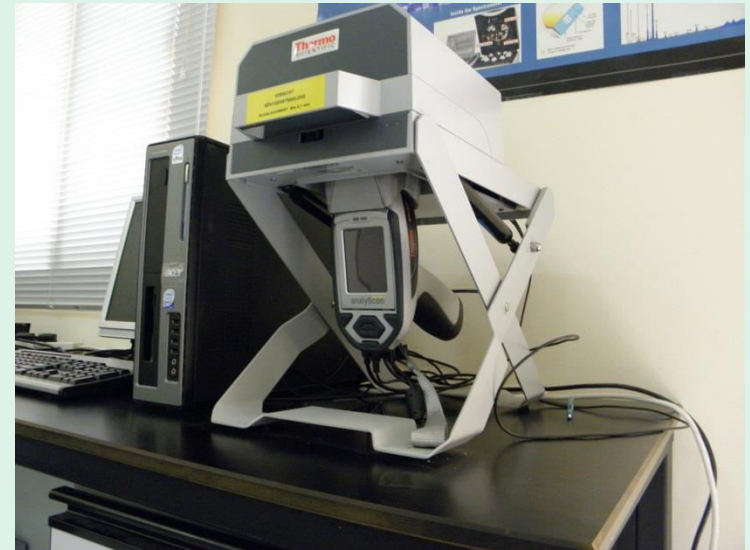
- Horiba XGT-7200  $\mu$ XRF system (50kV, 1mA, 1.2mm and 50 $\mu$ m beam, mapping capability)
- Bruker D8 ADVANCE powder XRD, (2.2 kW Cu tube,) a linear detector, Gobel mirrors (installed in October 2014) and a point detector
- Thermo-Niton XL3 hand held XRF system (50kV, 0.2mA, Ag anode, He purgeable).
- Renishaw inVia Reflex RAMAN : installed in September 2014
  - Laser spot size from 1 to 300  $\mu$ m
  - Confocal setup
  - XYZ mapping capability
  - 514/488/457/780 and 633 nm laser lines
  - 1 wavenumber resolution
- JASCO 6300 FTIR spectrometer (350-7800  $\text{cm}^{-1}$ , 0.07  $\text{cm}^{-1}$  resolution, ATR accessory)
- TSCAN SEM with EDS with 50  $\text{mm}^2$  low vacuum SDD detector LaB6 – lanthanum hexaboride – electron source
- Sample preparation equipment: optical microscope, microbalance, oven, ball mill, freezer mill, crusher



**Horiba u-XRF system**



- **Horiba XGT-7200  $\mu$ XRF system (50kV, 1mA, 1.2mm and 50mm beam, mapping capability)**



**Thermo-Niton XL3 hand held XRF system (50kV, 0.2mA, Ag anode, He purgeable)**



- **TESCAN Scanning Electron Microscope with EDS with 50 mm<sup>2</sup> low vacuum SDD detector LaB<sub>6</sub> – lanthanum hexaboride – electron source**

3/31/2021





Bruker D8 ADVANCE powder XRD system (2.2 kW Cu tube, point detector)

3/31/2021



3/31/2021



JASCO 6300 FTIR spectrometer ( $350\text{--}7800\text{ cm}^{-1}$ ,  $0.07\text{ cm}^{-1}$  resolution,  
ATR accessory)

3/31/2021



# The Group's involvement/Achievements

- Involved with several national, regional and international projects
  - Regional: IAEA TC projects: ARASIA member states.
  - International: CRP on the nuclear and related techniques in environmental research (PM) and the use of synchrotron Radiation in PM

# The Group's involvement/Achievements

- Capacity Building:
  - Organizing regional workshops and training courses.
  - Organizing local workshops on PM sampling and analysis

# Aerosol sampling and analysis workshop for ARASIA countries: AUS April 19-24, 2015





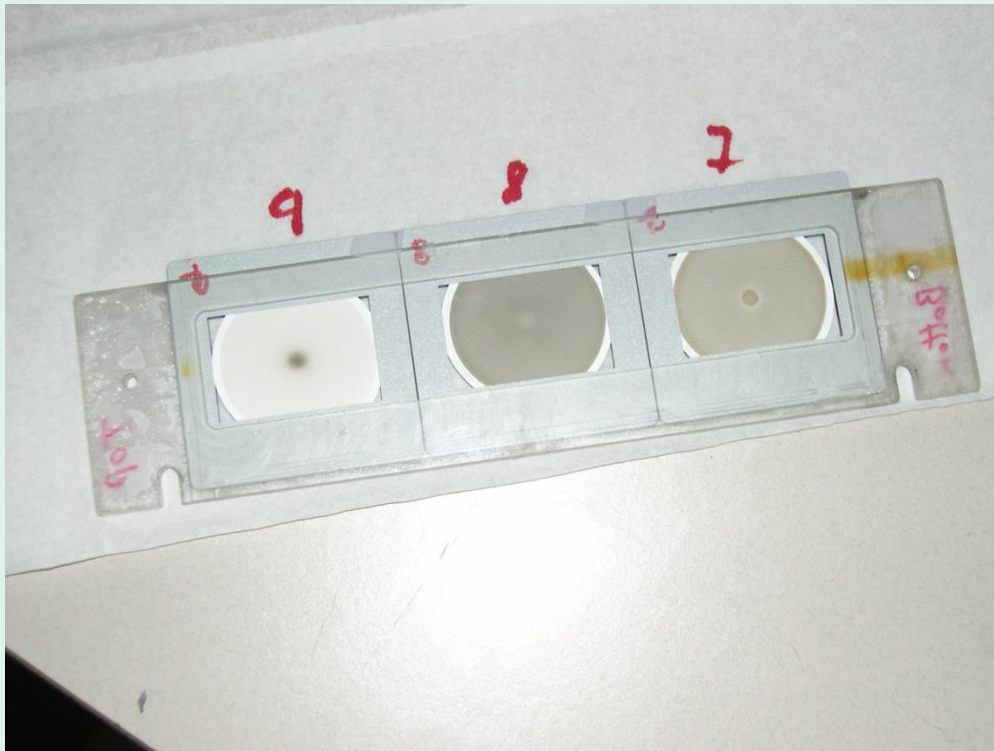
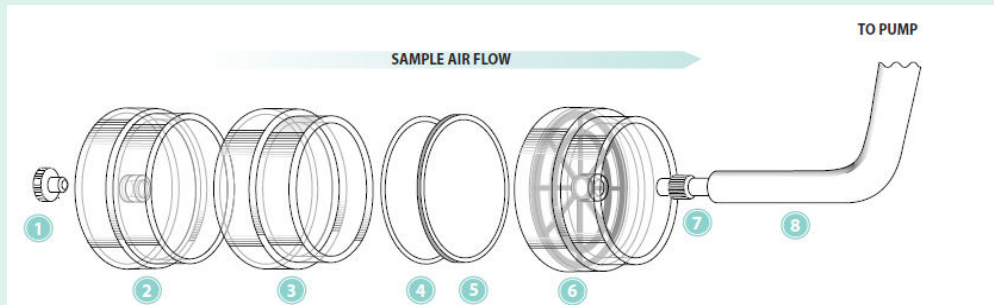
# Hands-on



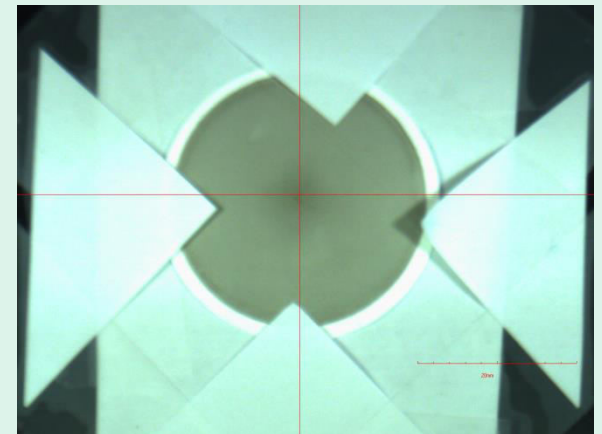
# Sampling Methods

- TSP: 37 mm Mixed Cellulose Ester (MCE)
- Multistage (9 stages) Inertial cascade Impactor using Kapton coated membranes (with cutoff diameters:  $(16 - 0.06) \mu\text{m}$ )
- Double stage Low volume Sampler ( $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ ):  
47mm Teflon Filters for  $\text{PM}_{2.5}$  and Custom designed ring filters for  $\text{PM}_{10}$

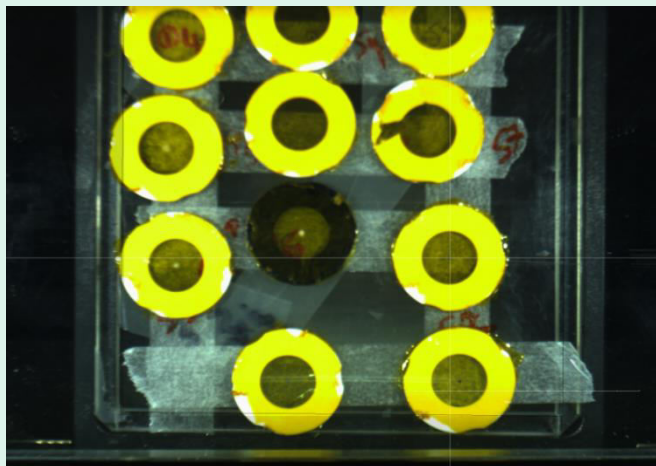
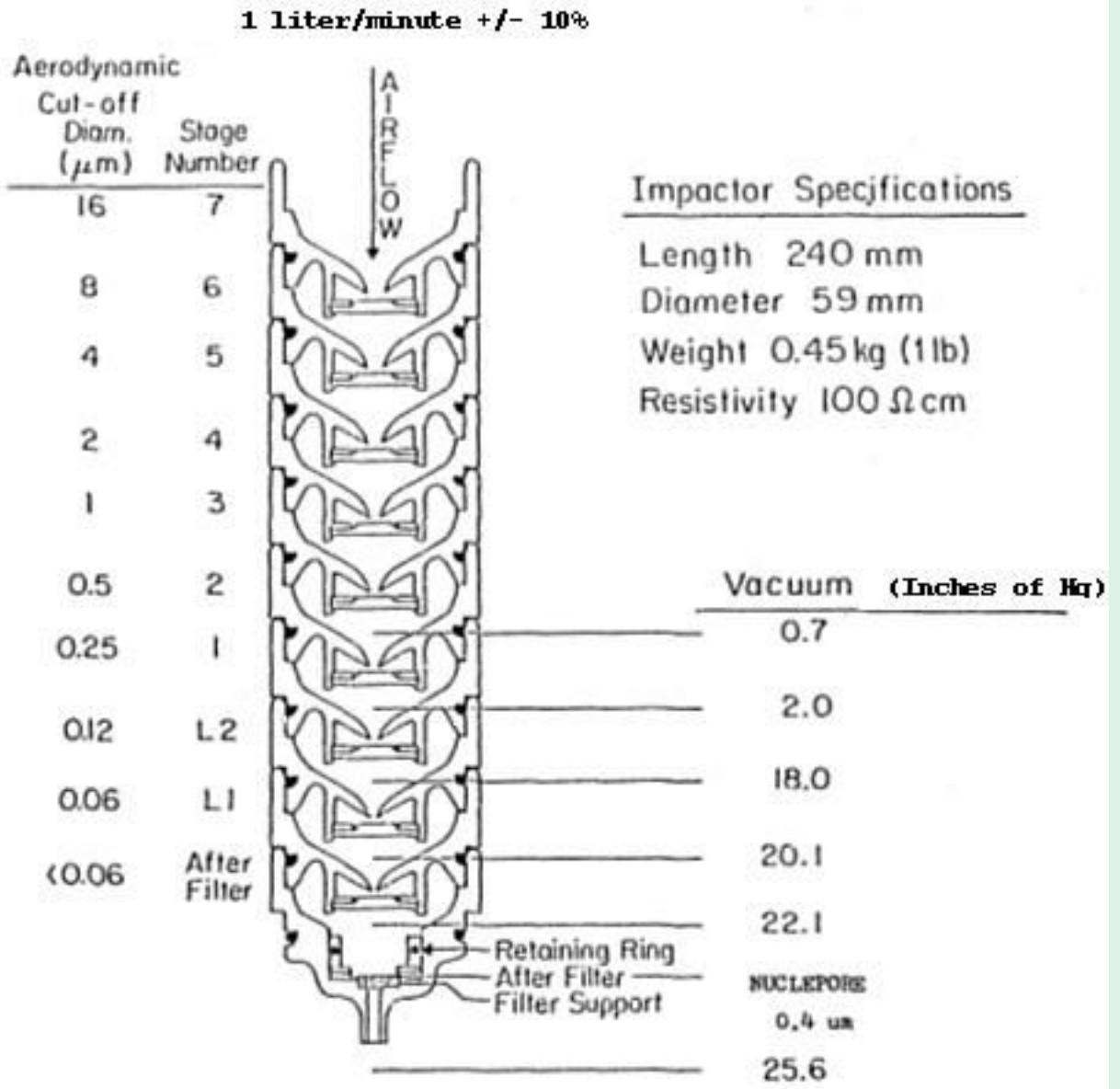
# TSP Sampling



Three-piece 37mm cassette







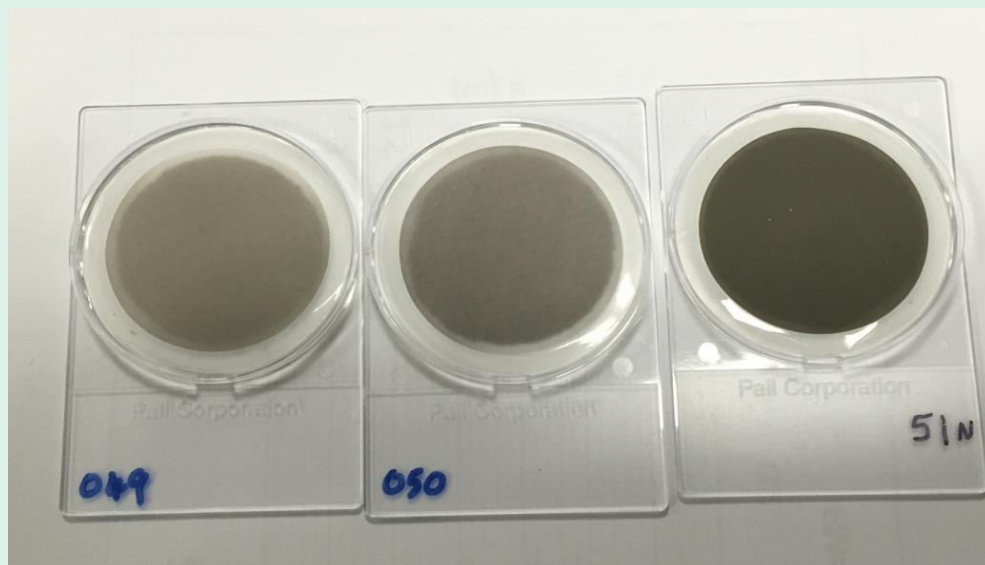
**Multistage inertial cascade impactor**



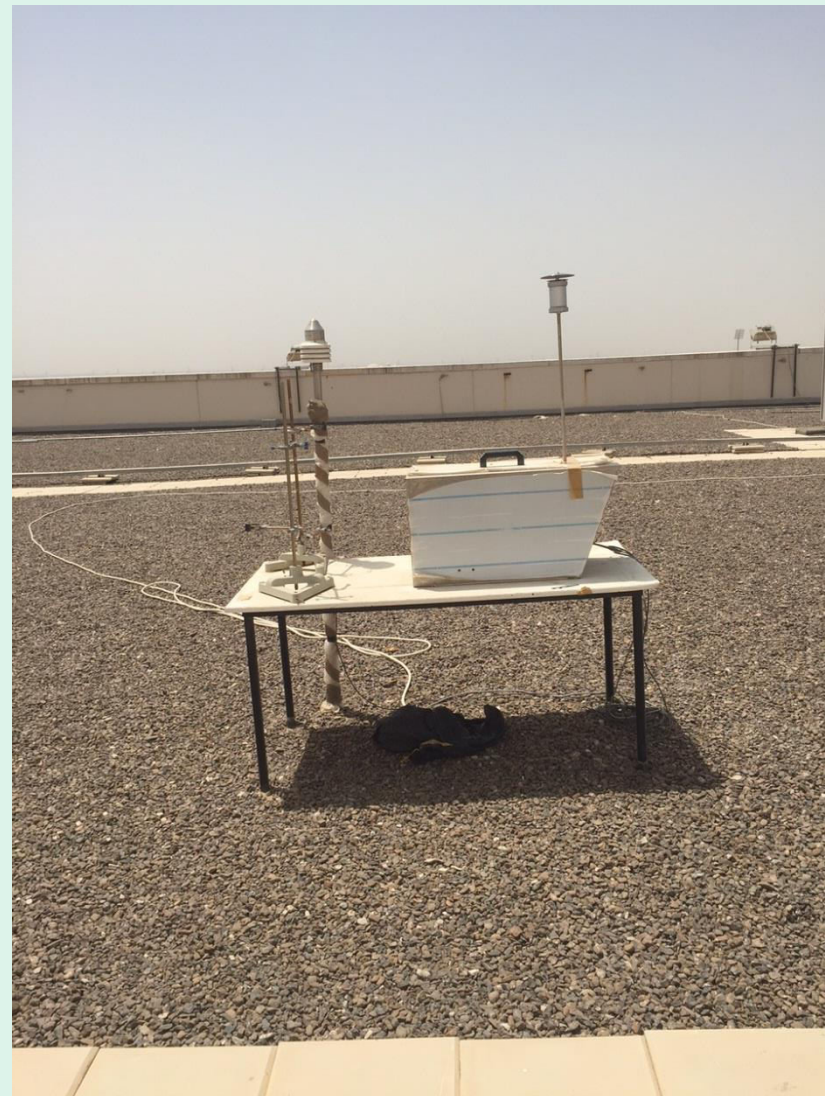
# ISAP<sup>®</sup> 1050e with dual inlet sampling head



**Sampling Site for phase I: AUS; roof between student center and  
CAD: October 15, 2014 – March 20, 2015**  
**Sampling site for Phase II: Roof of the main building (March 26-  
December 2015)**



**Double stage sampler ( $PM_{2.5}$  and  $PM_{10}$ )**



**New site: AUS Main Building  
Roof; starting April 5**

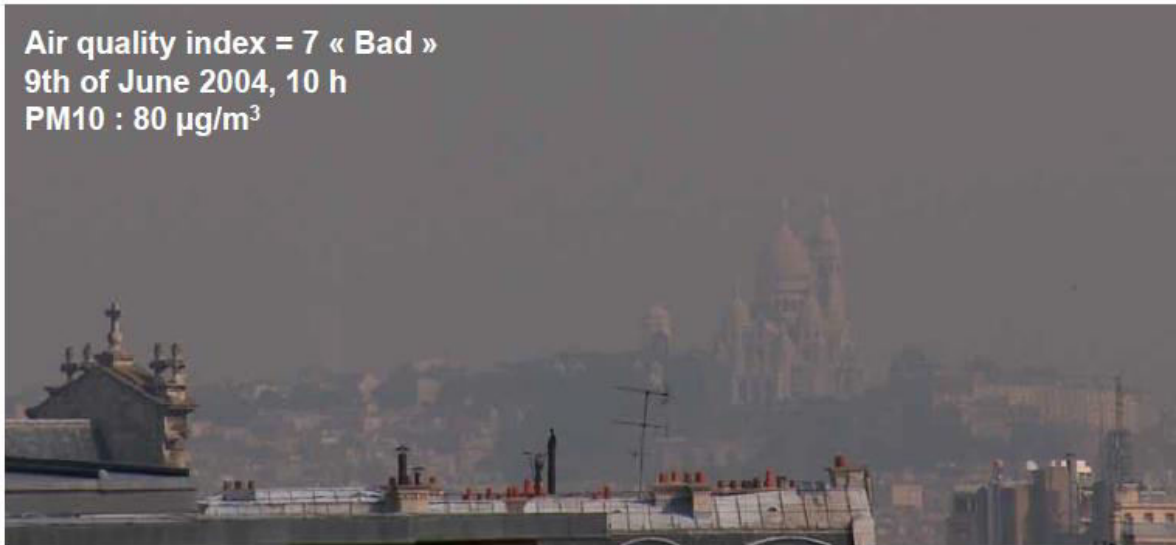
# An Important Issue: Visibility

## Paris

Air quality index = 3 « Good »  
14th of June 2004, 10 h  
PM10 : 20  $\mu\text{g}/\text{m}^3$



Air quality index = 7 « Bad »  
9th of June 2004, 10 h  
PM10 : 80  $\mu\text{g}/\text{m}^3$



Courtesy of  
Paulo Prati

# Desert Storms





# Impact on Cultural Heritage



Courtesy of  
Paulo Prati

# TS: MCM Filters

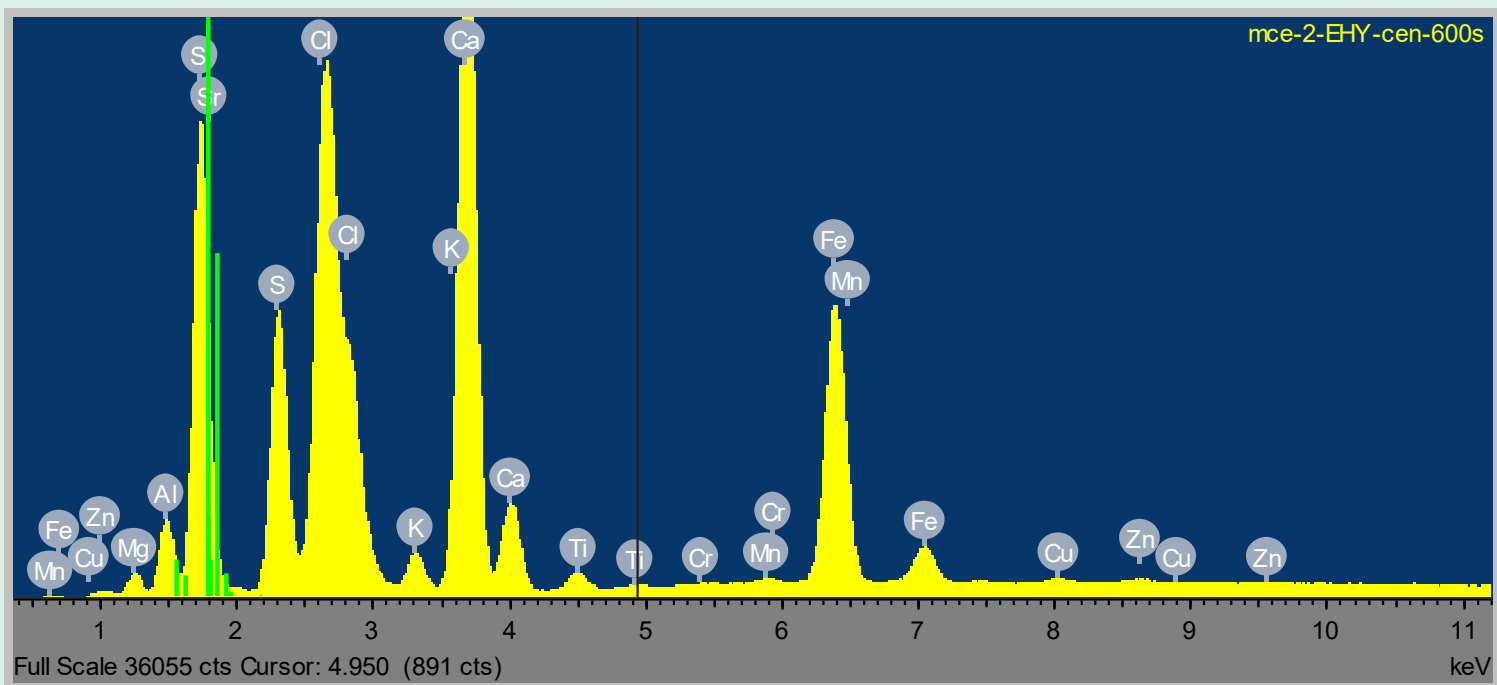
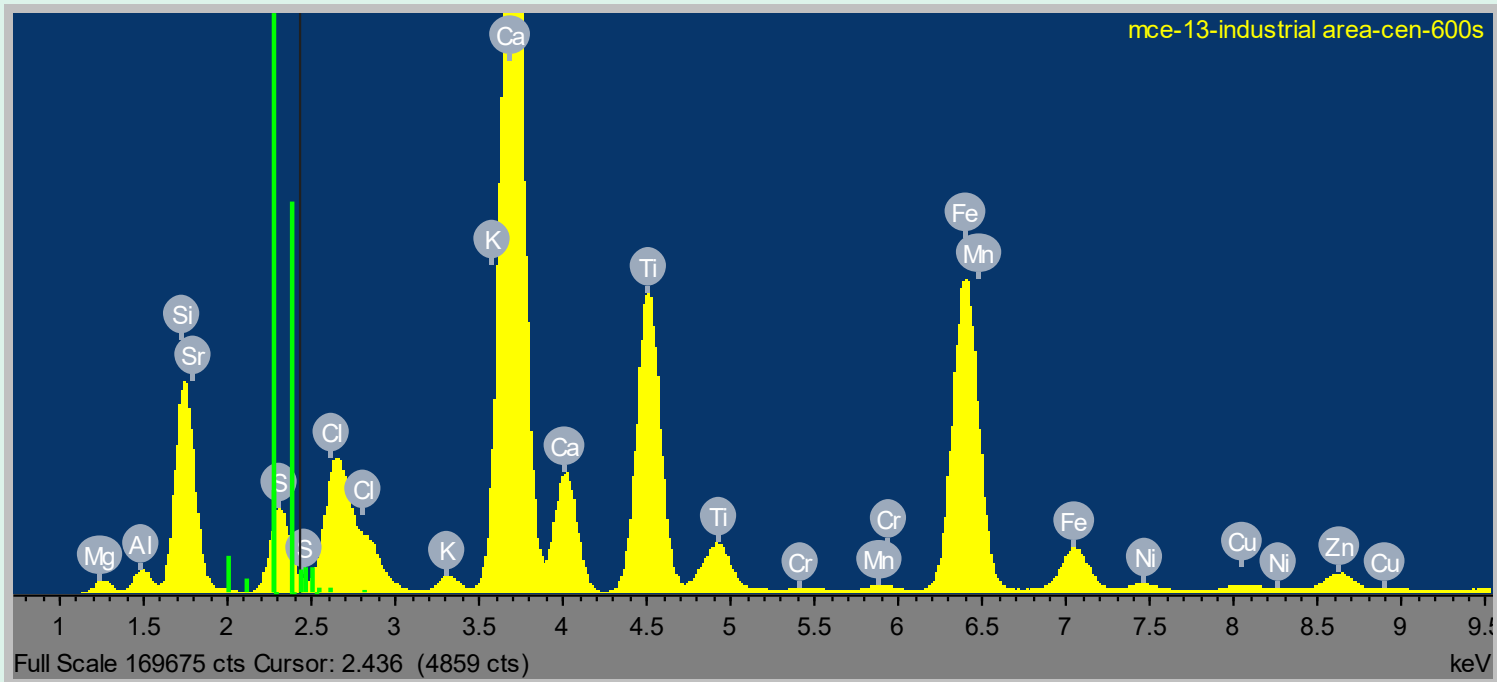
Sampling:

Urban

Traffic

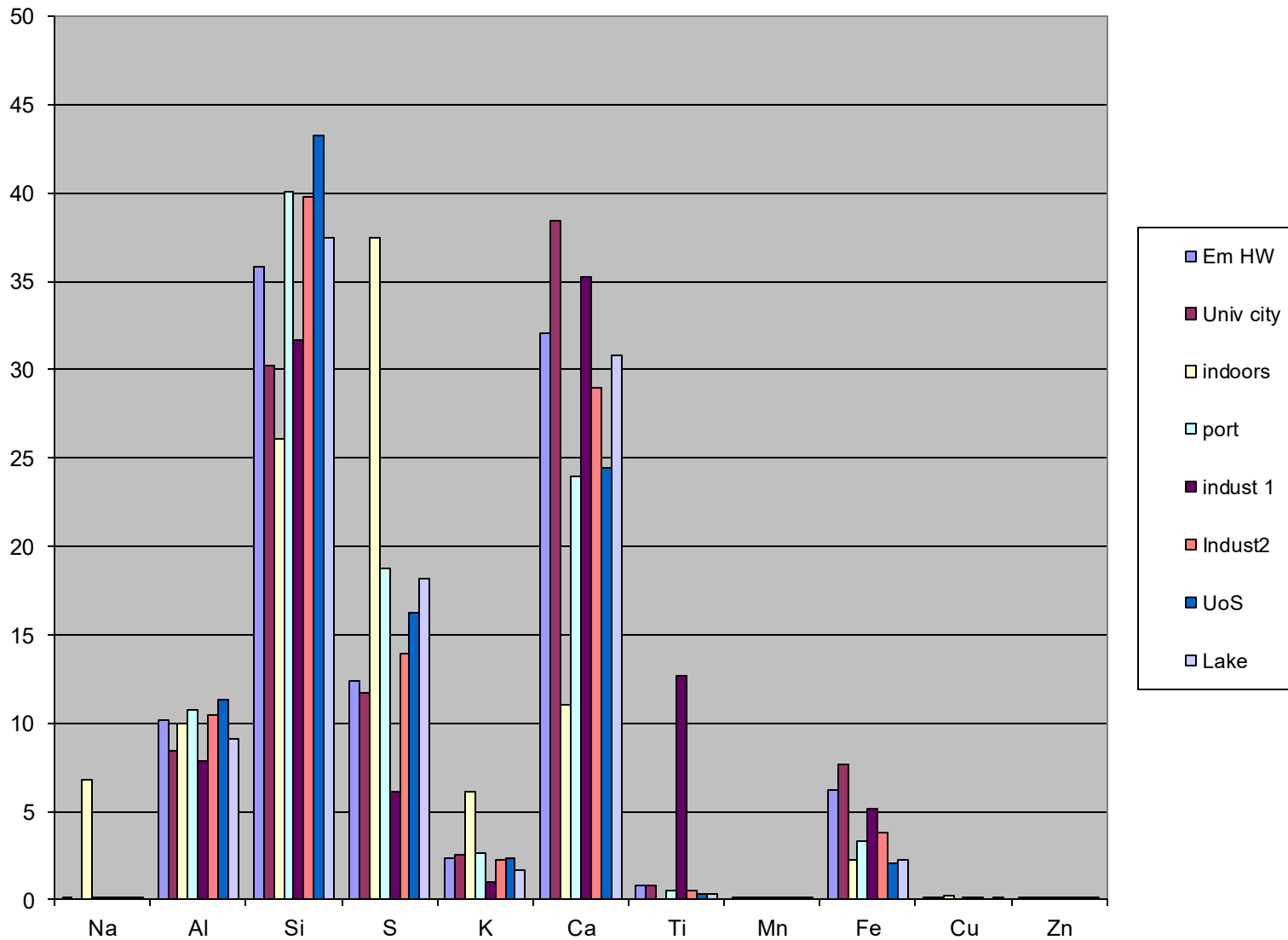
Industrial

Urban background





# TSP: elemental distribution

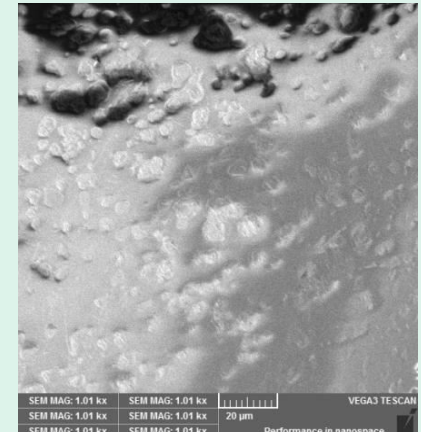
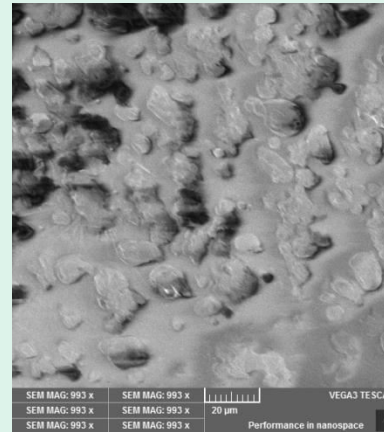
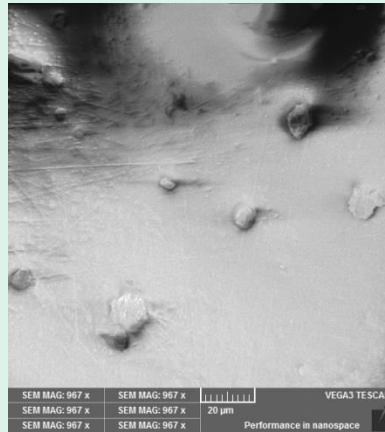


# **Size distribution of pollutants**

**Using multistage cascade impactor**

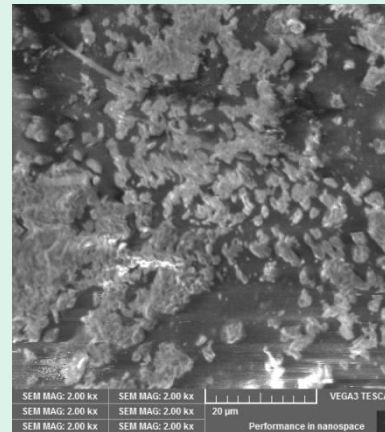
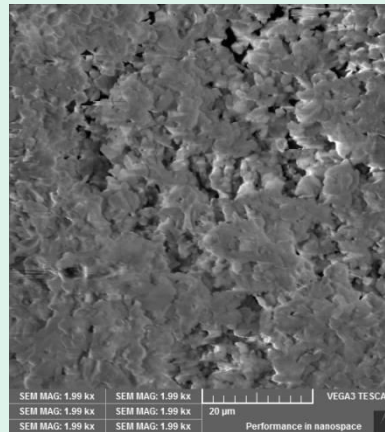
# Sampling sites





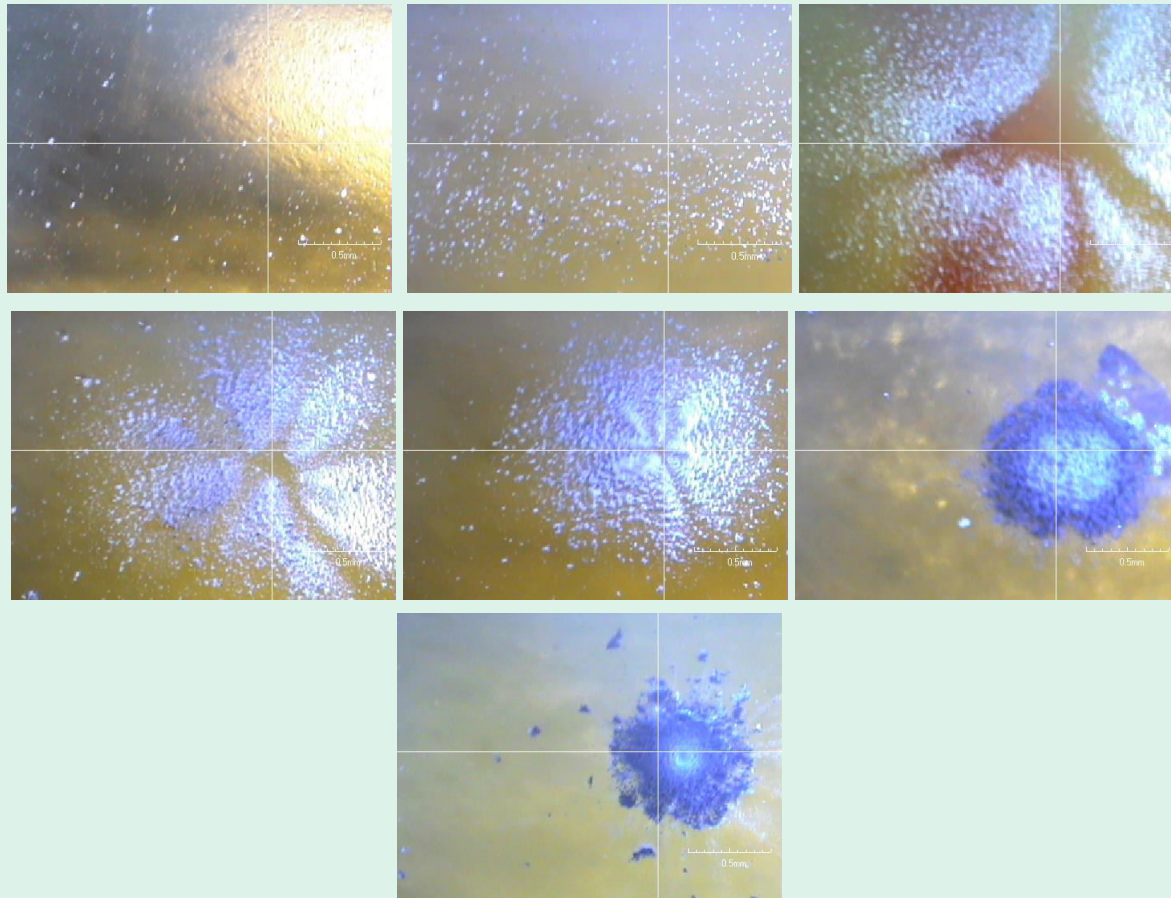
**SEM Micrographs: cutoff diameters: 16, 8 µm;  
X1000**

**SEM Micrographs: cutoff diameters: 4,2 µm; X1000**

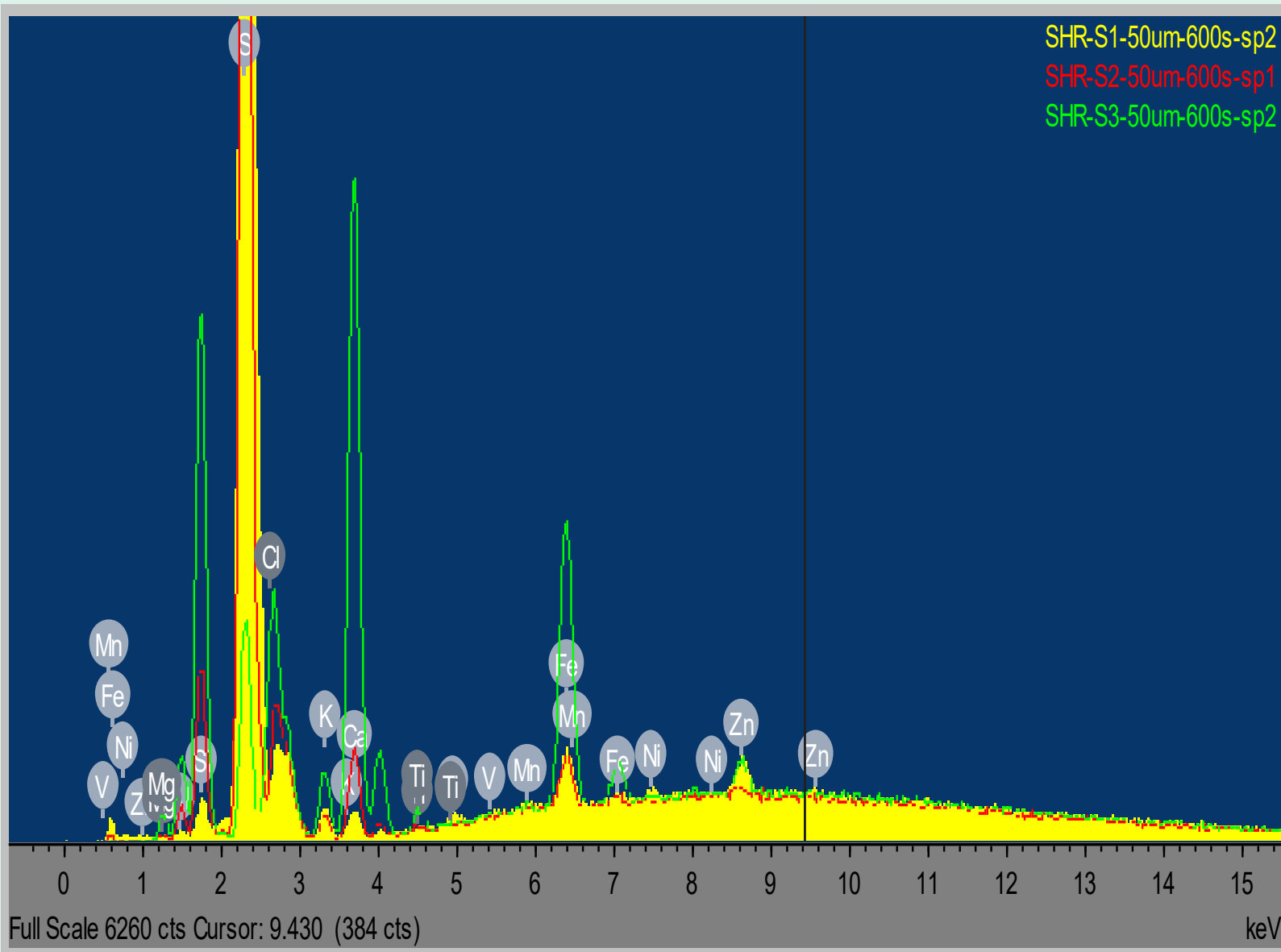


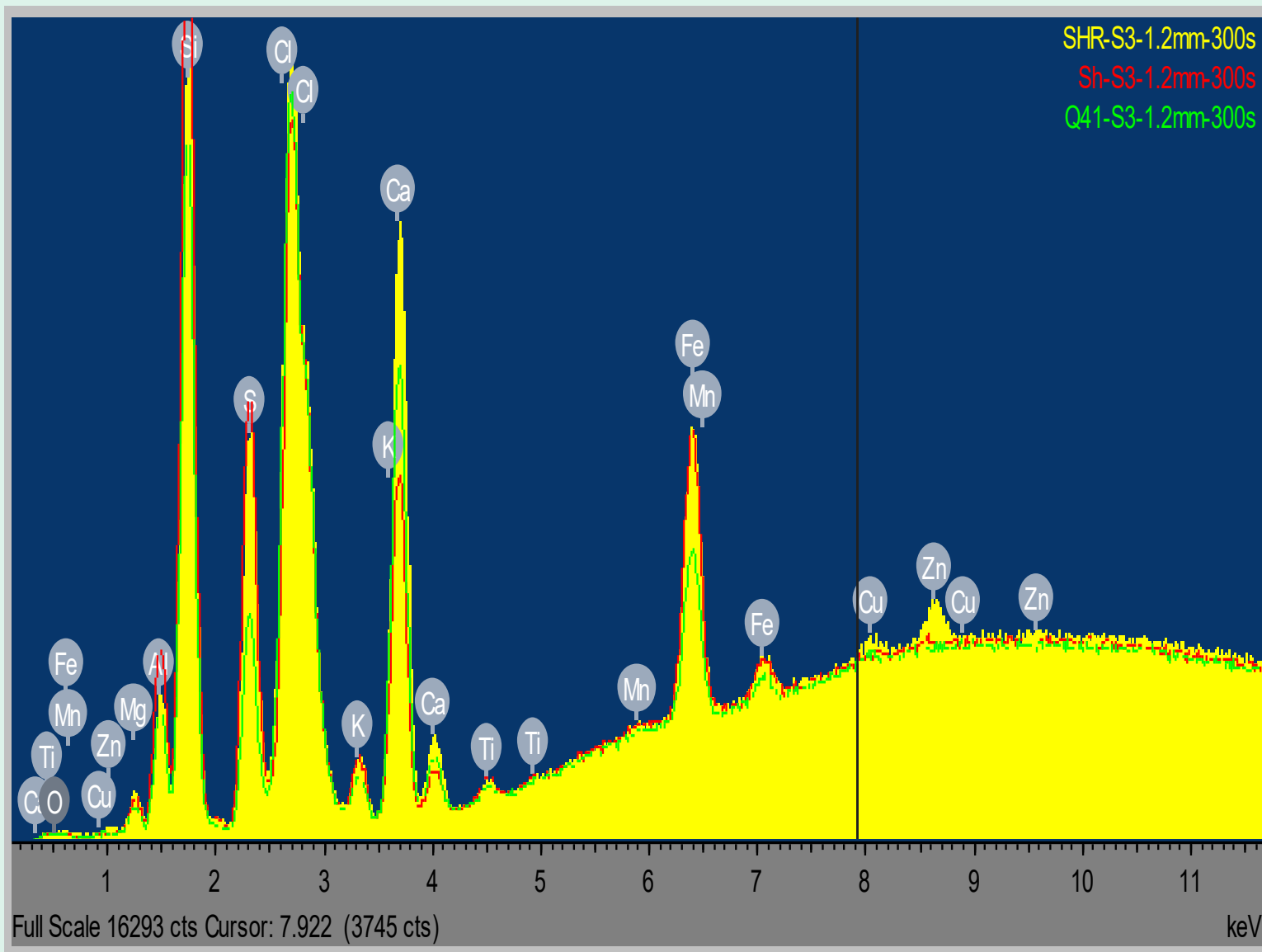
**SEM Micrographs: cutoff diameters: 1, 0.5 µm; X2000**



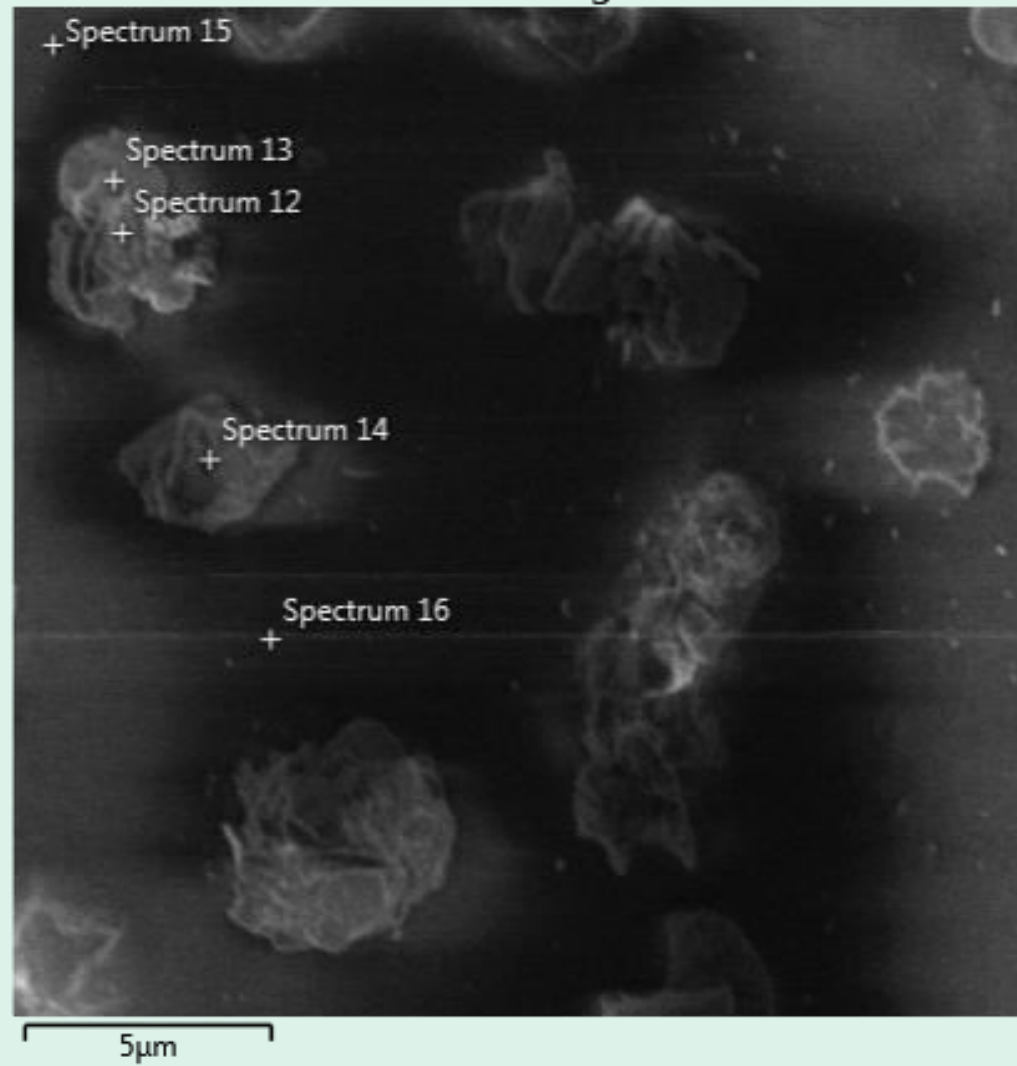


Optical images obtained inside the XRF spectrometer for all seven stage filters of samples SHR (with cutoff diameters: 16, 8, 4, 2, 1, 0.5, 0.25  $\mu\text{m}$ ) showing that the fine particles are the dominant pollutants in Sharjah.

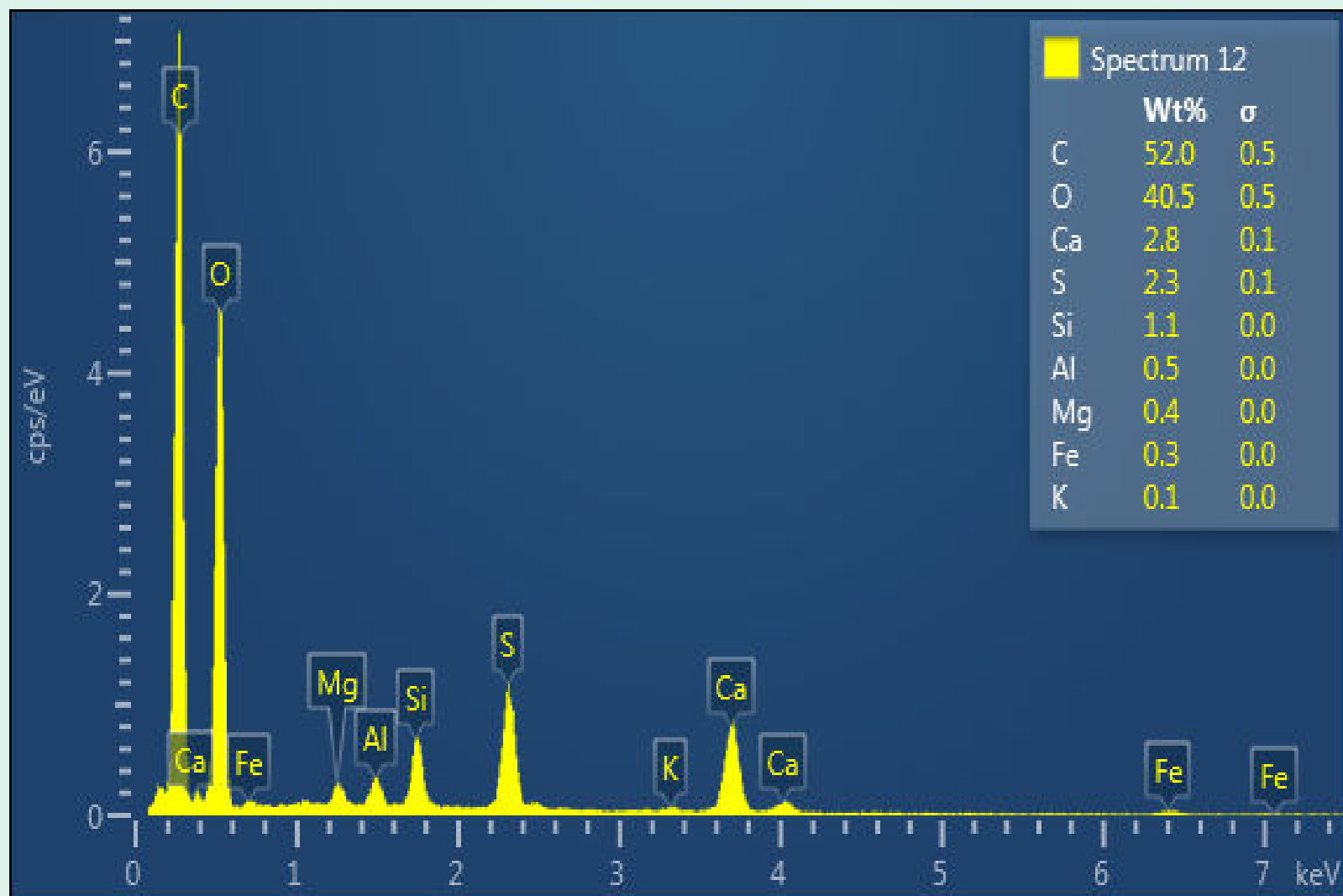




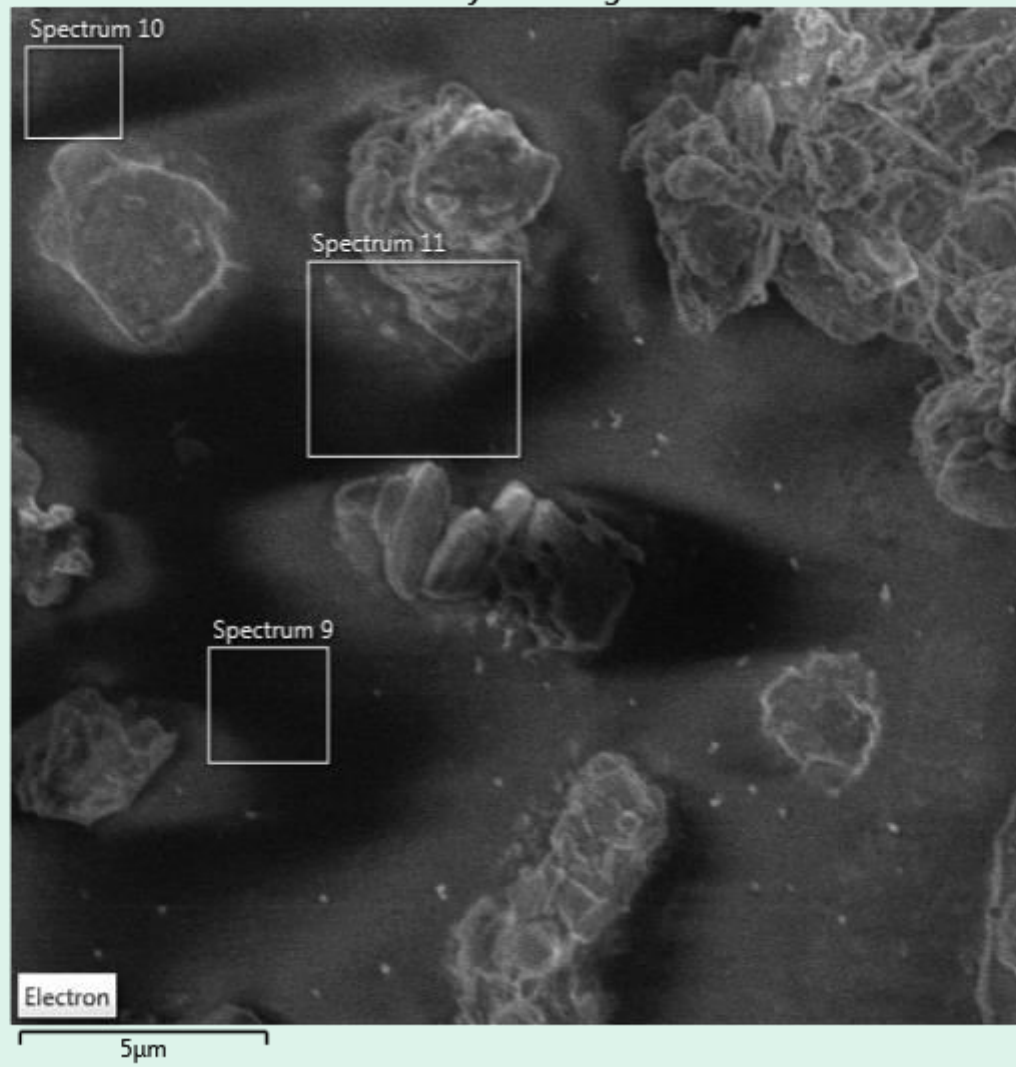
Electron Image 3







EDS Layered Image 2



**Other projects**

**IAEA REGIONAL PROJECTS**

# Urban Background PM Mapping Project

## IAEA RAS0072 Project

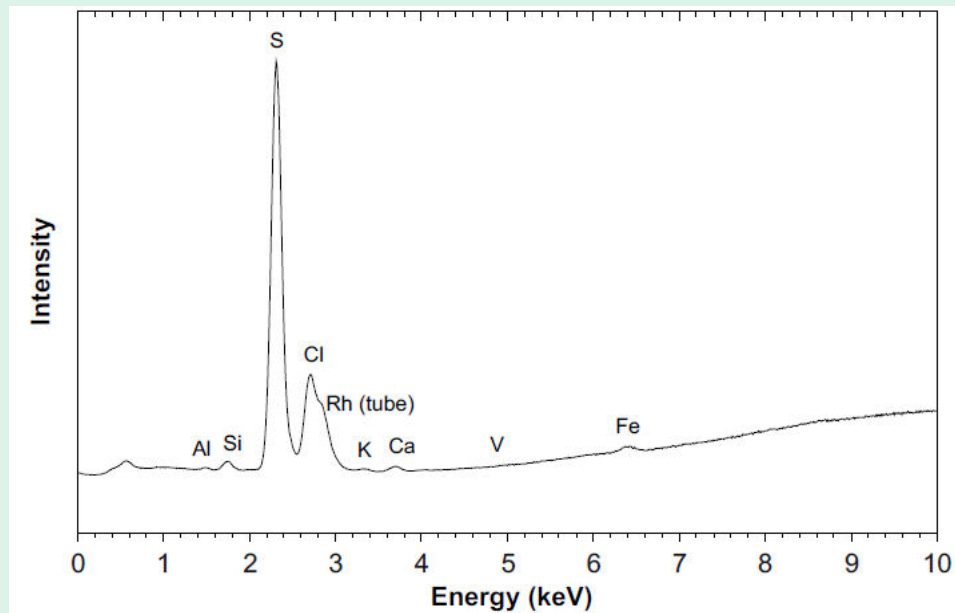
- Regional project (9 countries involved: **UAE, Lebanon, Jordan, Oman, Syria, Yemen, Iraq, Qatar, Saudi Arabia**)
- Simultaneous sampling (Common: PM<sub>2.5</sub>, ours both PM<sub>2.5</sub> and PM<sub>10</sub>)
- Common Analysis (Gravimetric, XRF IBA)
- Our analysis: XRD, SEM and RAMAN
- 24 h sampling every six days starting October 15, 2014 until December 31 2015



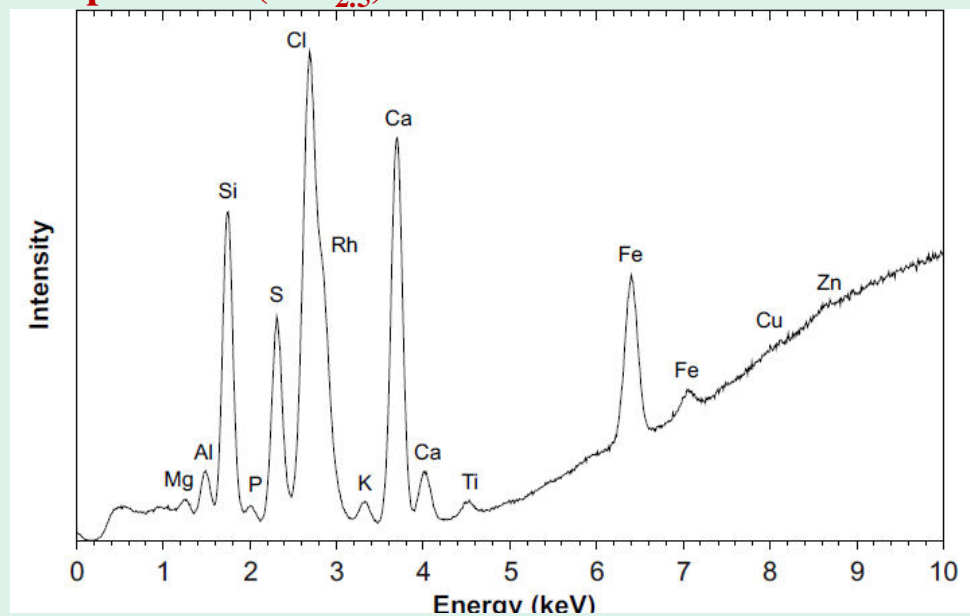
# Gravimetric Analysis

For urban  
background  
PM<sub>2.5</sub> samples  
collected from  
AUS site on 47  
mm  
Teflon Filters

Filter #	mg/m <sup>3</sup>
<b>26</b>	<b>0.042985</b>
27	<b>0.029651</b>
28	<b>0.031863</b>
<b>29</b>	<b>0.043478</b>
<b>31R</b>	<b>0.063264</b>
<b>31</b>	<b>0.065952</b>
32	<b>0.020975</b>
33	<b>0.028497</b>
34	<b>0.018953</b>
35	<b>0.019476</b>
36	<b>0.032317</b>
<b>37</b>	<b>0.042325</b>
38	<b>0.033583</b>
39	<b>0.024792</b>
40	<b>0.043696</b>
41	<b>0.04656</b>
42	<b>0.030849</b>
48	<b>0.022812</b>
43	<b>0.017497</b>
44	<b>0.034364</b>
45	<b>0.033086</b>



**XRF spectrum PM particles (PM<sub>2.5</sub>) that were collected on a 47 mm Teflon filter.**



**XRF spectrum for the coarse particles with cutoff diameter of 10 μm that was collected on the ring filter with the ISAP sampler.**

# Elemental Contents Present in PM2.5

Elemental contents present on few PM2.5 filters (Mass%)

filter No	Mg	AL	Si	S	Cl	K	Ca	Ti	Cr	V	Mn	Fe	Zn	Br	Sr	Pb
26	0	0	49	32	0	2.7	13	0.4	0	0.12	0.1	3	0.1	0	0	0
27	9	9.5	28	46	0	0	5.7	0.2	0	0	0.1	1.1	0.1	0	0	0
29	0	0	30	44	0	2.3	21	0.4	0.05	0	0.1	2	0.1	0.01	0.02	0.05
31	0	0	57	14	4.5	3.8	17	0.6	0	0.12	0.1	3.4	0	0	0	0
32	10	8.8	34	36	0	0	8.8	0.2	0	0	0	1.4	0.1	0	0	0
35	0	0	4.6	87	7	0	0	0	0	0	0	0.7	0.6	0	0	0
48	4.9	5	11	65	8.3	3.3	3.6	0.2	0	0	0.1	0.8	0	0.01		0
37	13	10	38	21	0	1.4	14	0	0	0	0	1.7	0	0	0	0.2
39	6.5	4	14	65		2.8	6.7	0.1	0	0.06	0.1	0.8	0	0.01	0	0.2

# Publications

- Nasser M. Hamdan, Hussain Alawadhi, and Najeh Jisrawi, "Elemental and Chemical Analysis of PM<sub>10</sub> and PM<sub>2.5</sub> Indoor and Outdoor Pollutants in the UAE," *International Journal of Environmental Science and Development* vol. 6, no. 8, pp. 566-570, 2015.
- Nasser Hamdan, Hussain Alawadhi and Najeh Jisrawi, "Elemental Identification, Chemical Speciation And Source Apportionment Of PM<sub>10</sub> And PM<sub>2.5</sub> Indoor And Outdoor Air Pollution In The UAE" Qatar Foundation annual Research conference, November 17-18, 2014
- Hamdan Nasser, Najeh Jisrawi, and Hussain Alawadhi. "Size-dependent elemental analysis of particulate matter pollutants in the UAE." Paper presented at the Qatar Foundation Annual Research Conference 2013, November 24-25, 2013.
- N. M. Hamdan, N. Jisrawi H. Alawadhi, "Particle Size distribution of Aerosol Pollutants in Dubai" *Proceedings of the International Conference on Environmental Pollution and Remediation* Ottawa, Ontario, Canada, 17-19 August. (A Peer Reviewed Proceeding Article).
- Hamdan N.M., Alawadhi H. and Jisrawi N., Recent Activities at the National X-ray Fluorescence Laboratory (NXFL), United Arab Emirates IAEA XRF Newsletter Vienna, Issue No. 23, September 2012, p:20-26
- Hamdan N.M., Jisrawi N., Alawadhi H., AIR POLLUTANTS IN THE UAE: A STUDY OF AEROSOL PARTICLES USING  $\mu$  X-RAY TECHNIQUES" First progress report of the international Coordinated Research Project (No.1576), International Atomic Energy Agency, Vienna, Austria, March 15, 2011.
- Hamdan N.M., Jisrawi N., Alawadhi H., AIR POLLUTANTS IN THE UAE: A STUDY OF AEROSOL PARTICLES USING  $\mu$  X-RAY TECHNIQUES" Second progress report of the international Coordinated Research Project (No.1576), International Atomic Energy Agency, Vienna, Austria, May 16, 2010.



**Thank You For Your Attention!**