THE COLLABORATIVE IAEA TC PROJECT ON THE INVESTIGATION OF FINE AND COARSE ATMOSPHERIC PARTICULATE MATTER IN ARASIA REGION

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ABSTRACT

There is lack of enough data and study dealing with air pollution in Arasia region (Arab countries in Asia). Since atmospheric particulate matter PM10 and PM2.5 are trans-boundary and can effectively contribute to air pollution in certain localized areas, it is proposed to investigate these air pollution factors in a regional context. This work is a part of a study conducted among several Arab countries in West Asia, under an IAEA regional technical cooperation project for Arasia region. In a first phase, some preliminary results were obtained as moderate number of samples was collected from the different participating countries. It concerned the characterization of fine particles (PM2.5), collected on Teflon filters every sixth day for 24-h with an air flow of 2.3 m^3/h, as weight in air volume and elemental composition using only PIXE technique. Some of these first results confirmed the high values of PM2.5 as predicted and showed some similarities in the variability with time of the obtained results when the concerned sampling areas are close, such as Beirut, Amman and Damascus. However, in the subsequent ongoing phases, more samples per country are collected, as continuous sampling is still running since several months at the rate of two days per week. So, this behavior of the PM variability could be better highlighted when compared between the different sampling sites.

KEYWORDS
Air pollution, APM, ARASIA, PIXE, PM2.5

1. INTROCUCTION

Air pollution is a worldwide problem that can affect the environment and human health. Therefore, the COP21 conference [1], which was held in Paris end of 2015, aimed to increase awareness and to agree on the necessary practical steps to undertake in order to limit the anthropogenic gas emissions. In fact, atmospheric aerosols or particulate matter (PM) are considered one of the most challenging environmental issues, since they play a crucial role in atmospheric processes and climate change. Furthermore, they have harmful effects on the ecological system and human health. Indeed, several studies highlighted the fact that aerosol exposure is associated with diseases related to respiratory system, lung cancer and heart problems [2]. The severity of the PM effects usually depends on some related properties like the particle size and composition. By convention, atmospheric aerosols are classified according to their aerodynamic diameter, hence, the most studied are PM_{10} and $PM_{2.5}$ (particulate matter having aerodynamic diameter less than 10 and 2.5 µm respectively). Usually, more attention is given to $PM_{2.5}$ (called also fine particles) as they can go deeper into the respiratory system of human body and can even be transferred to the blood circulation system. Atmospheric aerosols and environmental issues have largely been recognized not to have geographic boundaries and therefore, collaborative regional and perhaps international efforts must be integrated and coordinated as part of regional responsibility to study air pollution and to assess the adverse effects on human health and environment.

The ARASIA region is a geographical group that includes the Arab states in Asia that are members of the International Atomic Energy Agency, IAEA, and include Iraq, Jordan, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen and recently Kuwait joined this group (Fig. 1).

Figure 1. A map of the ARASIA countries

In this region, there is lack of enough analytical data and study dealing with the issue of air pollution and air quality. It is obvious from the few studies conducted in the Eastern Mediterranean region that Particulate Matter (PM) levels in air are higher than in other region, even when compared to the Western Mediterranean [3-7]. Most probably, high PM background levels in ARASIA region cities could be attributed to several factors like high population density, frequent dust outbreaks, low precipitation rates, poor vegetal coverage and, in some cases, lack of rules and regulations concerning PM levels. Besides, this area 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. This region can be exposed to several sources of air pollution, natural or anthropogenic, local or trans boundary, Saharan dust and storm, marine aerosols, emission from urban activities, petroleum refinery, fuel combustion, vehicular traffic, biomass burning, industrial activities from Europe in the West and from India and south Asia in the East, etc. In this context, ARASIA member states have made the strategic decision to embark on the establishment of a collaborative network to study pollution problems related to atmospheric aerosols, and to emphasize their contribution to improve air quality of the region. This work is a part of an IAEA regional technical cooperation project started in 2014 (IAEA TC project RAS/0/072) and it is still operational under the IAEA TC project RAS/0/076. This continuous collaborative project is based on the sampling and elemental analysis of urban background air pollutants, using harmonized sampling and analysis protocol in all participating member states. For now, it mainly focuses on gravimetric measurements and on the elemental analysis of PM2.5 pollutants using *ion beam analysis* techniques IBA, in particular "*proton induced X-ray emission*" technique PIXE. In fact, these techniques have been proven to be an effective tool for studying materials or objects pertinent to applications in different fields such as materials science [8], art and archeology [9], environment, bio-medicine, etc. Furthermore, it was aimed to build human capacities and expertise in ARASIA MS related to environmental air pollution monitoring. The first campaign of sampling and analysis has revealed for the first time a database of PM elemental concentrations in the region and in a regional context. Some of these first results confirmed the high values of PM2.5 as predicted and showed some similarities in the variability with time of the obtained results when the concerned sampling areas are geographically close, such as Beirut, Amman and Damascus. However, in the subsequent ongoing phases, more samples per country are collected, as continuous sampling is still running since several months at the rate of two days per week. So, this behavior of the PM variability could be better highlighted and inter-compared between the different sampling sites. Indeed, these primary obtained results are expanded and pursued by some follow up subsequent sampling campaigns, using additional samplers in each country to cover residential and urban areas thus increasing the number of collected aerosol samples. Thus, it is expected that more valuable data will be produced during 2018, allowing pollution source apportionment using models such as the Chemical Mass Balance Model (CMB) and the Positive Matrix Factorization model (PMF). The identification of local or regional pollution sources in PM 2.5 and PM10 is very essential for enforcing measures to improve the air quality in the region. Finally, some results, as well as experimental setup including sampling protocol, will be shown and discussed in this paper.

2. EXPERIMENTAL

2.1. Sampling and site

Under the collaborative project, it was agreed between the participating countries to start a first campaign of sampling in October 2014. The sampling sites were identified in each participating member state, mainly to represent the urban background of PM10 and PM2.5. The protocol consists of 24 hours sampling, starting at midnight, every six days, on thin Teflon filters from PALL (47 mm diameter, 30-40 µm thick and 2-3 µm of pore size). The collection of $PM_{2.5}$ samples was assured by the same model of sampler, ISAP®1050e (Fig. 2), having a cascade impactor and air flow rate at 38 L/min (the device is conform to European directives and standards). A greased metal plate at the air entrance allows the retention of particulate matter larger than 10 µm of aerodynamic diameter, while the coarse particles $PM_{10\text{-}2.5}$ are retained on a greased customized ring shaped filter made by a very thin propylene foil with a thickness of few microns (Figure 1). The $PM_{2.5}$ Teflon filters were weighed by a microbalance presenting an accuracy of 1 µg, before and after sampling, according to a routine protocol and under the same conditions (50 ±5% of relative humidity, 24 ±1°C of ambient temperature, pre-conditioning, static charge elimination, storage, handling, repeatability and reproducibility of measurements).

Figure 2. Microprocessor Controlled Aerosol Sampling device ISAP 1050e with combined inlet for $PM_{10\text{-}2.5}$ and $PM_{2.5}$

In Lebanon, samples are collected from an urban area in the southern part of Beirut, at the Lebanese Atomic Energy Commission (LAEC) site, located at the airport road, heavy traffic, in front of a very populated area, 1 km from the sea and 2 km away from the International airport. In Jordan, samples are collected at the campus of the University of Jordan in Amman, an urban background site at the center of the Faculty of Science and far from traffic. In Syria, samples are collected from two different sites, one is located at Damascus center in an urbanized residential area located at Kafarsouseh and the other is a rural site which is far from car traffic and populated areas. In Iraq, Baghdad site is located at the Ministry of Science and Technology (MOST) in a crowded and populated urban area in the center of Baghdad, characterized by car traffic, 3-4 km far from a power station and an oil refinery and 500 m away from the river. In United Arab Emirates, samples are collected at the campus of the American University of Sharjah in Sharjah. In Yemen, the project counterparts are still collecting samples, despite the difficult situation in Sana'a due to the civil war, and many of these samples are already analyzed and characterized. In fact, the collected samples cover different seasonal and meteorological conditions (fall, winter, rainy, dusty, dry, sunny, windy, etc.). During the second phase which was started in May 2017 and is still ongoing, the sampling frequency is twice a week and synchronized in all participating countries. Thus, the collected samples will be more representative of time and seasonal variability.

2.2 Analytical setup

In Arasia region, several capabilities can contribute to perform the elemental analysis of the aerosol samples collected on Teflon filters. The used techniques are mainly XRF and PIXE (X-ray fluorescence and proton induced X-ray emission), with full capabilities at Sharjah and Beirut respectively. In this paper, only a brief description of the Lebanese facility will be given. It is based on a tandem Pelletron accelerator (Fig. 3) from NEC of 1.7 MV, model 5SDH [10]. The elemental composition of the samples is measured by a conventional in vacuum PIXE. The multipurpose scattering chamber, 30 cm diameter, is designed to carry out simultaneous ion beam analysis techniques, when necessary, such as PIXE, RBS and PIGE.

Figure 3. Side view of the tandem Pelletron accelerator 5SDH

The beam hits the target under normal incidence with a beam spot of 2-3 mm of circular shape. The detection of characteristic X-rays is assured by an AMPTEK SDD of 0.5 mm Si crystal thickness, 17 mm^2 of collimated area and 8 µm thickness of Be window and 130 eV measured FWHM energy resolution at 5.9 keV, placed at 135° to the beam direction. A well calibration of the detection system (filter thickness, solid angle or geometry) was done in order to have no energy dependence of the so-called H value, using a set of Micromatter standards (Fig. 4). PIXE spectra are processed with the Gupixwin package (Guelph PIXE software package with Windows version) [11]. This software code is based on the fundamental parameter approach including x-ray production cross sections, x-ray attenuation coefficients, proton stopping powers, detector efficiency, collected charge and geometry effects to produce an output of elemental concentrations in ppm or in µg/cm^2 for thin target as it is the case for aerosol samples.

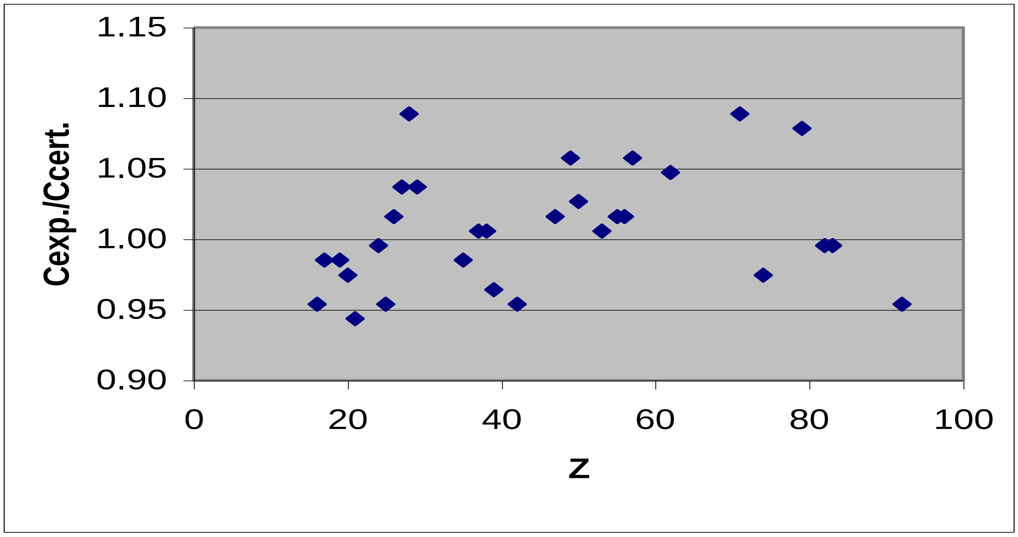

Figure 4. A fixed H value for PIXE measurements is determined from the ratio of the experimental concentration over the certified one, as function of the atomic number from S to U using Micromatter thin film standards.

3. MEASUREMENTS AND CASE STUDIES

As mentioned above and shown in the previous figure 3, a set of Micromatter thin film standards is used to calculate the solid angle or what it is called the H value, in order to calibrate the PIXE conditions setup. To check accuracy of the experimental setup, before analyzing the studied samples, the multi-element thin film standard from NIST (SRM-2788) was analyzed and showed close results to the certified values (Table I).

Table I. Comparison of the experimental values obtained by PIXE and the certified values of the NIST standard SRM-2788

	Si	S	K	Ca	Ti	Mn	Fe	Ni	Cu	Zn	Pb
LAEC	6.894	0.163	0.505	1.346	0.153	0.034	2.646	0.009	0.037	0.18	0.031
CV	5.884	0.105	0.53	1.325	0.15	0.032	2.661	0.007	0.041	0.18	0.032

The analysis protocol consists on using a proton beam of 3 MeV energy and of low intensity (~5 nA) with a beam charge of few µC. To protect the detector from the hazardous effects of the backscattered protons and to have the maximum detection of potential elements including the low z ones, a thinnest possible Kapton® filter (~87 µm of thickness) is positioned in front of the SDD detector. Therefore, it is possible to detect and quantify, in just one run using 3 MeV proton beam, with enough accuracy elements as low as Si and above (Fig. 5).

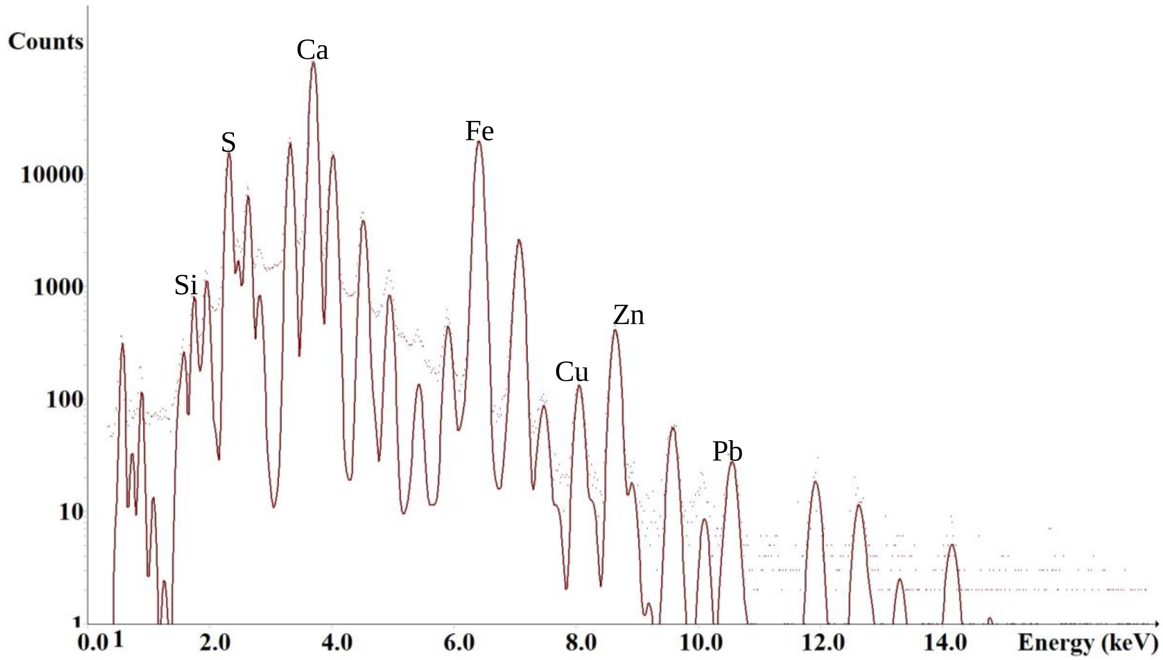

Figure 5. Typical PIXE spectrum of PM2.5-Teflon filter using Amptek SDD. It represents the acquired experimental spectrrum with the fitted one using Gupixwin code

However, it will be better, if necessary, to use two-run measurements: the first one involves the use of 1 MeV proton with no filter in front of the detector, in order to determine the low Z elemental content from Na to Ca. The second run measurement is performed by using 3 MeV protons with a 128 µm Kapton filter, in order to determine elements of medium and high Z, from Ti till Pb. However, PIGE technique can be used as an alternative to PIXE to measure, simultaneously with the 3 MeV PIXE, the concentration of low Z elements, such as Na and Al. Furthermore, it will be also possible to perform RBS measurements, simultaneously with PIXE and PIGE, to determine the total elemental content of C. In this issue, an ongoing promising work is undertaken using Simnra software. In the future, we aim to use dual SDD detectors in order to handle the increased number of samples to be analyzed, using only one run measurement of 3 MeV protons.

From October 2014 till February 2015, a first sampling campaign was started with modest expectations. However, despite the low number of the collected samples, the preliminary results showed some trend of the variability of the PM2.5 masses with time, for the four concerned cities, as well as for their elemental contents (Fig. 6). It can be observed that Amman has the lowest PM2.5 values since it is on a campus while Beirut, Damascus and Bagdad represent sampling in high traffic area. However, Amman and Beirut and even Damascus exhibit similar trend. In Beirut, low values are observed with rain episodes while highest values are related to Monday and Friday (beginning and end of the week). More details about these results are shown in [12]. The below table 2 shows the elemental composition determined by PIXE for some PM2.5 samples collected during March and April 2015 where a mild dust storm occurred.

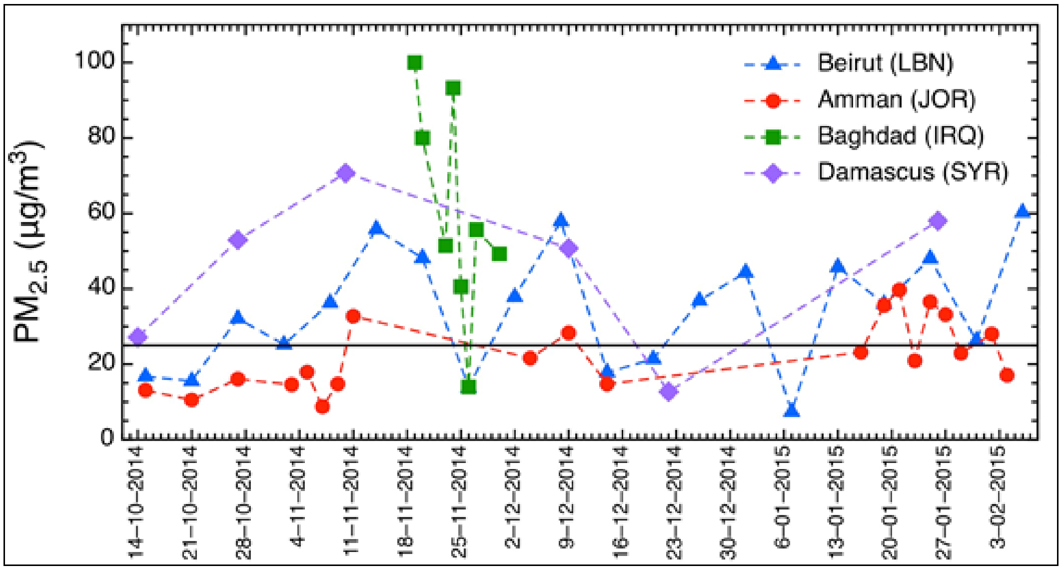

Figure 6. Variation of the PM2.5 with sampling day in four Capital Cities [11].

Table 2. Some of the PIXE results of PM2.5 elemental concentration in ng/cm^2

	Si	P	S	Cl	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn
Tues_10_3_15	5238	239.5	9983	1362	1121	2513	155.8	7.637	48.04	1988	93.9	54.61	395.9
Wed_11_3_15	3928	85.5	5391	2445	820.8	1689	113.3	9.869	25.62	1296	14.58	16.73	143.3
Thur_12_3_15	1287	23.56	2624	1840	331.4	1968	68.07	2.573	12.78	585.2	15.07	120.6	224.5
Thur_16_4_15	9881	7.368	8377	955.3	1314	8370	308.5	10.17	60.6	3336	80.18	48.98	352.6
Wed_29_4_15	15612	0	10867	563.5	1797	8524	460.8	9.069	78.17	4559	87.21	96.57	258.1

4. SUMMARY

This project represents an opportunist work that deals with an important issue about air pollution and air quality in a controversial and challenging region. It aims to a build the necessary infrastructure and human resources, in each participating country and at the regional level, that are capable to deal with such environmental issues which are crucial sometimes. Extensive, continuous and good samplings, as well as the commitment of the participating counterparts are the key success of this project in a regional context. Therefore, a source apportionment and a collaborative network in the region will be derived from this valuable work, and a possible interregional collaboration and synergy would be needed to overcome the hazardous effects of air pollution that should be treated as global.

ACKNOWLEDGMENTS

The author would like to thank the IAEA, though its TC department and NAPC division, as well as ARASIA board for supporting this vital project within the regional technical cooperation programme. I would like also to thank the IAEA for supporting my travel grant to attend the AccApp 2017 conference.

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