Research article

Air quality at La Plata Conglomerate, Argentina: Review and prospective study to improve the present situation

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Abstract: Many Latin American cities today face the misbalance between economic productivity and environmental sustainability while they have to tackle both global and local threats to ecosystems and people's health. La Plata Conglomerate (800,000 inhabitants)—placed in an area where the atmosphere has low self-cleansing capacity—has intense industrial, power plant and traffic activities; nevertheless and considering the importance it deserves, air pollution monitoring has been largely denied to the public. Taking into account historical, social, geographical and environmental aspects, the present prospective work compiles for the first time significant information and reports that allow gaining insight in the sources' role linked to the air quality status as well as getting a panoramic view of the present needs. The involved discussion, together with a robust statistical analysis of winds carried out at four weather stations, permitted providing guidelines for the installation of a primary continuous air quality network. The establishment of such network (which has many advantages) is considered a key tool to improve the present situation in which people deserve knowing the air quality they breathe as an aspect of their life quality. Our analysis suggest the installation of seven monitoring sites to follow up ten species such as SO_2, NO_x, VOCs (Volatile Organic Compounds) and PM2.5 (Particulate Matter ≤ 2.5 μm) among others together with basic meteorological parameters (surface winds, mixing height, etc.). Time frames and equipment to be employed are also suggested. Considering the broad context of the study, it was possible to infer

that there is a great need for the creation of a law to make mandatory the installation and operation of networks for cities with similar problems. Finally, the study recalls that several environmental closely related issues (such as urban heat island, traffic air pollution, landfill control, etc.) should be addressed in the future.

Keywords: air monitoring stations; air pollution; La Plata; meteorological parameters; network; robust correlation coefficient; wind analysis

1.   Introduction

1.1. General perspective

At the global level, the consequences of the misbalance between economic productivity and environmental sustainability are many and serious [1]. It has long been recognized that air pollution has negative impacts on human health and ecosystems [2–10]. More recently, due to its importance and its psychosocial dimension [11,12], many actors such as entrepreneurs, NGO (Non-Governmental Organizations) and decision makers have become more aware of the situation [13]. Progressively, since the early 1970s, several authors have tackle the issues of the political philosophy and environmental justice as well as the environmental ethic one [14–19] contributing to different forms of environmental policies.

Traditionally, national or global meteorological networks have not instrumented urban areas because they were focused on the wider region in order to provide weather predictions and long-term climate but, nowadays, urban meteorology, climatology and air quality constitutes true sub-disciplines [20] and their applications are quite important to assess the global climate issue. Some studies show clearly how changes in the air quality of a city are due to changes in regional meteorological parameters [21]. Besides the potential intertwined relationships between global climate changes and local air pollution at any given place, air quality monitoring networks focused on studying emission sources role, surveillance, population exposure, urban background and rural concentrations remain fundamental to assess life quality in cities and their surroundings.

Today, cities are the places in which most of the people in the world live [22,23] becoming the immediate and dominant environment for the development of the individuals [24]. In Latin America, around 80% of the population is urban [25], this index rises to 92% in Argentina [26]. Worldwide most of the cities possess environmental threats [27–31] since they are by nature, concentrations of humans, materials and activities and therefore, they exhibit both the highest levels of pollution and the largest targets of impact [32–34]. In year 2014 UNEP [35] has identified the air pollution as one of the key issues that require the immediate action by the international community. Particularly, in Latin America, official information on ground level air pollutants is scarce and annual mean of inhalable particles concentration is estimated to be significantly above WHO (World Health Organization) air quality guidelines in most of the countries [36]. The recent signing of the Paris Agreement (4 November 2016), in which many countries are involved, is quite important because it promotes air quality and human health improvement by, for example, encouraging the electrification of transportation and a transition from coal to sustainable energy [37].

Khare and Beckman [38] and Thornbush [39] provide several ideas, tools and solutions to project what modern cities will need to do in terms of efficiency, mobility, planning and design of the habitat and infrastructure, as well as to make adaptations to climate change. For example, the traditional way to improve the economy of a city is to increase consumption but generally, the activities involved contribute to increase climate change factors, then it is proposed [40] to switch from the consumption-based to a resource-based economic model.

Finally, it is worthwhile to consider that, as far as cities diagnosis deepens and people become aware of the problems that have been underestimated and denied for a long time (in the present case mostly the air quality), cities themselves can become the leaders of a significant part of the solution. And this is the perspective embracing the objectives and the proposals of this work.
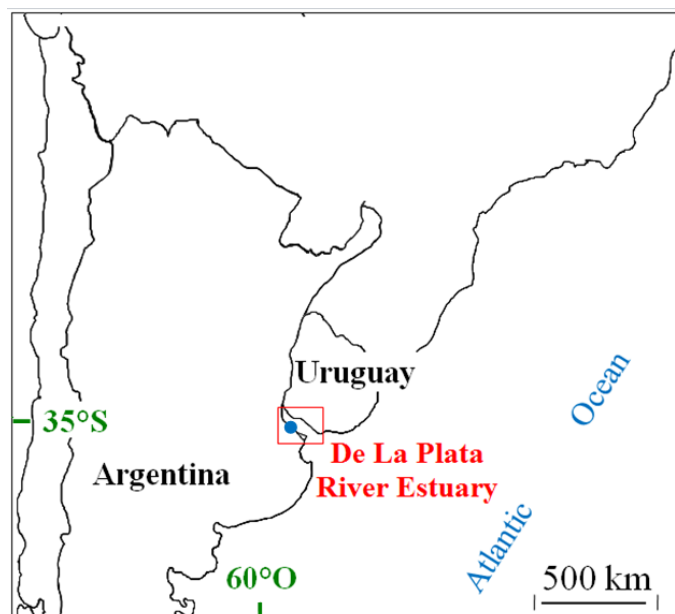
1.2. National context

Historically, Argentina has been a country with little tradition in which air pollutant monitoring concerns [25,41–44]. Several important cities of Argentina such as Buenos Aires [45–47], Córdoba [48–50], Mendoza [51–53], Santa Fe [54], Rosario, Tucuman [25,55] and Bahía Blanca [56,57] have been making efforts to evidence and control the increasing air pollution problems, some of them possess surveillance networks with different degree of efficiency regarding species, areas and continuity. Puliafito [58] points out the generalized absence of an operating management system for the air as a resource (including municipal, county, national and international levels). This reveals not only how the lack of air pollution records limits the evaluation of the impact over the human health [59] and different parts of the ecosystem such as land use [60,61] but also how the air pollution remains masked in governmental costs, e.g. health costs [62–64]. At the same time, the lack of policies to materialize the commitment to the systematic follow up of air quality parameters implies a "policy" in which "if is not measured or the public is not aware of, may be it does not exist". But monitoring should be a fundamental component of environmental science and policy [65], moreover and in order to gain environmental awareness, "the only way to certainly know if the air quality problems exist, are taking place o are getting worse is through measuring the pollutants" [42] on a systematic basis and make the information available to the public.

1.3. Focusing on the La Plata Conglomerate case: Historical aspects, environmental and social issues, economical activities

La Plata City (35°N, 58°W) is located at the De La Plata River estuary in South America in eastern Argentina (Figure 1). Founded in 1882 (as the capital city of Buenos Aires Province) when the country profile was agro-exporter [66] became a model of "healty metropoli" or "sustainable city" [67,68]. The layout of the city allowed a profuse urban woodland [69,70] with the limits between urban and rural areas somewhat unclear. Along the decades the city accompanied the country's territorial consolidation [71,72] but during 1920s, a national project pursuing Argentina to become an oil self-supplying country, distorted the original role and design of the city area. Several facts [73–81], such as the installation of a large oil refinery close to the urban area, provoked important environmental impacts preventing and worsening the urban sustainability [80].

The city is the head of La Plata County (around 942 km^2); its urban population together with those of Ensenada and Berisso (two neighbor counties of around 100 km^2 and 135 km^2 respectively)

constitute a true urban conglomerate with around 800,000 inhabitants being one of the six most populated areas of Argentina. The economy of the conglomerate is structured as follows [82]:

Figure 1. The rectangle embraces the estuary of the river where La Plata Conglomerate (indicated with a round point) is located.

Around 54% corresponds to the tertiary sector (trade and services), around 42% to the secondary sector (industry, construction) and around 3% to the primary sector (livestock, agriculture, fruit-horticulture, milking parlors, floriculture). Vehicular traffic is intense with around 350,000 cars, 1900 taxis, 1200 rent-cars or remise and 640 buses in 2010 [83]. An industrial park (located at Ensenada, around 8 km far from La Plata City center between the river bank and the city—see the rectangle in dashed lines of Figure 2) embraces the most important oil refinery of the country—with a crude oil processing capacity of 38,000 m^3 per day [84]—among a few petrochemical and non-petrochemical industries, a shipyard and a navy port (apt for large oil tankers). In the vicinity areas is located one of the great thermal power plants of Argentina with a capacity of 560 MW (megawatts) expandable to 840 MW (Point L in Figure 2). Other industrial parks (two in La Plata County and one in Berisso County) as well as many small industries located in the inner city and surroundings, mainly with manufacture industries, complete the general picture of the industrial activities. Towards north—west La Plata and Ensenada counties are bordered by two highly populated counties (Florencio Varela and Berazategui) characterized by urban sprawl that belong to the third urban ring of Buenos Aires city (one of the megacities in Latin America). La Plata conglomerate and the three urban rings of Buenos Aires city together with Buenos Aires city itself conform what is considered an urban continuity called "metropolitan area" [74,85].

The city has to encourage the global climate challenges [12,86–89] as well as the incidence of air pollution in respiratory diseases and health [90]. Considering life quality, particular portions of the inhabitants should be taken into account, such as children [91,92] and elderly [7,93]; furthermore, being Argentina a developing country, poverty should be accounted [94]. A recent article [95] informs that La Plata Conglomerate conurbations include numerous slums (129 belong to La Plata,

17 to Ensenada and 18 to Berisso counties). As a general context, it is worthwhile to mention that for the second semester of the year 2016 the poverty plus indigence in people had reached for the whole country a total of 36.4% [94]. These three indicators, among others related to the prosperity of a city [96,97], are only mentioned in order to show evidence of the vulnerability of a great number of people exposed to the air pollutants.
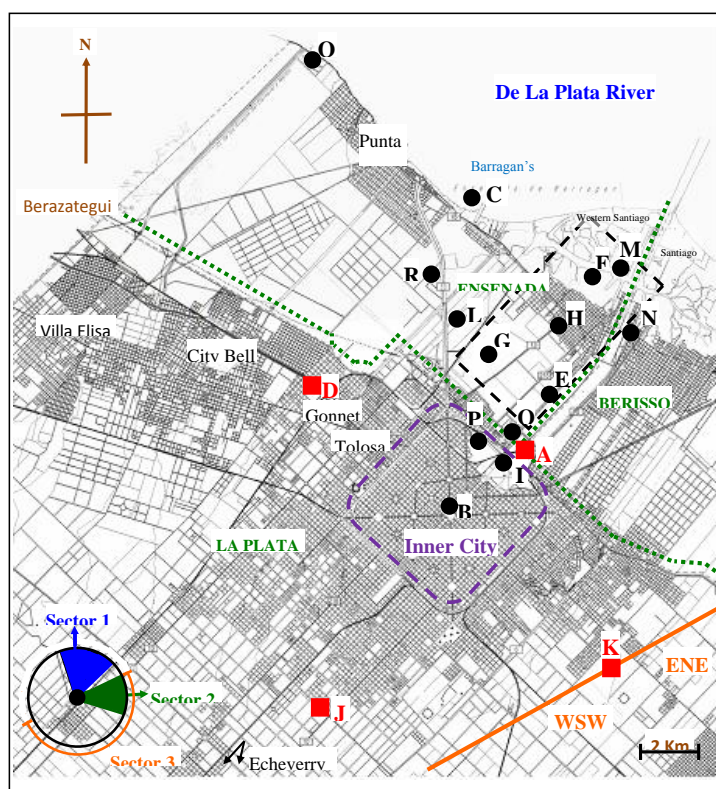
1.4. Air quality status and this work objectives

La Plata Conglomerate has been considered one of the most six potentially air polluted areas of Argentina [98] being the air pollution one of the most important anthropic risks [99]. Regarding air pollution potential this conglomerate is located in an area where the atmosphere has low self-cleansing capacity mainly during autumn and winter [100]. The information about air quality is discontinuous and scarce [25,44,98,101–103] and several environmental justice problems have been taken place along the years [104]. A group of reports provide a panoramic view of the air quality and its consequences (Section 1.4.1).

As states McGregor [105] meteorology is at the heart of the relationship between air pollution and health and so, meteorological parameters should be measured in accordance to the objectives of the air pollution network. Wieringa [106] states that the representativeness of meteorological data is user—dependent. Besides the four meteorological datasets employed in this paper (Section 3) La Plata Conglomerate has, since recently, other meteorological data sources: Six municipal weather stations are operational since year 2016 with the purpose of providing daily weather conditions to the public as well as meteorological alarms. Raw data from this network is not still available. The main source of meteorological data in the area (that is to say, which follows the National Meteorological Service requirements, i.e. data are official) is located at the airport (represented by Point K in Figure 2). But such wind observations, mainly devoted to help with plane traffic [107] are not very appropriate for air pollution considerations [108]. Consequently, there is, in the area under study, a need to make a specific and systematic continuous follow up of some basic meteorological parameters at different sites [103] in such a way that allows official data retrieving. Moreover, this absence has been early detected by Mazzeo et al. [109].

Although all the various facts mentioned above, up to date, there is no official air monitoring network (including meteorological parameters) providing air quality information to the public.

1.4.1.   Background studies: Sites, meteorological parameters and air pollutants

Since the 1960s and under different perspectives, several studies related with air pollution in La Plata Conglomerate area have been taking place. Different authors have selected some particular areas of interest (most of them identifiable in Figure 2), as well as, some air pollutants and meteorological parameters to assess the status of the air quality:

Figure 2. Map of La Plata and surroundings. The four reference points involved in the present study are indicated with squares while other ones with circles. Point A: National Technological University (UTN)—La Plata Regional Faculty. Point B: Geometrical center of the inner city (square with rounded corners in dash lines). Point C: River bank. Point D: CIOp (Optical Research Center). Point E: Oil Refinery (0.3 km²). Point F: Shippyard. Point G: Steel processing plants. Point H: Center of the rectangle (dash line) with high industrial activity. Point I: Observatory of the National University of La Plata (at "Paseo del Bosque"). Point J: Agrometeorological Station Julio A. Hirschhorn belonging to the National University of La Plata. Point K: La Plata Airport. Point L: Thermal Power plant. Point M: La Plata Port. Point N: Berisso Industrial Poligon (created in 1999). Point O: Chronic's Hospital "El Dique" (Naval Hospital). Point P: De la Plata Hippodrome. Point Q: Natural Reserve "Punta Lara" (60 km²). Point R: Urban Solid Waste Landfill area. The distance between points B and D is approximately 6.5 km, from Point D to E aprox. 8.5 km, from D to E aprox. 5 km, from B to J aprox. 8 km and from B to K aprox. 7 km. Out of the Map around 8 km far from Point B towards south west (and around 11 km far from Point K), in the intersection of the Provintial Route N°13 and the National Route N°2, is placed the La Plata Industrial Park I (around 0.58 km²) since 1997. Another Industrial Park of around 0.93 km² is located along the National Route N°2 at the kilometer N°50. In the lower left corner of the map are indicated groups of wind directions important for this study: Sector 1 covering NNW-NE clockwise. Sector 2 covering ENE-ESE clockwise; the arrow in sector 1 indicates north while the one in sector 2 indicates east, both arrows indicate the direction from where the wind flows. Sector 3 covers ESE-WSW clockwise (also indicated in the area at Point K).

- Nieto et al. [110] point out the "real problem of visible pollutants and odors" stating that "a systematic study of the different polluting substances in the air must be performed".
- Mazzeo et al. [111] employing data taken from Point I found during the daytime that the maxima mixing layer were, in general, lower than the critical value of 1500 m, indicating long periods with low vertical dispersion.
- Mazzeo et al. [109] based on data from Point I and Point K, point out the need of a meteorological network to follow up several meteorological parameters.
- Mazzeo et al. [112] studied the ventilation indices which for May, June and July were below the critical value of 6000 $m^2\,s^{-1}$ indicating the main probability for potential pollution.
- Cattogio et al. [113] measured twelve PAHs (Polycyclic Aromatic Hydrocarbons) in particulate matter in the vicinity area of Point I.
- Herbarth et al. [114] studied VOCs (Volatile Organic Compounds) at three sites, one at Ensenada near a petrochemical plant (measuring outdoors and indoors) and two within the inner city (one close to Point I while the other in the inner city towards SW direction from Point I). Taking into account the sources (oil refinery and/or traffic) locally dependent pollution profiles were observed. While aromatics and aldehydes were distributed relatively uniformly, the combination of aromatics and alkanes at several localities pointed clearly to the refinery as the source of pollution.
- Colombo et al. [115] measured total suspended particles, aliphatic particles and semi-volatile aliphatic hydrocarbons while Bilos et al. [116] measured airborne trace metals at four sites: One in the area of La Plata Port in the vicinity area of Point M, a second at the petrochemical area near Point E, a third within the inner city and the fourth around 14 km far from Point B in the south-west direction at the rural suburb of Echeverry.
- D ́scoli et al. [117] studied the balance between the CO_2 (carbon dioxide) absorbed by the natural environment and the anthropogenic emissions due to the energetic consumption. They characterized the inner city as well as some of its peripheral areas and found a great misbalance (around 99%) at the expense of the natural media. Other local studies such as [118–120] point out the importance of considering the air quality issue regarding the development of the city.
- Massolo et al. [121] tested mutagenicity and cytotoxicity in dust of different sizes sampled in the urban and the industrial areas. Urban areas of La Plata had burdens about one order of magnitude higher for particles < 0.49 μm than for the rest of the sizes. Mutagenic potency was found to be high in industrial sites.
- Mara ñon Di Leo et al. [122] studied wind turbulence at Point A and found an important dependence between SO_2 concentrations and the turbulent structure of the oncoming wind.
- Rehwagen et al. [123] measured PAHs bounded to particulate matter at a vicinity area of Point H, at the inner city and at a control site located around 15 far from Point B towards south-east direction.
- AAPLP [99] reveals the influence of the solid urban waste landfills that for different periods have affected important sectors of the county with odors and toxics gases. Regarding the inner city and the vehicular traffic the study consider the area of the Central Bus Terminal and some roundabouts as serious cases to be addressed. Additionally, the report highlights some other air pollutant contributors such as the incineration furnaces of the hospitals.
- Nitiu [124,125] carried out an aeropalynological analysis of the city measuring during three years at a site near Point B. Pollen is of allergological importance; 79 types were recognized.

Pollen from arboreal taxa predominated from July to October while pollen from herbaceous taxa from November to March.

- Negrin et al. [126] studied bioaerosols (airborne fungal and bacteria) at five sites: One in the inner city, a second within the industrial rectangle, a third in a rural area, a fourth at a coastal area, and a fifth at a residential area (location details were not specified).

- Rosato et al. [127] reported SO_2 measurements at Point A while Ratto et al. [128] at Point D. Concentration peaks were found closely correlated to wind directions that transport air pollutants from the industrial park of Ensenada.

- Wichmann et al. [130] measured PM10, PM2.5, PM0.5 and VOCs during 4 week periods in wintertime 2005 and 2006 in order to study the effects of exposure to petrochemical pollution on the respiratory health of children at four places. One in the inner city, another in the industrial rectangle. Two sites were selected for control purposes (places considered with low pollution) due to socioeconomic reasons: One located in City Bell around 15 km far from Point B and the other in vicinity areas of Point K. Exposure to particulate matter and VOCs arising from petrochemical plants but not from high traffic density was associated with worse respiratory health in children.

- Massolo et al. [131] reported VOCs measurements (indoors and outdoors) at four sites, one located in the industrial rectangle, another in the inner city and two sites for control measurements: One located in City Bell around 15 km far from Point B and the other in vicinity areas of Point K. Vehicular traffic was identified as the main source of outdoor VOCs exposure in all sites with the exception of the industrial area where air (indoors and outdoors) were strongly affected by the industrial activity.

- Orte [132] reported SO_2, PM10 and total aerosols measurements at Point A while aerosols at Point D and at a site around 2 km far from Point N towards east direction at Berisso.

- Ratto et al. [133] analyzes the calm structure which is important due to the "accumulation effect" of air pollutants while Ratto and Nico [134] study the wind direction roses according their speeds and analyze wind patters within the first hour after calm occurrences.

- Blanco et al. [84] employing previous reports carried out by CIMA (Centro de Investigaciones del Medio Ambiente—Research Center of the Environment) and UFZ (Environmental Research Institute of Leipzig, Germany) covering 1999–2002 and 2006–2012 analyze data regarding total suspended particulate matter (TSPM), PAHs and VOCs in different sites: Two within the inner city (one about 1 km far from Point I towards east direction and the other at the southern area), one within the industrial rectangle, two sites for control measurements (one located in City Bell around 15 km far from Point B and the other in vicinity areas of Point K) and one site at Tolosa a small neighborhood located at the transect between Point D and Point B (out of the inner city). The authors study the existing conflict between public health and productive development in which is trapped La Plata Conglomerate and that put the public health at a true level of risk; accordingly, they suggest several corrective and preventive actions.

- Colman Lerner et al. [135] reported VOCs measurements during a four week campaign at four areas. Several points covering the inner city, one point in the industrial rectangle and two for control (one located in City Bell around 15 km far from Point B and the other around 8 km far from Point B towards south).

- Gutiérez [136] analyses ocular alterations due to the presence of PM2.5 and PM10 during 2013–2014 in both industrial and urban areas finding that these type of threats are more present in the industrial area.
- Orte et al. [137] reported PAHs (bounded to particulate matter and as a gas), PM10 and PM2.5 at eight sites: Two labeled as industrials (one is Point A and the other is inside the industrial rectangle between Point E and H), two within the inner city (one towards its southern corner and the other towards north-west direction close to the border of the square), three in the eastern neighborhoods of Gonnet and City Bell (one is Point D, another is located towards west around 2.5 km from far Point D and the third was located towards west-nor-west around 4.5 km far from Point D), finally, a "control" site located approximately 4 km towards south-east from Point K [Orte, Private Communication].

1.4.2.   This work objectives

The first purpose of this paper is to document and justify the need that the La Plata Conglomerate has, since a long time, of air pollution planning and control. At the same time it is intended to highlight the importance to provide the public relevant air quality information as an issue that plays a fundamental role in democratic environmental policy making.

Regarding contextual data, focusing on the main industrial activity of the area and analyzing winds by employing a robust statistical approach, the second purpose of this prospective study is to suggest the basic characteristics of an air quality monitoring network as a key element towards the improvement of the present situation.

As a result of this research it was found sound information as well as referential studies which are compiled for the first time providing large amount of specific and contextual data as well as a panoramic view of the air quality status in the area. The involved review permitted satisfying the first objective. Regarding the second one, the applied methodology allowed gaining insight on some characteristics that a primary network should count. As a consequence of these findings, guidelines to improve several environmental closely related issues were possible to be given together with tools that allow envision future perspectives.

2.   Geographical and climatological characteristics of the region under study

Geographically, La Plata Conglomerate is placed in an area which is mainly a typical plain named "pampa"; the low portion (or low terrace) also called coastal plain of the De La Plata River (a coastal strip) is the subaerial continuation of the river bed. The width of this strip is around 10 km (from the NE side of the inner city rectangle towards the river bank—Figure 2) and has a slope that goes from 5 m (meters) towards 0 m when reaching the river [138]. The high portion has an elevation between 5 m and 30 m with an average height of 15 m above the mean sea level [69]. Both portions are separated by a low cliff along a line in the WNW-ESE orientation, this border has a height of at least 5 m above the mean sea level [138]. Most of Berisso and Ensenada counties belong to the low terrace while the major part of La Plata County belong to the higher portion of the plain; the inner city has a small area in the low portion (located at the northern corner). The main natural ecosystems in the area are composed by: Beaches and waters from the river, scrublands and

floodable grasslands, riverine mount and riparian forest (hydrophilic woods), lagoons, quarries, streams and water mirrors and, grasslands and *celtis ehrenbergiana* xorophytic woods ("talas") [139].

La Plata City center is around 11 km far from the De La Plata River bank (Figure 2), this river is one of the most important in South America (its basins covers 3,200,000 km^2) and is part of the boundary between Argentina and Uruguay (Figure 1). The geographical context of the river, which flows into the Atlantic Ocean as an estuary, creates a considerable surface temperature contrast with the continent and set the stage for the development of a low level circulation with sea—land breeze characteristics [140,141].

According to Thornthwaite [142] the climate is "wet, mesothermal with null or small water deficiency" and according to Köppens modified classification the climatic area corresponds to a "humid subtropical" [143]. The annual mean temperature is around 16 ℃, January is the hottest month (22.4 ℃) and July the coldest one (9.9 ℃). The annual average relative humidity is 70% with a minimum in January and a maximum in July. The annual mean precipitation is 1010 mm and approximately 36% corresponds to the period December–March [144]. The low-level wind field in La Plata and surroundings follow the general pattern of that of the southern part of the estuary of the De La Plata River as shown in [145]. Wind circulations over the river area and the adjacent ocean depend mainly on the oriental flank of the subtropical anticyclone of the South Atlantic Ocean which plays a fundamental role on determining the winds over the estuary. The location of this high pressure system changes during the year at the same time that interacts with different cyclonic centers along the Argentinian territory, this produces for example that, in winter the mean wind direction be north-west (NW) while in summer east-north-east (ENE). The annual cycle involves a clockwise rotation through the four seasons from winter to summer [86]. As shown in [141] predominant winds regarding 8 direction wind roses at La Plata Airport (Point K—Figure 2) for the three decades involving 1981–2010 are E, NE and N.

3. Characteristics of the data employed

Due to scarcity of meteorological data in the area, Point K records have been considered for the present study. The rest of the weather stations referred in this paper belong to institutions that have their own objectives and so they do not follow, necessarily, protocols such as those of the World Meteorological Organization [146] or of the United States Environmental Protection Agency [147]. This explains the differences in data quality.

The four sites from which data was retrieved have been represented with red squares in Figure 2; they are shown together with other reference points in the area. Point K in this figure corresponds to La Plata Airport (rural area) which is located around 8 km far from Point B (inner city), data from this source covers the period 1995–2005 and was provided by the National Meteorological Service (SMN) under request. The data consists of hourly averages involving wind directions, velocities and calms and were measured at 10 m above the ground. Data from Point A (urban area) belongs to the Technological National University (Universidad Tecnológica Nacional—UTN) located in Berisso, it operated a Weather Monitor II Euro version weather station (Davis Instruments®, CA) with a weather cock and anemometer installed at 12 m height. Data covers the period 1997–2003 and consists of 15 minutes averages. Data from Point D (urban low density area) belongs to the Optical Research Institute (CIOp—Centro de Investigaciones Opticas) at Gonnet neighborhood, the two year period registries (2006–2007) consisting of 15 minutes averages were obtained with the same

weather station as Point A installed at 12 m above the ground. Data from Point J (semi-rural area) belongs to the Agrometeorological Station J. A. Hirschhorn that is part of the National University of La Plata. It operated a Gro Weather Industry weather station (Davis Instruments®, CA). The height above the ground in this case was of 5 m and the period covered is 1998–2009 with data taken as hourly averages. Both models of Davis stations take winds every 22.5 ° covering 360 ° of the compass with 16 directions. The four monitoring sites provided complete data sets for the different periods under study with the exception of Point J during winter 2000 which records were very poor: Missing data were treated as referred in [141].

Throughout this paper hourly averages imply hourly blocks (for example, 00:00–00:59 hrs. is equivalent to "hour 0" local time). Regarding seasons, summer includes December of the precedent year and January and February of the actual one, whereas autumn included March, April and May, winter included June, July and August and spring included September, October and November. Regarding wind directions north is frequently written as N, north-west as NW and so on.

4.   Legal aspects

Regarding air pollution legislation applicable to the area under study (i.e. provincial and/or national) it can be stated that the air quality standards are somewhat overdue compared to the international guidelines such as those of WHO, USEPA (United States Environmental Protection Agency) and EEA (European Environmental Agency). For example, in the provincial legislation (last issue in 1996) the limit for the annual average of SO_2 is 30 ppbv; there are also some legal voids, e.g. regarding PM2.5 and its bounded species. Besides, since 2004 there is a national law that rules the access to the environmental information. Among other issues the law emphasizes the role of the environmental indicators (such us, variables that allow the follow up of the air quality). Unfortunately, the articles of this law are not yet fully regulated.

Finally, in which air quality monitoring concerns, there is no law neither national nor provincial that considers mandatory the installation and operation of air pollution networks.

5.   Methods

Seasonal wind patterns among the four monitoring sites were compared employing MCD (Minimum Covariant Determinant) statistic introduced by Rousseeuw [148]. This coefficient can be considered as a robust version of the well-known Pearson product-moment correlation coefficient *r* [also named as Pearson's "rho" (ρ)]. The employment of the MCD coefficient was done in order to minimize the influence of atypical observations (potential outliers) that may distort the results by inflating or deflating the *r* estimate.

MCD computations have been carried out applying the statistical software package SCOUT version 1.0 from [149]. MCD properties are described in [150]. For the purpose of the present study we supposed the contamination of the data to be around 5% and so a value $h = 0.9$ was chosen (*h* is the coverage).

A weighted average was employed to compute the central tendency of the data (section 6.2.1 and 6.2.2), instead of the classical one, this allows to take into account the differences between time scales of the available data sets (section 3). In this way the sites with more years of observation have more relevance than the ones with less.

In order to correct the differences of height in which the anemometers are installed, it was employed the power law velocity profile (a very well-known empirical approach [151]).

6. Results and discussion

6.1. Discussion as regards of previous studies

Overall, the studies cited in the section 1.4.1 involved short campaigns (during weeks or months). They ordinarily employ non-continuous methods, the follow up of some parameters is discontinuous or rather intermittent, data quality is not homogeneous and there is a generalized absence of correlation between wind characteristics and air pollution. Nevertheless, these studies contributed very much to characterize the air quality status in the area by, e.g., assessing the contribution of the different sources (e.g., traffic vs. industrial), indicating differences between indoors and outdoors pollution, quantifying the aerobiological characteristics of the air, providing a large variety of species (inorganic, organic and biological) analyses and their impact on welfare and health, determining wind patterns which are important for air pollutant transport towards exposed population and, detecting seasonal phenomena among others. Considering that the punctual sites employed by the authors represent larger areas (in which the "vision" towards the sources remain similar), it is possible to realize that in many cases the authors followed analog criteria.

No standardized study have been found characterizing "environmental areas" of the city but, for the purpose of this preliminary work and concerning the different degrees of population densities and the prevalent economic activities, the monitoring sites can be broadly labeled as: Residential (outskirts neighborhoods), coastal (sometimes superimposed to the industrial area, for example, near the port or the shipyard), urban (mostly within the inner city of La Plata but the urban areas of Berisso and Ensenada could be added), industrial (mainly referred to the industrial rectangle at Ensenada but other industrial areas could be added) and semirural and rural areas (which in some cases have been considered as background or control sites).

Although not carried out in a continuous way, it is worthwhile to point out as an example, that different research works show clearly that particulate matter, i.e, PM10 and PM2.5 often exceeds the WHO guidelines annual averages (20 μg m^{-3} and 10 μg m^{-3} respectively). As health effects have been observed at very low levels of particulate matter exposure, there is a lack of proof whether a lower threshold exist [152,153]. This fact together with the significant values found, make us highlight the need of a continuous follow up of particulate matter in its various sizes. Also that many of the 16 PAHs considered as priority [186] are present bounded in the particulate matter or in gaseous forms in different degrees and areas of the city and surroundings while carcinogenic substances (such as benzene) were often quantified.

US ATSDR [154] considers that annual averages of SO_2 of 10 ppbv or more in the presence of particulate matter have impact on respiratory diseases. Daily averages exceeding OMS guidelines [153] of 7.6 ppbv (20 μg/m^3) were founded during short campaigns. Although this gas is considered mainly from industrial origin (because gasolines employed in Argentina are of low sulfur content) it should be considered the contribution of diesel engines (sulfur content for the various kinds of diesel is on average 500 ppmv since 2012). Also, some of the measured air pollutants (for example, metals in air) need to be updated because of changes and the growth in sources (e.g. traffic, industrial, power plant).
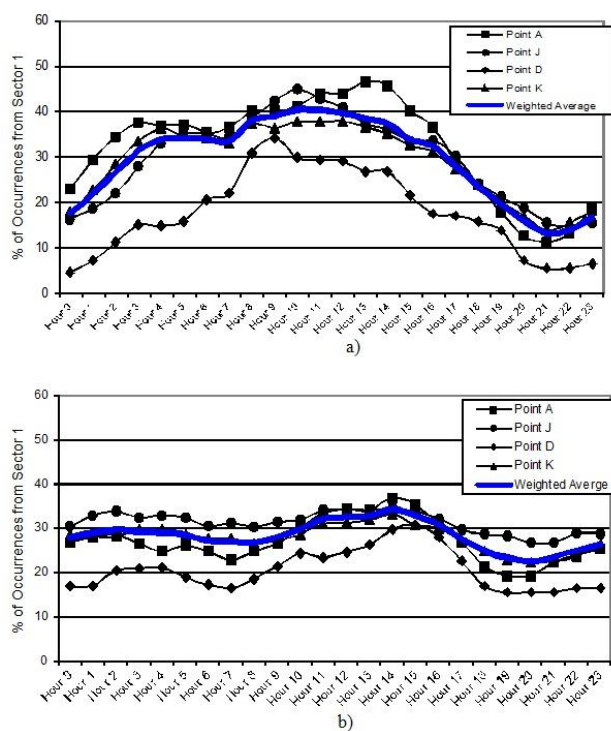
Out of the scope of the compiled studies (and considering the sources and the international criteria ruling air quality—section 6.3.2) remain the assessment of some clue pollutants such as NO-NO$_2$ (nitric oxide-nitrogen dioxide), O$_3$ (ozone) both playing an important role in the photochemistry of the air and CO (carbon monoxide) closed related to traffic exhausts [155].

Finally, the panoramic view the authors infer is that the status of air quality is of general concern to health, ecosystem and goods and, particularly, in relation to the health of children and elderly as well as its relationship to poverty.

6.2. Wind characteristics

6.2.1. Main wind directions transporting industrial air pollutants

It is frequent and useful to link air pollutants transport with groups of wind directions [156,157]. In previous reports [128,129,141,158] particular groups of wind directions were analyzed: Sector 1 (involving NNW-N-NNE-NE) that transport air pollutants from the main industrial area (industrial park of Ensenada—Point H in Figure 2) to the inner city and sector 2 (involving ESE-E-ENE) that transport the pollutants towards a large residential area (eastern neighborhoods such as Tolosa, Gonnet, City Bell and Villa Elisa—Figure 2). It has been shown that both sectors keep strong correlation with SO$_2$ concentrations at Point A [158] and at Point D [141]. Sector 1 and 2 (shown in the circle with arrows in the bottom left corner of Figure 2) have been presented and discussed for Point A during 1998–2003 and for Point J during 1998–2009 [141]. The present section expands the monitoring sites (adding Point D and Point K) and compares them in the search of a more generalized wind pattern.

Figure 3. Observed wind frequencies for Sector 1 in different sites and time periods.
a) Summer (overall average 29.2%); b) Winter (overall average 28.4 %).

Figure 3 shows the hourly profiles of wind occurrences from sector 1 corresponding to the four monitoring sites for summer and winter (both seasons selected to save space and because they show seasonal extreme behaviors). The bolded line indicates the weighted average for the four sites. This figure allows visualizing the presence of the sector according the hours of the day; all sites show similarity among patterns being Point D the one that most differ (but also the one with fewer years of records).

All the wind profiles (also those not shown of autumn and spring) have time ranges where the frequencies show peaks. For summer, the high values involve Hour 9–Hour 14 with a weighted average occurrences of 39.1% while for winter involves Hour 11–Hour 16 with a weighted average of 32.6%. Autumn and spring showed intermediate patterns, autumn is more intense than winter while spring is less intense than summer. The minimums where found around hours 19 and 20 for all seasons. The general weighted average covering all seasons and sites was 27.3% for sector 1. Table 1 shows the MCD (Section 5) coefficients for sector 1 computed for all the possible combinations of patterns taken by pairs for the four seasons of the year. Its results allow inferring that there exists a generalized linear relationship between sites (note that the lowest values for the MCD coefficient involve Point D) which implies that sector 1 is "seen" from the four sites in a very similar way.

Table 1. MCD estimates for sector 1. The wind profile curves for the four sites under study were taken in couples to assess similarity along the four seasons. This table provides a degree of linear relationship among the curves for the seasons and sites as the ones shown in Figure 3 for summer.

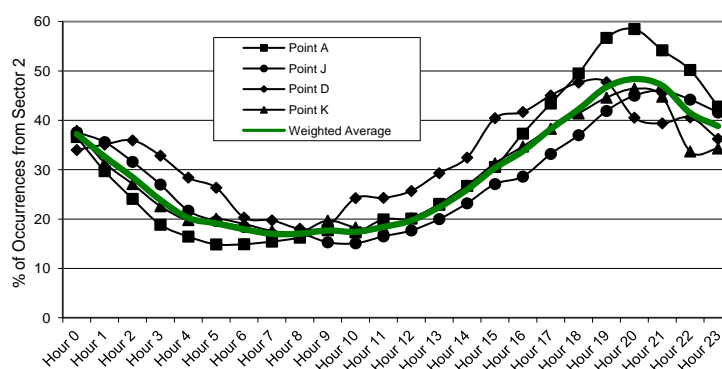| Sector 1 (NNW-N-NNE-NE)				
Correlated sites	Summer	Autumn	Winter	Spring
A,J	0.85	0.91	0.87	0.90
A,D	0.78	0.86	0.85	0.93
A,K	0.98	0.84	0.93	0.90
J,D	0.97	0.83	0.75	0.95
J,K	0.98	0.94	0.96	0.99
K,D	0.94	0.75	0.79	0.98

Figure 4 is an analogous representation of Figure 3 but for sector 2. This sector also show great similarity patterns when observed from the four monitoring sites. The maximums are observed in twilight between hours 19 and 21 (with a weighted average of occurrences of 47.4% in summer while 25.7% in winter). The minimums are observed close to sunrise. Autumn and spring showed intermediate patterns, warm seasons have more intense peaks than cold ones. The general weighted average covering all seasons and sites for sector 2 was 24.4%. Table 2 shows the MCD values for sector 2 computed for all possible pairs of sites and seasons. The result allows inferring that, like sector 1, sector 2 exhibits a generalized linear relationship between sites along the seasons.

In summary, Figures 3 and 4 allow visualize that the four sites "see" wind occurrences in a very similar way. While Figure 3 allows predict that industrial air pollutants are transported towards the inner city and downward—predominantly during midday and the early afternoon—Figure 4 indicates that these pollutants are transported towards the residential areas (as Tolosa, Gonnet, City Bell, etc., see Figure 2) at the end of the afternoon and when the night starts. On average, sectors 1 and 2 have
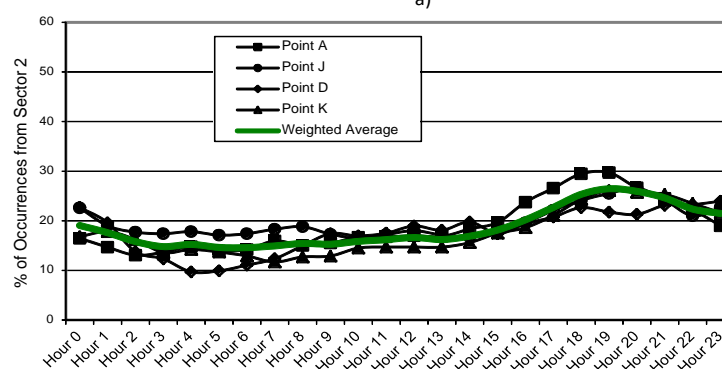
together at least 50% of total wind occurrences. The different time intervals in which sectors 1 or 2 are prevalent allows inferring, for example, that people who have activities during the day in the inner city and live in the mentioned eastern residential areas may be added to those groups of people most potentially exposed to industrial pollution. Additionally, it has to be reminded that the exposure to air pollutants in the urban area is composed not only by those coming from industrial sources but also by the vehicular traffic ones.

Table 2. MCD estimates for sector 2. The wind profile curves for the four sites under study were taken in couples to assess similarity along the four seasons. This table provides a degree of linear relationship among the curves for the seasons and sites as the ones shown in Figure 4 for summer.

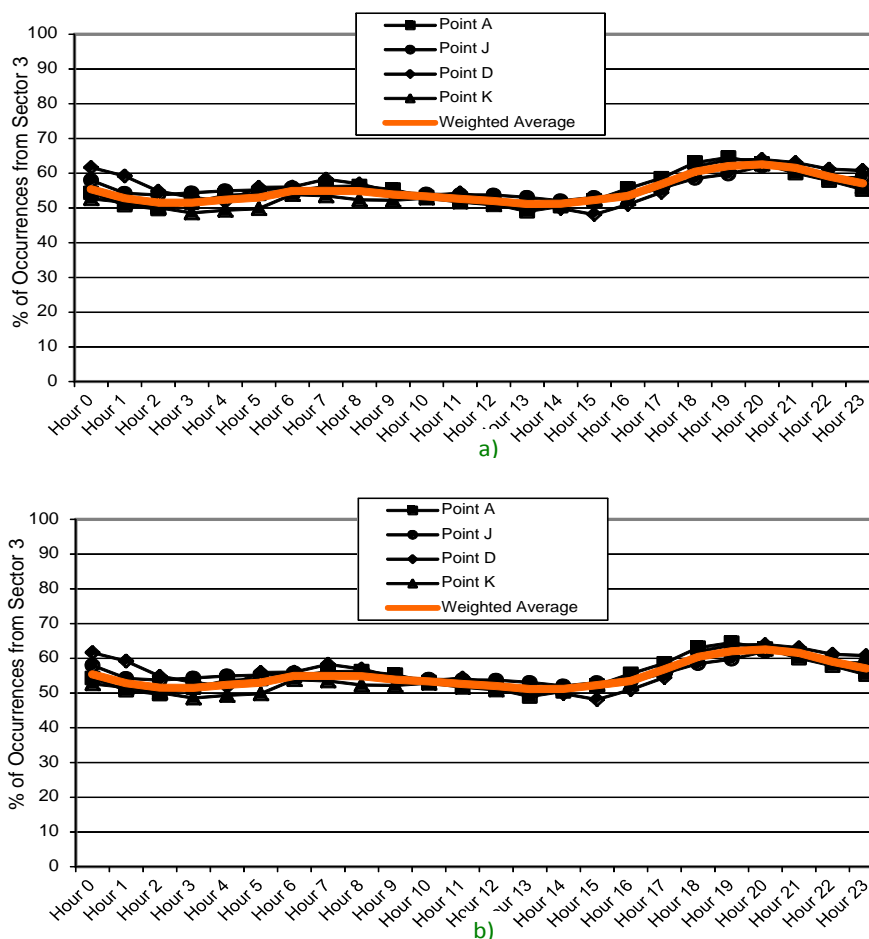| Sector 2 (ENE-E-ESE)				
Correlated sites	Summer	Autumn	Winter	Spring
A,J	0.96	0.98	0.65	0.95
A,D	0.87	0.83	0.69	0.90
A,K	0.99	0.96	0.84	0.96
J,D	0.86	0.94	0.68	0.91
J,K	0.95	0.96	0.89	0.96
K,D	0.95	0.94	0.79	0.96

a)

b)

Figure 4. Observed wind frequencies for Sector 2 in different sites and time periods. a) Summer (overall average 29.3%); b) Winter (overall average 18.6%).

6.2.2.   Wind directions and a potential site to follow up background concentrations

As discussed in previous reports and in section 6.2.1 points A and D appear as "strategic" sites to monitor industrial airborne pollutants.

Figure 5. Observed wind frequencies for Sector 3 in different sites and time periods. a) Summer (overall average 63.2%); b) Winter (overall average 55.7%).

On the other hand, Point K is the receptor of industrial pollutants when winds are NNW or N. Regarding the air pollution from the urban area and following the geometrical criterion, wind directions involving ENE-WSW clockwise are the ones that do not transport neither industrial nor vehicular air pollutants towards Point K. Given its distance to the industrial sources (around 9 km far) and located in a rural area—average wind velocities around 14.0 km h^{-1} while average calms around 11.1% [159] during the decade 2001–2010, it looks (among the four points where winds have been measured) as a good candidate to measure background concentrations. We call this new group of wind directions as sector 3 (ENE-E-ESE-SE-SSE-S-SSW-SW-WSW), see Figure 2 (bottom left and right corners).

Table 3. MCD estimates for sector 3. The wind profile curves for the four sites under study were taken in couples to assess similarity along the four seasons. This table provides a degree of linear relationship among the curves for the seasons and sites as the ones shown in Figure 5 for summer.

Sector 3 (ENE-E-ESE-SE-SSE-S-SSW-SW-WSW-W-WNW)				
Correlated sites	Summer	Autumn	Winter	Spring
A,J	0.83	0.93	0.73	0.92
A,D	0.77	0.90	0.56	0.91
A,K	0.98	0.95	0.79	0.91
J,D	0.99	0.95	0.94	0.97
J,K	0.97	0.93	0.71	0.95
K,D	0.97	0.68	0.87	0.96

Analogously to Figures 3 and 4, Figure 5 shows the wind profiles for sector 3. All the seasons (autumn and spring not shown) show a very good correlation among all monitoring sites (Table 3). As this sector has a very important presence along the "day", since occurs on average at least more than 50% of the time, Point K results in a very appropriate site to follow background concentrations. Furthermore, Figure 5 allows detecting two important moments of the day to settle reference, one around midday when this sector has its minimums and the other around twilight when it has its maximums along the seasons.

Sites studied in sections 6.2.1 and section 6.2.2, i.e. A, D, J and K, according to hourly wind profiles support the "ad hoc" criteria adopted by some of the research works mentioned in section 1.4.1.

6.2.3. Wind velocities and calms

Recall that, the available meteorological data are of different quality, for example, the anemometers were installed at different heights (section 3) and so horizontal wind velocities were corrected (section 5).

The total corrected averages were 7.1 km h^{-1} at Point A, 8.2 km h^{-1} at Point D, 7.5 km h^{-1} at Point J while at Point K the average was 14.0 km h^{-1}. Leaving Point K out, the average is 7.6 km h^{-1} while including it 9.2 km h^{-1}. According to McCormik [160] the persistence of surface winds lower than 10.0 km h^{-1} tends to accumulate pollutants [161,162], which is the situation most of the time. The major stagnation factor, i.e. calm occurrences, has a general average of around 14% being at least 11% during spring (the windy season).

6.3. Main characteristics of a primary network

The term "primary network" employed in this paper is considered a starting point for the continuous and systematic measurement of several air pollutants as well as meteorological variables. We think that such network should fully operate at least two or three years in order to get enough records to finally establish a base line for all the parameters. The emerging analysis will settle reference for the confirmation, re-design and/or the expansion of the network (in sites and species) as well as to refine specific objectives [163,165,167–172].

6.3.1.   Monitoring stations allocations

- At Point A it is expected to find air pollutant emissions mainly from the industrial park and from the power plant, both at Ensenada but also pollutants from vehicular traffic should be considered due to its proximity to a road. The surrounding areas of Point A embrace important receptors, among them recreational places.
- At Point B (or another covering the inner city) it is expected to detect industrial, vehicular traffic and power plant emissions. This site (which is the geometrical center of the inner city) is very representative of the mixed exposure to which many people are involved.
- At Point D (or another towards eastern directions at residential areas such as City Bell or Villa Elisa) it is expected to detect industrial and power plant air pollutants from the industrial rectangle at Ensenada in lower concentrations than, for example, at Point A. Also vehicular traffic immissions from the local area (expected to be lower compared to those of Point B) and those from the inner city.
- At Point H, including a large area around, it is expected to found airborne emissions mainly from the oil refinery and the petrochemical complex. Due to its proximity to the sources, the measurements at this site are somewhat independent of the wind direction occurrences. This site is interesting to investigate industrial emissions proximate to the sources. Local residents and two nautical clubs among other recreational places are the main receptors.
- At Point J (or another towards southern directions—for example, SSW and S—at rural areas such as Echeverry) it is expected to detect low concentrations from the industrial rectangle, from the power station emissions and from vehicular traffic.
- At Point K (discussed in section 6.2.2) or another located more far away towards SE appears to be a very important place to follow background concentrations. In terms of the receptors Point K is important due to the uncontrolled urbanization that it is taking place in the vicinity areas.
- At Point M it is expected to detect pollutants from the port activities strongly influenced by the petrochemical complex. The derived air pollution is important mainly for the exposed workers and people in general but, the impact on nature must be assessed permanently as shown by [173,174].

It is important to highlight that some of the proposed monitoring sites belong to state organizations which may contribute to management issues and costs [175,176].

The proposed monitoring sites can be very well complemented if open path (non punctual) multispecies monitors are employed. Accordingly, we suggest the installation of one DOAS (Differential Optical Absorption Spectroscopy) device (section 6.3.4) to cover the industrial zone (Ensenada) and another at the center of the inner city.

Although the design of a monitoring network depends strongly on the historical information available as well as the particular characteristics of the city and its surroundings, it is useful to consider, as examples, some characteristics of design of different cities. Krakow city (Poland) of around 700,000 inhabitants (inh.) in 1999 had 17 air monitoring stations [177]. Montevideo city (Uruguay) of around 1,200,000 inh. operates a network with 8 monitoring stations [178]. Rosario city (Argentina) of around 1,200,000 inh. in 2010 had installed 25 monitoring sites to the follow up of NO_2 from the vehicular traffic source [179]. London and surroundings with around 7,500,000 inh.

had 160 air quality monitoring stations in 2005 [9]. Moscow and surroundings with around 10, 500,000 inh. had 37 automatic monitoring stations in 2009 [180].

6.3.2.   Species to be monitored

Regarding the background studies (section 1.4.1) as well as international criteria for urban air pollution networks [9,175,181–185] the basic species to be monitored should be: Particulate matter (total suspended particulate matter, PM10, PM2.5, and PM1.0 or Black Carbon) and their bounded species (metals, etc.), O_3 (ozone), SO_2 (sulphur dioxide), CO (carbon monoxide), CO_2 (carbon dioxide), NO_x (NO-NO_2) (nitrogen monoxide and dioxide), VOCs (hydrocarbons with a boiling point range between of 50–150 ℃ which includes compounds such as *n*-alkanes, cycloalkanes, aromatics and chlorinated hydrocarbons, terpenes and alcohols and PAHs. According to USEPA (United States Environmental Protection Agency) there are 16 PAHs compounds that have been considered as a priority [186], but recent studies show clearly the need to expand that list [187].

6.3.3.   Meteorological parameters to be monitored

Among the many meteorological parameters [147] there are some basic ones that should be measured at least at each monitoring station: Wind direction, wind velocity, ambient temperature, relative humidity, barometric pressure, solar insolation, UV radiation. Vertical wind velocity, mixing height and precipitation (rain) may be measured only at some specific areas. For example, mixing height at Points H (where the atmosphere is influenced by the industrial refinery torches), at Point B (a typical urban site) and at points J, K or D (which are less dense populated). All the above mentioned parameters can have a raw data collection frequency of 1 minute, except for rain which can be recorded each 5 minutes.

6.3.4.   Equipment

General criteria for the selection of equipment and techniques to measure both air quality and meteorological parameters are given in [147,165,176,188–195].

DOAS equipment allows the simultaneous real time measurements of a variety of the species of interest (such as, nitrogen monoxide, nitrogen dioxide, ozone, sulfur dioxide, benzene, m-xylene, p-xylene, toluene, formaldehyde, ethyl-benzene, and ammonium) among others as well as visibility and have been largely employed at both urban and industrial areas [195–204]. For open path monitors 40 CFR Part 58 Appendix E and D [205] contains specific location criteria such as spatial scales of representativeness. In many cases, these types of devices help very much to compare air quality parameters with the point analyzers as well as to upgrade air quality modeling.

LIDAR (Light Detection and Ranging) device has been successfully employed to the follow up of the mixing heights [206–208] and a SODAR (Sound Detection and Ranging) device to determine vertical wind profiles [147,189,209] and/or turbulence [210]. In general, open path monitors are of low-cost in the long term [195].

6.3.5.   Data quality and treatment

Many of the international guidelines employed in this work, i.e. EPA, WHO, WMO contain data quality tools [211] provides guidance on statistical tools for data treatment. Also, a protocol to make data available to the public should be addressed.

6.4. *Further issues to be considered*

The revision presented in this work as well as the results of the precedent subsections from section 6.1 to section 6.2 allowed to reveal some closely related environmental issues that remain somewhat out of the scope of the proposed primary network but are worthy to mention.

Acid rain: The continuous follow up of species such as SO_2, NO_x and CO will provide basis to carry out a systematic acid rain program.

Aerobiology control: Since the seminal work of Philiph Gregroy in 1973 [212] the study of the biological particles in the air has grown but, given its great role in human diseases, it has not reach yet the importance it deserves. Local studies [124–126] show the importance of the follow up of the aerobiological aspects of the air at La Plata Conglomerate.

Landfill control: As in many parts of the world [213,214] municipal solid waste landfills at La Plata Conglomerate represent the dominant option for waste disposal. SH_2 (gaseous hydrogen sulfide) may be considered as a witness gas of landfill emissions [215] while other gases such as methane, VOCs, specific aromatic compounds and hazardous air pollutants should be taken into account [216–218].

Modeling: Worldwide air quality modeling constitutes a very effective tool to gain insight in the air pollutants fate and their consequences.

Odors: Along the years and with a constant pace, many complaints have been reported regarding odors in the vicinity areas of the industrial park of Ensenada and/or other zones of La Plata Conglomerate residential areas [219–228]. Available methods for abatement should be encouraged [214,229].

Rural air quality monitoring: It is commonly accepted that cities are polluted and that "the larger the population base, the dirtier the air will be" [230] but, the quality of air in rural areas have been so far neglected. The common belief is that rural areas are free from air pollution although it has been found that many rural areas over the world can be more polluted than cities [231]. Long term studies have demonstrated the importance of rural air quality monitoring [231–233]. The follow up of meteorological variables in rural areas may become important to assess heat and cold island effects.

Sea and land breeze: As mentioned in section 2, sea-land breeze phenomena are important in the region. In order to study their relationship with air pollution [234–236] it is important to tackle, for example, the sea and land fronts evolution (inland and seaward penetration) with time and their associated circulation cells (diurnal and nocturnal) [237]. Applying to ground based devices this task would constitute a special arrangement of meteorological sensors on land and water.

Shippyard: Air pollution derived from the specific activities carried out in the shipyard area should be characterized.

Street canyons of La Plata: Some areas of the city have contiguous tall buildings with the characteristics of street canyons of interest for air pollution research. This issue should be assessed.

Urban areas of Berisso and Ensenada: [139] points out that the prevalent north wind makes that smokes, vapors and odors from the port-industrial complex arrive frequently to Berisso city causing

tangible air pollution events. Analyzing the wind rose at Berisso (Figure 2) from a geometrical point of view the group of winds that transport air pollutants from that complex are NW-NNW-N-NNE. The same methodology applied to Ensenada city finds that winds from S-SSE-SE-ESE-E-ENE-NE are of main concern regarding the air pollution transport from the industrial sources towards population exposed. So, an enlargement of the proposed basic network should consider in the future for these two urban centers.

Urban heat island: The physical issues of the urban heat island effect are nicely described in [239]. Heat islands do not just cause a bit of additional, minor discomfort; their higher temperatures, lack of shade and role in increasing air pollution have serious effects on human mortality and disease [240,241]. More precisely, it becomes a priority to understand the strong interactions between urban micrometeorology and air pollution in order to better adapt air quality policies [242]; furthermore, a changing climate with increasing heatwaves also points out that the traditional architectural designs and materials need to be revised [243] being the energy supply network the most vulnerable system [244]. Muller et al. [20] points out that the only appropriate way to monitor urban environments is with high-density networks and [245] discuss protocols for siting. Chapman et al. [246] provides an example of a sound low-cost high-density meteorological weather stations network to monitor the heat island in Birmingham (UK). Analyzing data from 29 stations that cover around 10 km^2 Bassett et al. [243] provide interesting methodology and results for that city. Chen et al. [247] give an example of assessment, mitigation and formalization of future scenarios of the urban heat island. A local introductory study to the subject [119] settles reference of the importance to count with an urban heat island monitoring network in La Plata Conglomerate area.

Power plant: Due to the magnitude of the installed power plant (section 1.3) and given that northern winds would transport its emissions towards urban areas a site for the detection of its influence should be particularly considered.

Vehicular traffic: Road and urban vehicular traffic are subjects to be tackled worldwide [38,248]. Although the proposed network (section 6.3) covers the major pollutants from vehicular traffic, it has to be considered that vehicular emission estimates are difficult to make because of: The fuel type and consumption, the vehicle technology and the conditions of use for the very heterogeneous fleets [249,250]. Vehicular traffic emissions have particular characteristics that make their follow up need a special network design [205,251–254]. In section 1.3 it was mentioned the high density of the vehicular traffic in the La Plata Conglomerate while in section 1.4.1 [114,115,123,131,135] some hot-spots were referred. Accordingly, we consider that a starting point to the design of a specific network for the follow up of vehicular traffic immissions with low costs can be the establishment of a network of passive tubes to measure NO_2 [251,257–262]. An updated survey should be done in order to establish siting. Also at least one point to follow lead (Pb) should be considered.

7.   Miscellaneous

Beyond the scope of this study we consider important to mention another pending issue that frequently have been concerning people of different sectors of La Plata Conglomerate: Noise [263–266]. Several local studies [78,120,267] reveal the need of systematic continuous monitoring of noise as an aspect of the life quality.

8.   Conclusions and perspectives

La Plata Conglomerate has several contributors to air pollution (mainly of industrial, traffic, and power plant origin) together with a great exposed population. The present study emphasizes on: a) reminding the importance of controlling local air pollution at cities as sources contributing for the global air pollution and for individuals life quality; b) pointing out historical aspects as well as the current "state of the art" of the air as a natural resource in La Plata Conglomerate as an example of an Argentinian urban area that needs the political commitment to tackle one of the very lagged environmental issues: Air pollution and its consequences; c) the need of providing air pollution information to the population as a clue fact to gain social awareness and as an important issue for the sustainability of the city; d) the importance of the statistical winds analysis in setting basis for monitoring site allocation.

In this context, the present work results provide background founded information at the same time that gives a basic "design" for the installation of a continuous air quality monitoring network as part of the solution to the present situation. The design involves primary aspects, such as, species and meteorological parameters to be monitored and their time frame, number of sites and their location and, some of the characteristics of the equipment to be employed.

Given the inherent complexity of urban environments, even in experienced cities worldwide, the authors are aware that the estimate of urban air quality is a challenging task [65,268], particularly, taking into account that some experts in Europe consider that air quality standards are still not safe [269]. The installation of a network would bring many benefits as have been reported worldwide [25,65,175,177,178,270–274] from both local and global perspectives and should be considered as a part of a more integrated environmental assessment [120,275] as well as a platform to launch an air quality index as a simple tool to inform people. As just an example, it can be mentioned that in USA the federal requirements establish that cities with a population of more than 350,000 inhabitants must report an air quality index to the general public on a daily basis [165]. This fact must be considered important for many reasons [276] with a starting point on the quality of the air that the people breathe. Accordingly and considering the history of the air quality management in the country, the authors consider that a law to make mandatory the installation and operation of a continuous air quality monitoring network should be created.

The compilation involved in this work allowed recalling closely related air pollution lagged issues which have been highlighted and that should be tackled in the near future.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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