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Magnitude of Air Pollution by Heavy Metals Associated with Aerosols Particles in Algiers

Nassima Oucher[a,]*, Rabah Kerbachi[b], Anissa Ghezloun[a], Hamza Merabet[a]

[a]*Centre de Développement des Energies Renouvelables, CDER, BP 62 Route de l'Observatoire, Bouzaréah, 16340, Algiers, Algeria*
[b]*Ecole Nationale Polytechnique, ENP,10 Avenue Hassen Badi, B.P. 182, El Harrach – Algiers, Algeria*

Abstract

This study evaluated for the first time in Algeria the pollution levels reached by different size distribution of aerosol particles and heavy metals associated with them in a site influenced by the emissions of the road traffic in Algiers. The analysis of heavy metals Fe, Pb, Cu, Mn, Ni, Co and Cd transported by the aerosol particles shows that heavy metals are enriched in varying degrees in the different size distributions. The Pb and Cd and to a lesser degree the Ni and Co are more abundant in the PM-1. The Pb, for example shows a mass fraction of 0.58% in the PM-1, whereas this is only up to 0.40% in the PM-10. Conversely, Fe, Mn and Cu are enriched in the PM-10 than in the PM-1. In order to check in which extent some heavy metals present correlations between them, we compared the levels of heavy metals in pairs in size distribution PM-10, PM-3 and PM-1.These results confirm the data on the enrichment of Pb and Cd in the fraction of very fine particles and the predominant presence of Fe and Mn in coarse particles. Similar to the case of PM-10, we determined the median aerodynamic diameter d_{50} of both heavy metals Fe and Pb, respectively representative of natural sources and entropy sources (road traffic). The differences in the sizes of metal particles and differences of origin or source can also be visualized by the curves of modal distribution. Distribution curves obtained both for Fe than for Pb are of the mono-modal type.

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* Corresponding author. Tel.: +21321901654; fax: +21321901560.
E-mail address: n.oucher@cder.dz

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1. Introduction

Transportation activities contribute significantly to air pollution by particles matter [1, 2, 3, 4]. In urban areas, traffic is in fact one of the main emission sources of fine particles [5, 6, 7, 8, 9, 10, 11]. These fine particles carry mainly unburned carbon and cores from the combustion process, secondary particles resulting from the conversion gas / particle, mineral elements associated with soil erosion and re-suspension of deposited particles and various metals toxic heavy such as Pb, Cu, Ni, Cr, etc. which may play an important role in the toxicity of the aerosol [12, 13, 14, 15]. In Algeria, the growth of the fleet-induced socio-economic development and rapid urbanization has led to the emergence in the urban population of chronic diseases related to the deteriorating air quality. Recent studies have shown that the Greater Algiers is, like any large urban area, faces severe air pollution [16, 17, 18]. The main source of emissions is traffic. However, for deploing a prevention strategy, it is necessary to have data on levels and types of pollution and the compounds it contains. Thus, heavy metals Fe, Pb, Cu, Ni, Mn, Co and Cd associated with fine particles matter PM-10, PM-2.5 and PM-1 and their contribution to global pollution have been studied in Algiers.

Nomenclature

PM	Particles Matter
PM-10	inhalable particles
PM-2.5	alveolar particles
PM-1	very fine particles
NR	National Road
HVS	High Volume Sampler
AAS	Atomic Absorption Spectrometry
WHO	World Health Organization
D_{50}	median diameter

2. Methodology

The chosen site for the study is classified in the category of sites such as "traffic station" also called "local site". The daily measures were carried out at the National Polytechnic School at about 10 km from the center of Algiers. The sampling station is located at an altitude of 4m and 9m from the edge of the NR n°5. In 2000, the major highway was taken by over 25,000 vehicles per day with approximately 15% of buses and heavy diesel vehicles [19]. This site is characterized by the absence of obstacles and good natural ventilation.

For the measures by size distribution, a High Volume Sampler, the HVS-PM-10 equipped of cascade impactor Sierra-Andersen with four floors was used, those four floors offer access to the 5 size classes: 10 to 7 µm, 7 to 3 µm, 3 to 1.5 µm, 1.5 to 1 µm and below 1 µm (PM-10, PM-7, PM-3, PM-1.5 and PM-1) [20]. The flow rate is set at $1m^3$/mn. The sampling time is 24 hours.

The heavy metals Fe, Pb, Cu, Ni, Mn, Co and Cd, which have a significant health impact, are then analyzed by Atomic Absorption Spectrometry (AAS) with an air / acetylene flame.

3. Results and discussions

3.1. Level of pollution by heavy metals

The study of heavy metals (Fe, Mn, Pb, Cu, Ni, Co and Cd) transported by the different size distribution of fine particles has covered roughly 70 daily measures about 200 fractions size distribution during this study of one year (July 2002-June 2003).

Tab. 1 summarizes the average and maximum contents of heavy metals. Their mass distribution by size distribution is summarized in Fig. 1. The results show that in all the fractions, iron, among the elements studied is the most abundant. With an average level of about 639.8ng/m^3, it represents about 1% of the mass of particles of PM-10. This result was expected because of its abundance in the Earth's crust. Lead, in its abundance, following iron. In the PM-10 we recorded a level of 299.3ng/m^3 corresponding to a mass fraction of about 0.4%. These lead levels are relatively high. They exceed the new European standard of 0.2µg/m^3 and are slightly below the WHO standard of 0.5µg/m^3 [21].

Examination of the mass fractions shows that heavy metals are enriched unevenly in different size distribution (Fig. 1). Lead, cadmium and to a lesser extent nickel and cobalt are more abundant in fine particles. Lead, for example, shows a mass fraction of 0.58% in the PM-1, whereas it is present only up to 0.4% in the PM-10. Conversely, iron, manganese and copper which are mostly from the earth's crust are enriched in the PM-10 than in very fine particles PM-1.

Table. 1: Mean and maximum atmospheric contents of heavy metals measured in Algiers.

Fractions distribution	Contents of heavy metals (ng/m^3)							
	Fe		Pb		Cu		Mn	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
PM-1	*149.0*	*479.6*	*151.7*	*387.2*	*32.7*	*67.3*	*16.8*	*39.2*
PM-1.5	195.1	684.5	150.8	264.6	35.2	102.1	21.2	47.6
PM-3	*282.9*	*837.0*	*208.9*	*507.6*	*63.2*	*156.4*	*31.2*	*62.9*
PM-7	553.0	1031.5	273.4	549.0	81.5	195.1	48.2	102.6
PM-10	*639.8*	*1350.4*	*299.3*	*715.2*	*102.8*	*331.1*	*57.8*	*141.8*

	Ni		Co		Cd	
	Mean	Max	Mean	Max	Mean	Max
PM-1	*16.5*	*40.5*	*11.8*	*32.4*	*7.4*	*17.2*
PM-1.5	17.0	42.6	16.1	49.7	11.3	35.4
PM-3	*28.1*	*82.1*	*26.2*	*83.3*	*12.8*	*35.4*
PM-7	39.7	93.1	35.2	87.7	16.3	32.4
PM-10	*42.4*	*159.3*	*37.7*	*99.4*	*21.2*	*46.5*

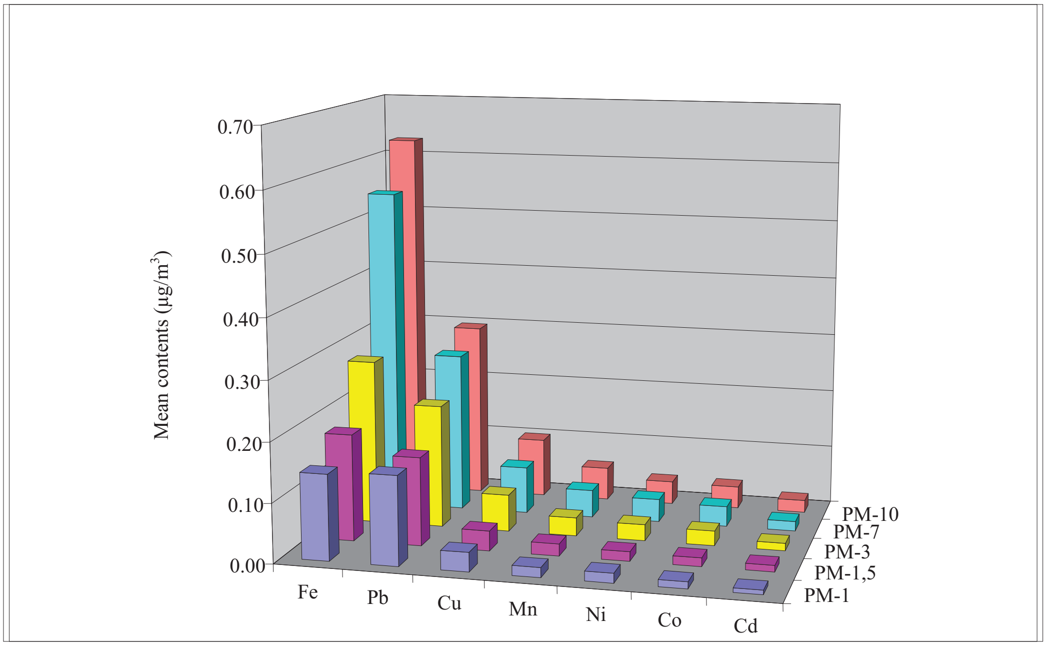

Fig. 1. Distribution of average atmospheric contents of metals in each size distribution.

Overall, except for lead, other heavy metals do not reach alarming levels and are characteristic of an urban environment that is not exposed to industrial emissions. Lead comes naturally from the use of the leaded gasoline [22]. This observed pollution would be reduced by a generalization of unleaded petrol, which is the case in Europe.

3.2. Correlation between heavy metals

In order to check the extent to which some heavy metals present correlations between them, we compared the levels of heavy metals in pairs in the size fractions PM-10, PM-3 and PM-1.

As an example we present, respectively, in Fig.2, 3 and 4 correlations Fe / Mn and Fe / Pb in the PM-10, correlations Fe / Mn, Fe / Cd and Pb / Cd in the PM-3 and correlations Pb / Mn, and Pb / Cd in PM-1.

Also it is possible to classify the heavy metals into two groups:

- The Pb, Cd and Ni which the levels are closely related especially in the very fine particles (PM-1 and PM-3). These heavy elements have probably the same emission source which is road traffic;
- The elements Fe, Mn and Cu which are in the coarser fraction are closely related. These elements belong to an emission source different from road traffic. They come from land erosion.

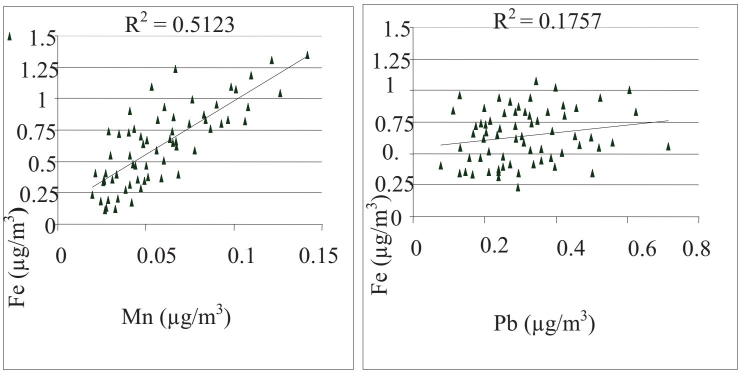

Fig.2 : (a) Correlation between *Fe* and *Mn* in PM-10; (b) Correlation between *Fe* and *Pb* in PM-10.

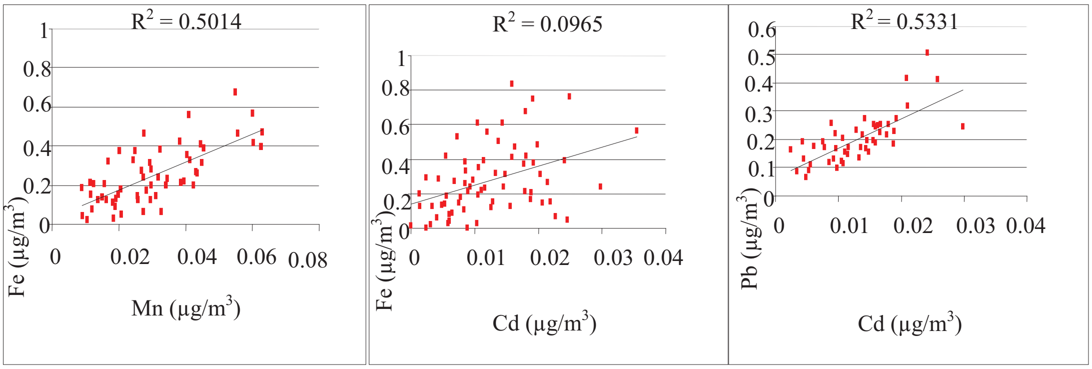

Fig.3 : (a) Correlation between *Fe* and *Mn* in PM-3; (b) Correlation between *Fe* and *Cd* in PM-3; (c) Correlation between *Pb* and *Cd* in PM-3.

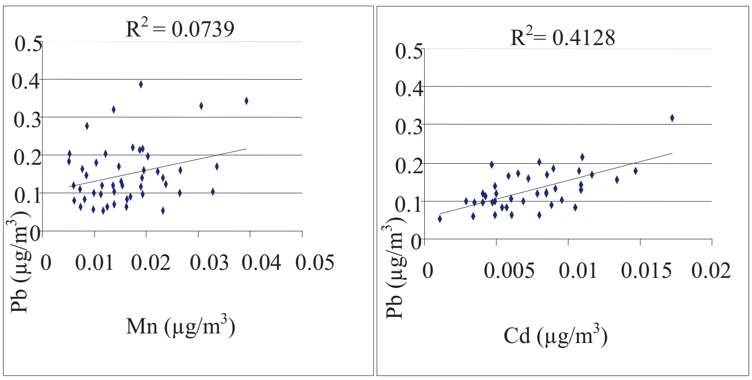

Fig.4 : (a) Correlation between *Pb* and *Mn* in PM-1; (b) Correlation between *Pb* and *Cd* in PM-1.

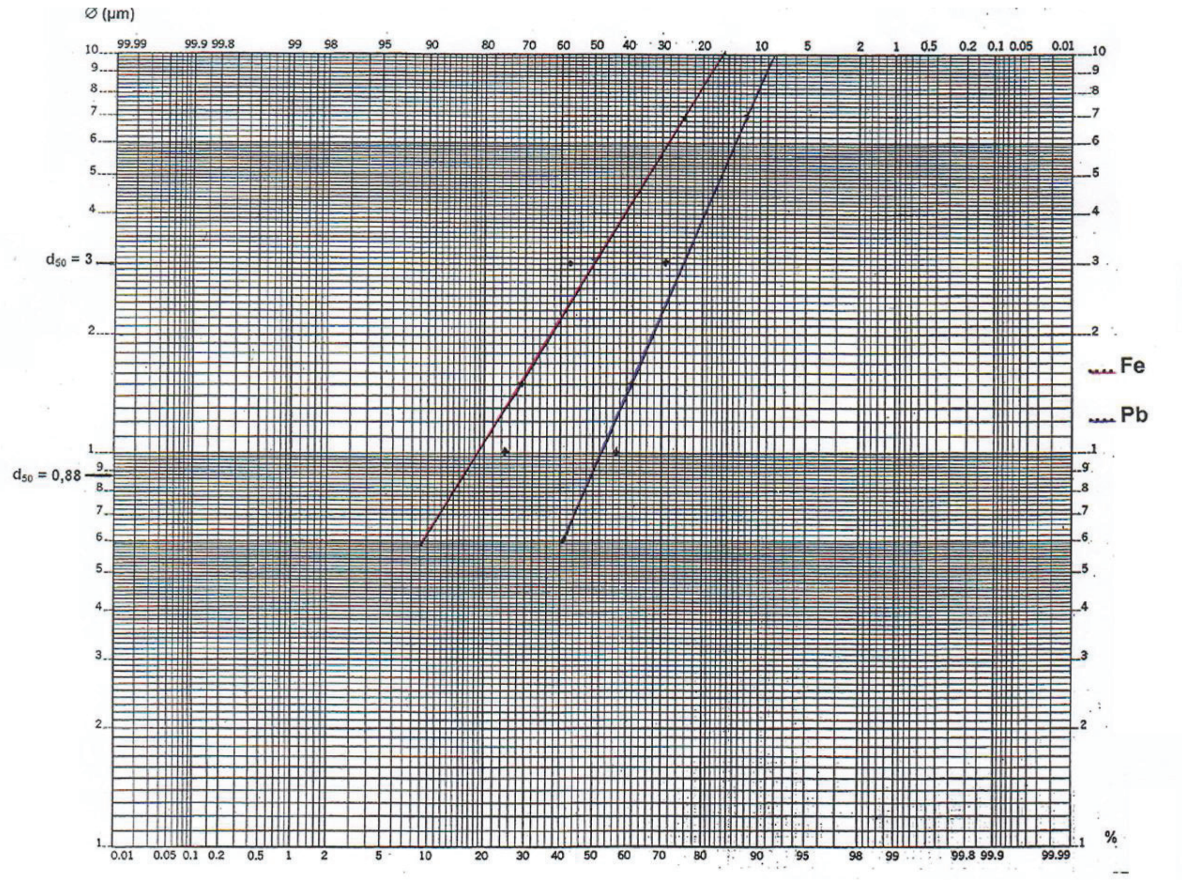

Fig. 5: Diagram log-probability of the cumulative mass of Fe and Pb according to the diameter of collected particles.

3.3. Statistical exploitation of atmospheric levels in heavy metals

- Diagram log / probability: Determination of d_{50}

As in the case of PM-10, we determined the median aerodynamic diameter d_{50} of the two heavy metals Fe and Pb which are respectively representative of the natural sources and of entropy sources (road traffic).

The determination of the d_{50} diameter can be done graphically on a log-probability diagram, the cumulative mass of Fe and Pb (y-axis logarithmic scale) and percentage of the aggregate mass of collected particles with a diameter ≤ di (x-axis scale probability) [23].

The log-probability diagram shown in Figure 5 gives:

- Fe: d_{50} = 3 µm;
- Pb: d_{50} = 0.88 µm.

This result confirms that the Pb is associated with very fine particles and the iron is predominant in the coarse particles (particles tracheobronchial).

- Modal distribution of Fe and Pb

Differences in the sizes of metal particles and differences of origin or source can also be visualized by the modal distribution curves. Distribution curves obtained for the iron and the lead are both mono-modal type. Both curves however, show a lag, one relative to another ; that the lead is centered around 2 µm and that of iron about 4 µm. Similar results were obtained for example in the characterization of heavy metals associated with urban particles in Los Angeles [24].

4. Conclusion

The study of heavy metals (Fe, Pb, Cu, Ni, Mn, Co and Cd) that are carried by different size fractions of PM-10 particles studied PM-2.5 and PM-1 shows that among these metals lead is, after iron, the most abundant element. Compared to other countries, or a severe restriction was applied, the lead pollution remains high. The size distribution of heavy metals shows that the compounds of the crust (Fe and Mn) are divided mainly on the class of coarse particles (between 3 and 10 microns), the most toxic heavy metals such as Pb and Cd, is found against by most in the respirable fraction (<3 microns). Their toxic power is there more accentuated. Distribution curves plotted from the results obtained show clearly the difference between heavy metals of natural origin and those from road traffic.

In light of the results obtained during this study, it can be said that Algiers has the distinction of being a capital city that is not highly powered, but has a more particles pollution than in the major cities of developed countries, where traffic is more intense.

Some improvement in the situation can be achieved by actions such as the rejuvenation of the fleet, the generalization of the technical inspection of vehicles, increased use of LPG / gasoline or natural gas for fleets of buses.

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