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Assessment of annual air pollution levels with PM1, PM2.5, PM10 and associated heavy metals in Algiers, Algeria☆

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ABSTRACT

Concentrations of particulate matter less than 1 μm, 2.5 μm, 10 μm and their contents of heavy metals were investigated in two different stations, urban and roadside at Algiers (Algeria). Sampling was conducted during two years by a high volume samplers (HVS) equipped with a cascade impactor at four levels stage, for one year sampling. The characterization of the heavy metals associated to the particulate matter (PM) was carried out by X-Ray Fluorescence analysis (XRF). The annual average concentration of PM_1, $PM_{2.5}$ and PM_{10} in both stations were 18.24, 32.23 and 60.01 μg m^{-3} respectively. The PM_1, $PM_{2.5}$ and PM_{10} concentrations in roadside varied from 13.46 to 25.59 μg m^{-3}, 20.82–49.85 μg m^{-3} and 45.90 –77.23 μg m^{-3} respectively. However in the urban station, the PM_1, $PM_{2.5}$ and PM_{10} concentrations varied from 10.45 to 26.24 μg m^{-3}, 18.53–47.58 μg m^{-3} and 43.8–91.62 μg m^{-3}. The heavy metals associated to the PM were confirmed by Scanning Electron Microscopy-Energy Dispersive X-Ray analyses (SEM-EDX). The different spots of $PM_{2.5}$ analysis by SEM-EDX shows the presence of nineteen elements with anthropogenic and natural origins, within the heavy metal detected, the lead was found with maximum of 5% (weight percent). In order to determine the source contributions of PM levels at the two sampling sites sampling, principal compound analysis (PCA) was applied to the collected data. Statistical analysis confirmed anthropogenic source with traffic being a significant source and high contribution of natural emissions. At both sites, the $PM_{2.5}/PM_{10}$ ratio is lower than that usually recorded in developed countries. The study of the back-trajectories of the air masses starting from Sahara shows that desert dust influences the concentration and the composition of the PM measured in Algiers.

1. Introduction

In urban areas, the fractions of particulate matter with an aerodynamic diameter less than 1 μm (PM_1), 2.5 μm ($PM_{2.5}$) and 10 μm (PM_{10}) are a major air quality indicator (Cohen et al., 2005; Petkova et al., 2013).

These fractions of particulate matter (PM) mainly carry unburned and carbon rings from combustion processes, secondary particles from gas-particle conversion, mineral elements related to soil erosion and resuspension of dusts, so various heavy metals may play an important role in the aerosol toxicity (Brunekreef et al., 1997; Van Vliet et al., 1997; Bremner et al., 1999; Hoek et al., 2000).

Numerous and consistent studies show that particulate matter and heavy metals are responsible for the occurrence of a wide range of biological and health effects (Dockery et al., 1993; Pope et al., 1995), and contribute to the degradation of air and human health (Schaumann et al., 2004). According to the 2016 report by the World Health Organization on the global assessment of exposure and burden of disease, the rate of premature deaths caused by $PM_{2.5}$ in Algeria is about 11400 deaths/year (WHO, 2016).

Particulate matter contains a wide range of particle types having different compositions, sizes, shapes, and optical properties (Charlson et al., 1992). Particulate matter affects the Earth's energy budget by scattering and absorbing radiation (the "direct effect"), and modifying the total amounts and microphysical properties of clouds (the "indirect effects"). In particular, particles act as cloud condensation nuclei (CCN) and/or ice nuclei.

Several techniques are used to determine the concentration of heavy metals in the samples to be analyzed, such as Atomic

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Absorption Spectroscopy (AAS), Inductively Coupled Plasma- Optical Emission Spectrometry (ICP-OES), Inductively Coupled Plasma-Mass Spectrometry etc. Among these techniques X-ray fluorescence spectrometry (XRF) is often used. XRF has the advantage of measuring the solid sample with a very simple sample preparation. Recently, the XRF method has been preferred to determine the chemical composition of airborne particulate matter (Carvacho et al., 2004; Lough et al., 2005; Calzolai et al., 2008; Canepari et al., 2009; Niu et al., 2010; Richard et al., 2010; Weckwerth, 2010; Apeagyei et al., 2011; Lopez et al., 2011; Indresand and Dillner, 2012).

The north of Algeria is now experiencing a rapid development of urbanization which has contributed greatly to the degradation of the ambient air quality. Faced with this and according to our knowledge, as of July 2017, there is no network for the continuous measurement of air quality or data on the levels of air pollution in Algiers (APW, 2017). However, these data are essential for implementing, monitoring and evaluating policies that can help to tackle air pollution while also protecting health. At present, only some occasional data collected by scientists and researchers are available to give an idea of the air quality in Algiers (Kerbachi et al., 2006; Moussaoui et al., 2010; Kerchich and Kerbachi, 2013, 2016). However, these data are still insufficient and need to be further improved.

Several countries have recently revised their air quality guidelines and proposed new regulations. The European Union (EU) Air Quality Directives EC/30/1999 and EC/69/2000 established in 2010 the annual average limit for PM_{10}, set at 25 $\mu g\ m^{-3}$. For PM_{10}, a daily value of 50 $\mu g\ m^{-3}$ in a limit of 7 days per year has also been fixed. Regarding $PM_{2.5}$, annual primary standards were reduced to 12 $\mu g\ m^{-3}$ from the previous criterion of 15 $\mu g\ m^{-3}$ by the American Environmental Protection Agency (Pope and Dockery, 2006; Kim et al., 2015; Dunea et al., 2016).

According to the WHO's Urban Ambient Air Pollution database published in 2016 and recorded worldwide, there are many countries located in Africa, Western Pacific, South-East Asia and the Eastern Mediterranean where the PM_{10} levels exceed by far the value of 100 $\mu g\ m^{-3}$ and at same time a very high level of 350 $\mu g\ m^{-3}$ of PM10 has been recorded in Riyadh City (Kingdom of Saudi Arabia) (WHO, 2016).

Previous studies concerning the level of heavy metals around industrial areas, reported the concentration of lead in the ambient air equal to 195 ng m^{-3} in Hangzhou (China) (Qi-Li et al., 2015), 555 ng m^{-3} in Izmir (Turkey) (Cetin et al., 2007), and varying from 80 to 2537 ng m^{-3} in Zabrze (Poland) (Pastuszka et al., 2010).

In this work, we determined the levels of PM_1, $PM_{2.5}$ and PM_{10} pollution on a roadside and at background sites that are characterized by high population density at the urban periphery of eastern Algiers. An assessment of the heavy metals associated with these particles and their distribution by size range was also determined by a non-destructive method, XRF.

This paper adds new information to the current literature regarding the levels of PM_1, $PM_{2.5}$ PM_{10} and the associated heavy metals in the ambient air at Algiers City. Moreover, the study aims to better inform public debate, to assist the authorities in defining local plans for air quality management and to increase the awareness of decision makers and the population.

2. Material and methods

2.1. Area and period of the study

Algiers (latitude 36° 42′ N, longitude 3° 13′ E) is located in the coastal area on the Mediterranean Sea. Currently considered as one of the most populated cities in Algeria, Algiers has a population of around 3.5 million inhabitants (statistics 2009) or approximately 12% of the total population of Algeria. Over the past few years, the city has experienced a dense urbanization and rapid increase in the number of vehicles (NOS, 2009) including 1,200,000 registered vehicles.

The study area is located in the east of Algiers, which has a very diversified nature with the presence of a construction site for one of the largest mosque in Africa and other urban poles connected to a widespread road network, such as the South and North Ring Road and the East-West Highway, which are considered the main mobile sources of pollution. Other industrial activities are present within the study area and in particular the industrial zone of El Harrach with a steel foundry, an industrial waste incineration plant and a fuel storage and distribution company called NAFTAL.

Filter samples were collected near the Hassan Badi road (at the Polytechnic High School campus), at a distance of about 5 m from the road. In the urban area, sampling was carried out at the municipality of Mohammadia (Fig. 1). The international airport of Houari Boumediene is about 5 km away from the sampling stations.

The study lasted two years. Two sampling campaigns were carried out. The first campaign was conducted from January 1st to September 30th 2015 for the roadside site, while in the second campaign sampling was conducted from March 4th to November 30th, 2016 for the urban site. In total, 186 samples were collected over the two sampling campaigns for the three fractions PM_1, $PM_{2.5}$ and PM_1.

The meteorological data corresponding to the sampling period were obtained from the National Office of Meteorology of Algeria, whose measurement station is located in Dar-El-Beida, approximately 6 km from the studied area (Table 1) (NOM, 2010).

2.2. Sampling method

Particles were separated into three fractions onto glass fiber filters (GFF, Whatman) of different sizes (10 × 12 cm^2 for PM1 and PM2.5 and 20.3 × 25.4 cm^2 for PM10), using a high-volume sampler (Model VFC, Anderson, USA) equipped with size-selective inlet cascade impactors. Particles were collected over 24 h at a 1.1 $m^3\ min^{-1}$ flow rate, 3 days per week starting at 8:00 a.m. Thus, each sample corresponded to ~1584 m^3. The fiber filters (unused) were previously conditioned in a room of constant relative humidity and temperature, individually wrapped with aluminium foils (USEPA, 1999). The glass fiber filters used for the collection of particulate matter were weighted before (pre-sample) and after (sample) sampling at the same percentage of relative humidity (RH). After use, the loaded filters were wrapped again with aluminium foils and stored at low temperature (4 °C) until analysis, in order to prevent the analyte from any degradation.

The filters were conditioned at a temperature of 20 ± 1 °C and at 50 ± 5% relative humidity for 48 h before and after field sampling and weighed on an electronic balance (SARTORIUS, sensitivity: 0.01 mg) to determine the mass concentrations.

2.3. XRF analysis

The quantitative analysis of As, Ni, Pb, Hg, Cr, Cd, Mo, Zr, Sr, U, Rb,Th, Se, Au, Zn, W, Cu, Co, Fe, Mn, V, Ti, Sc, Ca, K, S, Ba, Cs, Te, Sb, Sn, Ag and Pd was performed using the XRF method. Blank filter and dust filters were cut to diameters of 31 mm and the analyses were performed with a handheld device named the Thermo Scientific NITON energy-dispersive X-ray fluorescence (EDXRF)

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