Characterization of particulate matter from urban, industrial and rural environments

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Abstract

Characterization studies of particulate matter were made in three cities of the Buenos Aires Province in Argentina. These cities have noticeable differences in relation to the number of inhabitants, vehicular density, industrial activities, etc. They are Vicente López, San Nicolás and Coronel Suárez towns.

The samples were picked up with high volume equipment and daily concentrations corresponding to total suspended solids (PM) were determined by a gravimetric method. The particles were characterized by optical microscopy, scanning electron microscopy (SEM) and electron diffraction analysis X-ray (EDAX).

The results obtained (PM concentration, particle size distribution, morphology and chemical composition) from the three towns showed important differences when compared. Carbonaceous particles, typically observed when traffic flow is high, were found in Vicente López samples. In San Nicolás samples, particles from industries can be differentiated and in Coronel Suárez samples, silicoaluminous particles, from local soil, are present.

In San Nicolás, particularly, a comparative study between two different periods of time was made. The main difference between them is the country's economic condition due to a serious economic crisis during 2001, which promoted the change of the vehicle motor power system from gasoline to compressed natural gas, with the environmental benefits that this situation involved.

The present study is part of the research project "Study of the Air Quality in Buenos Aires Province", financially supported by the National Agency of Scientific and Technologic Promotion, Argentina.

Keywords: urban and rural air, particulate matter.

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1 Introduction

Airborne particles can have an anthropogenic or a natural origin. The natural particles can be, for example, biological particles such as pollen or spores, mineral dust or background sea salt. The natural sources can also be volcanic emissions and forest fires.

In urban and industrial areas most particles result from human activities. All types of combustion generate particulate matter: burning of fuel in buses and cars, hydrocarbon combustion for heat and electricity, solid waste incineration and biomass burning. Several industrial processes such as iron and steel milling and metal smelting are PM sources.

The particulate matter is the only atmospheric pollutant without a definite composition. It can vary considerably from one place to another [1, 2] or within a city [3]. Chemical components of particulate matter range from near neutral and highly soluble substances such as ammonium sulfate, ammonium nitrate and sodium chloride through dirty particles made up largely of elemental carbon coated in organic compounds, to essentially insoluble minerals such as particles of clay [4].

The objective of the present work is to evaluate the quality of the air in three towns of Buenos Aires Province, which are very different in size and commercial activities, through the chemical and morphological characterization of its particulate matter. These towns are Vicente López, San Nicolás and Coronel Suárez.

Buenos Aires is the second largest province in Argentina and congregates the third part of its population.

Vicente López and Buenos Aires city, the country capital city, are close together. Vicente López belongs to the so called Gran Buenos Aires and it has over 270,000 inhabitants, heavy traffic and very important commercial activity, mainly textile and food industries.

San Nicolás has 160,000 inhabitants and a large number of industries being a steel factory, a chemical company and a power plant the most important ones. The traffic flow reaches 50,000 vehicles including public and private transportation [5]. It is located in the North of Buenos Aires Province in Argentina.

Coronel Suárez has almost 37,000 inhabitants and a traffic flow that reaches 18,000 vehicles. The main activities are based on agriculture and cattle raising.

In Argentina, the environmental control organism in Buenos Aires Province, where the studied cities stand, has fixed the daily concentration, expressed as particulate matter in air for 24 hours, of 0.150 mg m^{-3}, and a yearly mean value of 0.050 mg m^{-3} [6], following the values fixed by the Environmental Protection Agency (EPA) of United States.

2 Experimental

Air samples were collected with high volume equipment in three towns of the Buenos Aires Province in Argentina. The cities location is shown in Figure 1.

Figure 1: Location of the selected cities.

The measurements were carried out for two weeks in each town. During the analyzed period there were no rainy conditions. The mass of particle samples collected was determined by using a four decimal balance. First the clean dry filter is weighed, then after 24 hours, the filter with the collected sample is dried again and stored in a sterile Petri dish until it is weighed again.

The daylong filters were all analyzed in order to determine PM concentration values corresponding to 24 hours, average particle sizes and morphological characteristics.

The samples were characterized by optical microscopy (OM), scanning electron microscopy (SEM) and electron diffraction analysis X-ray (EDAX).

The samples were observed by optical and scanning electron microscopies. The optical observations were made with an Axiotech Zeiss microscope with annexed Philips video camera. The SEM analyses were carried out through a Philips 515 scanning electronic microscope with an EDAX X-ray detector.

3 Results and discussion

Macroscopic observations of the filters showed a noticeable difference in color and quantity of particulate matter retained, as can be seen in Figure 2.

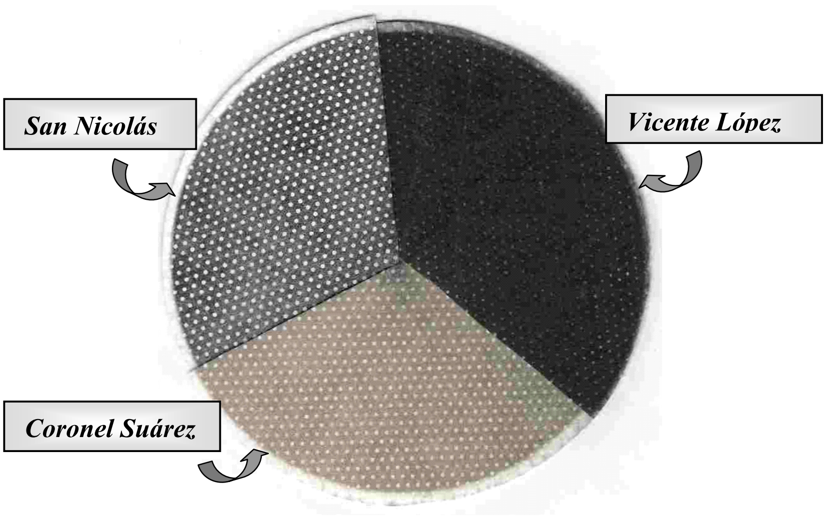

Figure 2: Filters pieces with PM samples obtained from the towns' analysis.

In Table 1 some cities data and the results of the particulate matter quantitative studies are shown.

Table 1: Cities characteristics and PM concentration and average particle size.

City	***Inhabitants number***	***Vehicles Number***	***Activity***	***PM [mg/m³]***	***Average particle size [μm]***
Vicente López	274,082	unavailable	Commercial	0.210	45
San Nicolás	160,000	50,000	Industrial	0.108	22
Coronel Suárez	36,723	18,041	Agriculture and cattle	0.076	42

Table 1 data in relation to inhabitant and vehicle numbers were obtained from Argentine Department of the Interior, National Direction of the Vehicle Proprietor Register and municipal information.

The PM values in Table 1 are mean values of the concentrations daily determined for two weeks. The particulate matter pollution in Vicente López city shows levels higher than those established by the regulation while the other towns' levels keep below the standard value. The average particle size measured in San Nicolás samples results significantly lower than those of the other cities. It can be explained if the important contribution of industrial particle emission is taken into account. These particles produced by combustion processes at high temperatures have particular characteristics such us low quantity of carbonaceous material, small particle sizes and an important presence of spherical particles typical of the fusion reactions.

The morphological analyses made by OM and SEM allow one to observe these noticeable differences.

Figure 3 shows the microscopic characterization of Vicente López samples. In these particulate matter samples it is possible to observe the presence of smaller particles nucleating on bigger ones, with homogeneous texture, like a mass of agglomerated particles. The EDAX analysis showed an important percentage of carbon and the presence of other chemical elements in small quantities (C-77.7, O-9.3, Al-2.9, Si-1.3, Fe-0.9, Cu-7.9), as well as the particulate matter produced by the internal combustion of oil and petrol in vehicles [7].

The analysis of PM samples from Coronel Suárez town is shown in Figure 4. The EDAX general chemical analysis presents the typical composition found in atmospheric dust, mainly consisting of earth particle in suspension, particulate materials arising from construction works and biological particles like pollen and spores. The dominant elements determined in these samples are Si, Al, and O, in similar proportion to that present in silicoaluminates compounds like clays and feldspars. The elemental content expressed in percentages is O-34.1, Al-10.7, Si-43.8, K-5.1, Ca-2.1, Ti-0.9, and Fe-3.3. The SEM images in the figure show that this kind of particulate matter preserves its crystalline shape, making it easily recognizable. In similar way the pollen particles can be identified for their morphological characteristics, they look like small spherical sponges.

In the case of PM collected in San Nicolás town centre, Figures 5 and 6, the general analysis shows a great variety of chemical elements, in high proportion, with an important quantity of carbonaceous material (C-49.8, O-13.7, Al-1.1, Si-6.7, K-3.7, Ca-1.9, Ti-1.8, Fe-11.4, Cu-7.4, Zn-2.5). The present particles are not exclusively typical of vehicular pollution but rather those originated from industrial high temperature processes such as metallurgical, steel or metal-mechanics industries. Most of the Fe and Cu particles identified are perfect spherules, although some irregular iron particles have also been observed.

The above photograph in Figure 5 shows a fine fraction of the PM sample studied, and it is possible to note a heterogeneous texture, with a great variety of particle shapes. The image below shows a particle consisting of a spherical Cu centre body (Cu-100) with other much smaller particles adhered to the surface. Some of them are carbonaceous particles and others are composed by Si, O, Ca and K in proportion corresponding to Ca-K silicate. The general analysis of this particle shows the following composition %: C-44.4, O-7.1, Si-3.7, Cl-1.2, K-6.2, Ca-2.5, Ti-1.3, Fe-1.6, Cu-28.2, Zn-3.8.

A wide variety of particles were observed in San Nicolás particulate matter sample, as it is shown in Figure 6. Silica, silicates and silicoaluminates particles with the crystalline characteristic aspect, and typical particles originated by industrial processes such as Cu, Fe, chlorides, etc., with rounded shapes without beard grains were identified.

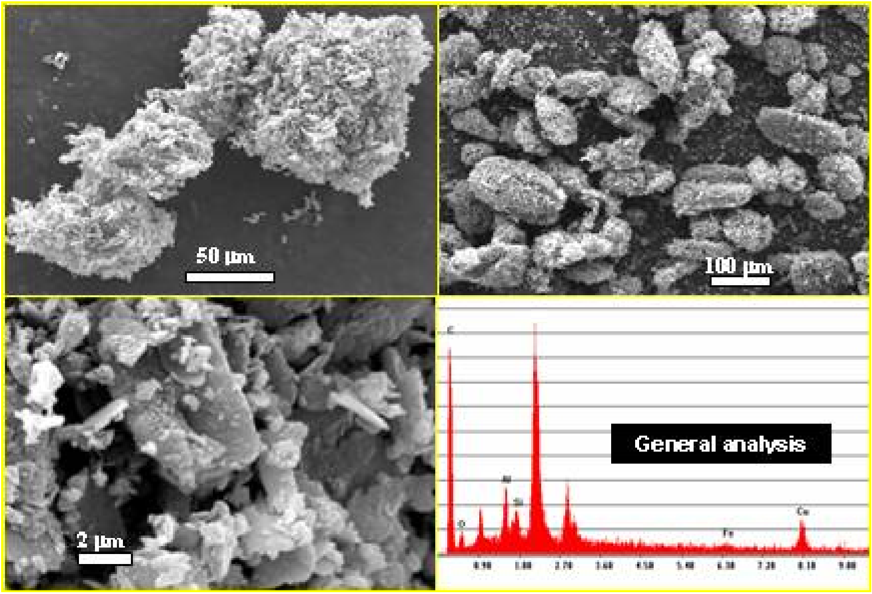

Figure 3: Characterization of PM from Vicente López.

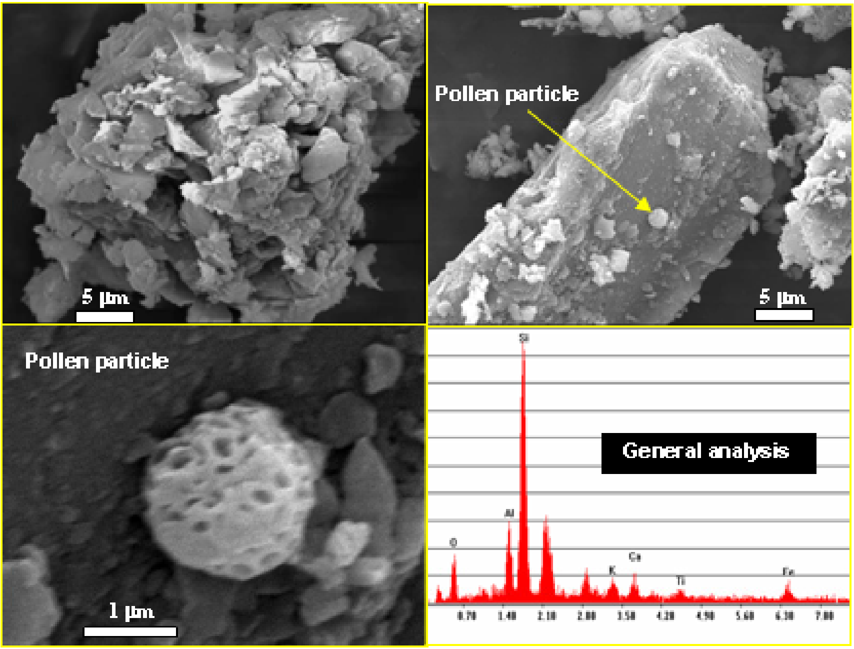

Figure 4: Characterization of PM from Coronel Suárez.

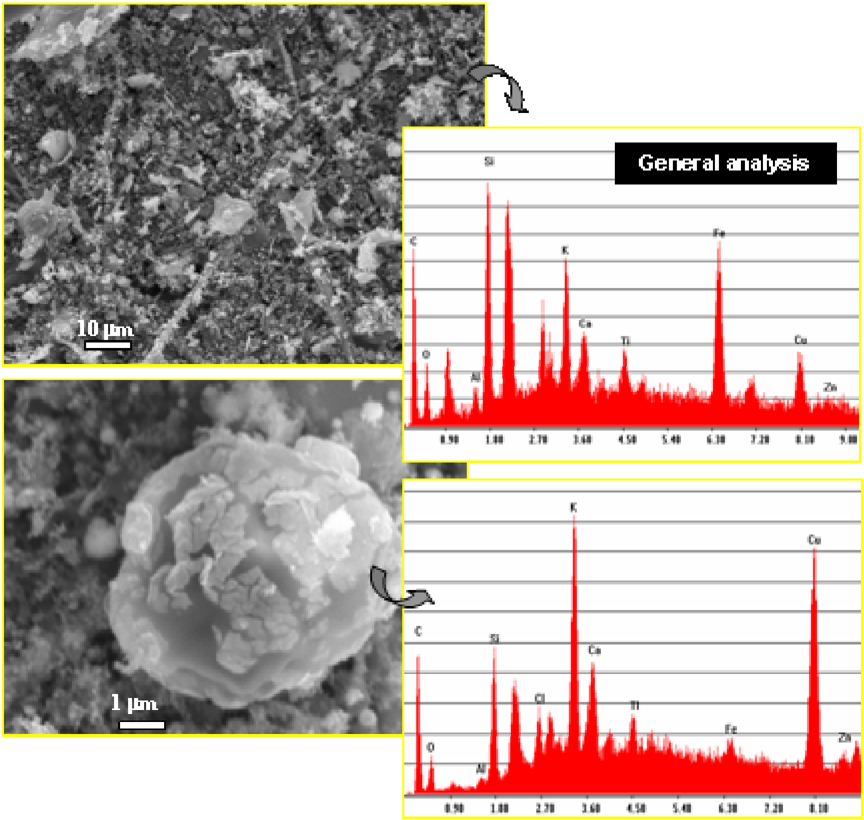

Figure 5: Characterization of PM from San Nicolás.

These samples analyzed in San Nicolás town were collected in an urban area located three kilometers from the industrial area. Other samples were taken in more distant areas but with similar characteristics in relation to the vehicular movement, situated at approximately ten kilometers from the mentioned zone. The analyses of them show a noticeable decrease of the particles with the characteristic pattern of industrial origin. The chemical composition analysis notably changed resulting similar to that obtained for Vicente López PM samples, with a high percentage of carbonaceous material. The average particle size also changed, taking a value of 44 µm.

It is important to note that in sustainable terms a few kilometers away from the industrial emission sources can mean a better air quality, due to the variation in particle characteristics: composition and sizes.

This work makes also a comparative study of particulate matter in this central area of San Nicolás city in two intervals of time separated by a period of three years, November 1999-March 2000 and November 2002-March 2003. The objective of this comparison is to determine the influence of the economic crisis occurred in the country during 2001 year, on the PM levels and characteristics. A complete comparative study of the air quality in San Nicolás centre focused in the mentioned situation can be found in a previous paper [8].

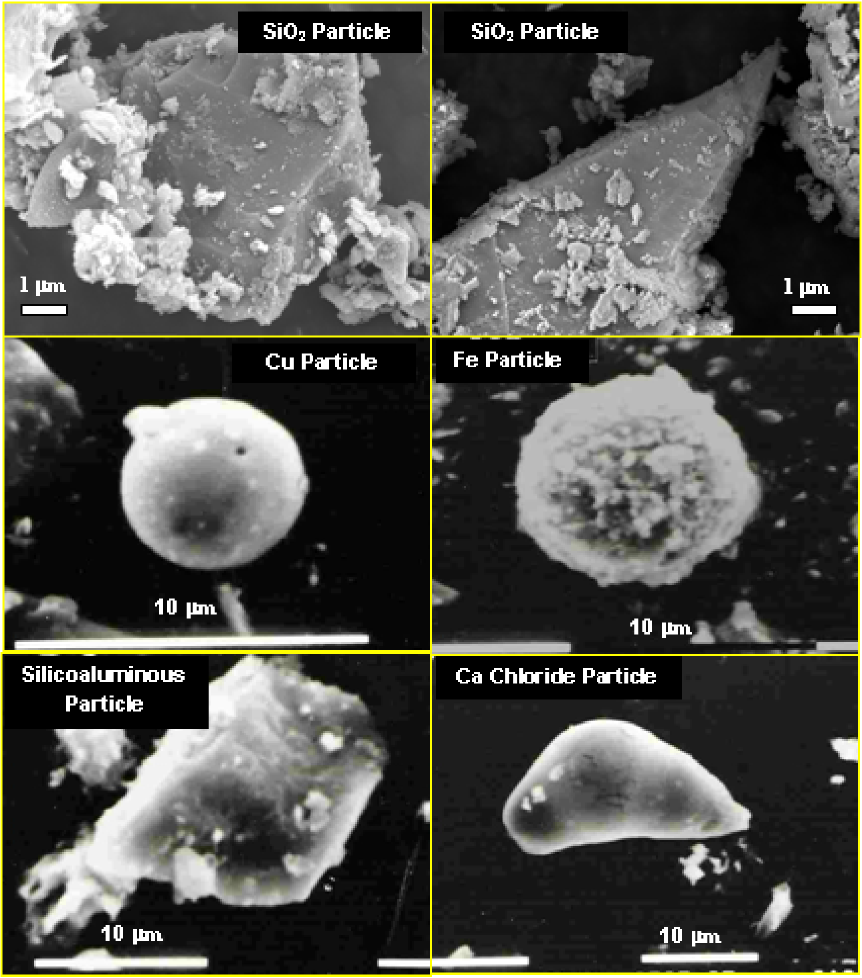

Figure 6: Different particles identified in San Nicolás samples.

Similar compositions of PM, typical of vehicular pollution with high presence of carbonaceous particles were observed.

In relation to the concentration levels it can be noticed that in 2002-2003 the pollution levels are considerably lower than those observed in previous years, as it is shown in Figure 7.

At first, it was thought that the crisis caused a decrease in the vehicular flow. However, it was observed that during the 2002-2003 period, the vehicular traffic kept the usual values, that is, the number of vehicles and the usage frequency of them were similar to those corresponding to 1999-2000.

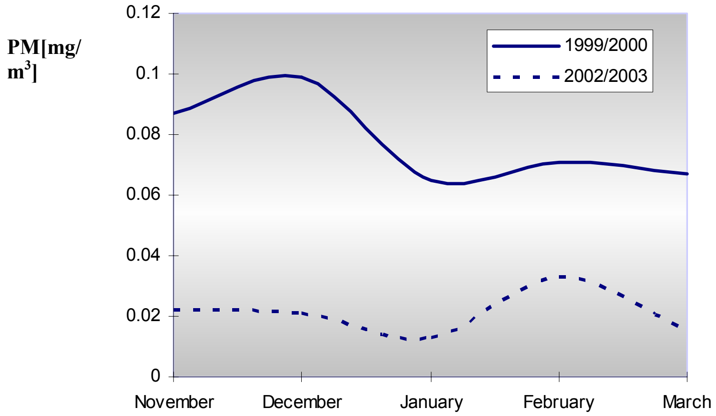

Figure 7: PM level in San Nicolás central area before and after the 2001 economic crisis.

This fact can be explained taking into account the important number of vehicles whose engines were adapted to work with compressed gas. As it is known this kind of fuel is considered "friend" of the environment due to the lower contaminant concentrations that produce. The average PM emissions of compressed natural gas in relation to ones corresponding to traditional fuel were established almost negligible [9].

In Argentina the cost of compressed gas used as fuel is notably inferior to one of liquid fuels, which explains the mentioned transformations. For example, to travel the same distance the money expense is six times lower if the vehicle uses compressed gas instead of liquid fuel.

This situation indirectly produced a positive impact on the air quality. This represents an important contribution in terms of sustainability. Argentine has appreciably increased the number of vehicle with the natural gas power system during the last years being at present about 1,500,000. In big cities the converted private vehicles represent about 30% of the total number of the automotive sector.

4 Conclusions

The particulate matter characterized from the three towns selected showed very different and typical composition as it was expected taking into account its origin environments: urban, industrial and rural.

A better air quality was observed only a few kilometers away from the industrial emission sources. Therefore, in order to get sustainable cities the governments shouldn't allow factories to settle close to the urban areas.

It was also observed that when compressed natural gas is used instead of liquid fuels, the particulate matter level in air is noticeably reduced. For this reason it is advisable to promote the usage of this kind of fuel.

Acknowledgements

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