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Evaluation and mapping of $PM_{2.5}$ atmospheric aerosols in Arasia region using PIXE and gravimetric measurements

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ABSTRACT

The present work is a part of a scientific study conducted among several Arab countries in west Asia, under an International Atomic Energy Agency (IAEA) regional technical cooperation project for Arasia region. The project aims at producing for the first time a database of particulate matter (PM) elemental concentrations in the region that will help in future air quality studies in order to identify commonalities and differences in the presence and contribution of fingerprint pollution sources among the Arasia Member States. The first regional campaign was launched simultaneously in Lebanon, Iraq, Jordan, Syria and United Arab Emirates, using a harmonized sampling and analysis protocol of PM_{10} and $PM_{2.5}$ samples. Different samples, collected between October 2014 and February 2015, from the participating countries, were analyzed by PIXE technique and gravimetric measurements were also carried out. The first results of the study will be discussed in a regional perspective. Our study shows that concentrations of fine aerosol fractions are often exceeding the WHO standard values as well as showing some disparities in the obtained values between the different sampling sites. However, some trend similarities of variations with time could also be observed, suggesting a common influence by trans-boundary or external sources of air pollution.

1. Introduction

Serious environmental degradation is perceived worldwide, where increasing related diseases have been noticed and have been attributed to environmental pollution. Atmospheric aerosols or particulate matter (PM) are considered one of the most challenging environmental issues, since they play a crucial role in atmospheric processes, climate change and even in the degradation of historic monuments. Furthermore, they have harmful effects on the ecological system and human health. Indeed, several studies highlighted the fact that aerosol exposure is associated with increased risk of mortality and serious illness such as respiratory problems, asthma, lung cancer and heart disease [1,2]. These effects are mainly attributed to aerosol properties like the particle size and composition. By convention, 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.

In Arasia region (Arab states in Asia who are members of the International Atomic Energy Agency, IAEA, and include Iraq, Jordan, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen), there is lack of enough analytical data and of relevant studies dealing with the air pollution issue. In fact, this area is considered one of the most controversial regions for aerosol

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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. Furthermore, it is obvious from the few studies conducted in the Eastern Mediterranean region that PM levels in air are much higher than in other regions [3–10], even when compared to the Western Mediterranean [11,12]. 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.

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 the air quality of the region. This work is a part of an IAEA regional technical cooperation project (IAEA TC project RAS/0/072), dealing with sampling and elemental analysis of urban background air pollutants, using harmonized sampling and analysis protocol in all participating member states. The first campaign of sampling and analysis by proton induced X-ray emission (PIXE) technique was launched within RAS0072 with the aim to produce for the first time a database of PM elemental concentrations in the region. In this work, it will be shown and discussed the first results concerning gravimetric measurement and elemental composition of $PM_{2.5}$, using PIXE. The relevant PM samples were collected between October 2014 and February 2015 on Teflon filters, using ISAP®1050e sampler, from cities of Amman (Jordan), Baghdad (Iraq), Beirut (Lebanon) and Damascus (Syria).

2. Experimental

2.1. Sampling and site

Under the RAS0072 project, it was agreed to start the first campaign of sampling on 15 October 2014. The sampling sites were identified in each participating member state, mainly to represent the urban background of PM_{10} and $PM_{2.5}$. The protocol consists of 24 h 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, 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 $PM_{10-2.5}$ are retained on a greased customized ring shaped filter made by a very thin propylene foil with a thickness of few microns (Fig. 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).

In this regard, 20 samples were collected from an urban area in the southern part of Beirut, at the Lebanese Atomic Energy Commission (LAEC) site (33°50′58.86″ N and 35°29′58.33″ E), located at the airport road, heavy traffic, in front of a very populated area, 1 km from the sea, 2 km away from the International airport; 20 samples from the campus of the University of Jordan in Amman, a urban background site (32°00′52.27″ N, 35°52′25.41″ E) at the center of the Faculty of Science, far from traffic; 6 samples from Damascus center in an urbanized residential area located at Kafarsouseh (33°50′48.31″ N, 36°27′73.67″ E); and 8 samples from Baghdad site (33°16′68.00″ N and 44°23′25.90″ E) located at the Ministry of Science and Technology (MOST) in an crowded and populated urban area in the center of Baghdad, characterized by car traffic, 3–4 km far from a power station and a oil refinery, 500 m from the river (Fig. 2). All the samples analyzed in this work belong to the fine air particulate fraction ($PM_{2.5}$) and refer to the period between 15 October 2014 and the first week of February 2015. Although not large in number, this set of samples covers different seasonal and meteorological conditions (fall, winter, rainy, dusty, dry, sunny, windy, etc.).

2.2. PIXE setup and methods

The collected samples from the different sites have been analyzed using the fully dedicated external beam line for aerosol analysis of the 3 MV Tandetron accelerator of the LABEC laboratory of INFN at Florence. A complete description of the experimental set-up can be found in Ref. [13,14], here only some details are recalled. A proton beam of 3 MeV of energy, on the samples, is extracted into air through a 500 nm Si_3N_4 window and samples

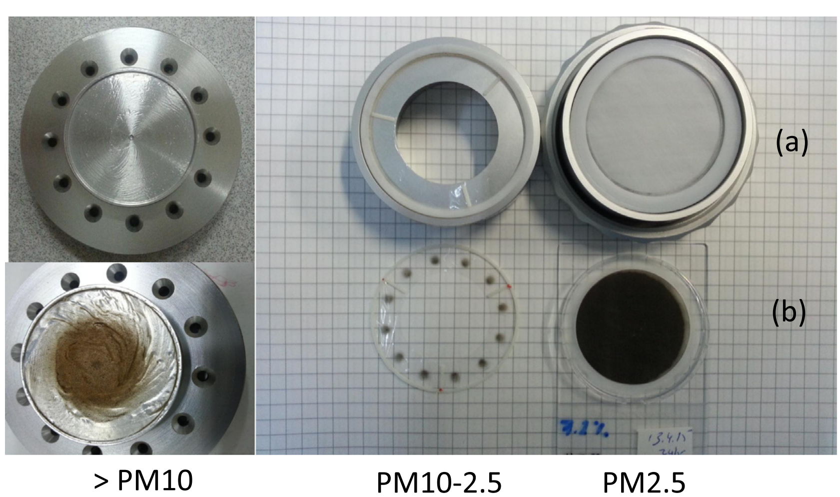

Fig. 1. The three different stages of ISAP sampler for the collection of atmospheric aerosols for 24 h (a) before and (b) after sampling: an upper greased metal plate for the retention of particles larger than PM_{10}, a greased customized ring-shaped filter for the $PM_{10-2.5}$ coarse fraction and Teflon filter for the $PM_{2.5}$ fine fraction.