Chapter 2

Airborne PM Impact on Health, Overview of Variables, and Key Factors to Decision Making in Air Quality

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Additional information is available at the end of the chapter

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Abstract

This chapter intends to contribute to the understanding of the multiple aspects related to particulate matter (PM) in an air urban environment, in particular, regarding its impact on human health. A general overview of variables and key factors is presented to identify, relate, and understand the diverse and multidisciplinary variables that contribute to PM concentration in urban environments associated with health impacts. This relation is difficult to quantify, given the numerous variables that are interlinked due to the multidisciplinary aspects involved. Our aim is to identify the main multidisciplinary aspects, namely, meteorology, urban geometry, buildings, roads and footpaths, road traffic, industries, air concentration measurements, and health. The main strategic aspects for decision making related to airborne PM impact on health are also discussed.

Keywords: airborne PM, urban air quality, variables, key factors, air pollution, public health

1. Introduction

According to the World Health Organisation (WHO), air pollution is defined as 'The presence of one or more contaminants in the atmosphere, such as dust, fumes, gases, gas, 'fog', odour or vapour in quantities or with characteristics, and of a duration that may be detrimental to human, animal or plant life, to property or that interferes unfavourably in the comfortable enjoyment of life or property' [1]. Thus, it is said that an atmospheric condition, where there are substances at higher concentrations than ambient levels, is polluting if there are effects that can be measured on humans, animals, flora or materials. Within air pollutants, particulate matter (PM) is undoubtedly one of the most important in terms of impact on health. Indeed, all over the years, a growing number of scientific studies have attempted to correlate the outcome of possible adverse health effects with exposure to levels of particle concentration in atmospheric air. In order to try to understand and analyse this correlation, it is necessary to understand what particles are in the atmospheric air, their constitution, their origin, and the mechanisms that govern them. Generally, a very large group of pollutants in the air are grouped together under the designation of particles and may originate from such sources as cars, steelworks, thermal power plants, heating systems, cement plants, volcanoes, deserts, and oceans. Generally speaking, the NIST [2] definition for a particle is 'any condensed-phase three-dimensional discontinuity in a dispersed system may be considered a particle'. However, in terms of atmospheric pollution, a particle can be defined as a solid, liquid or solid and liquid dispersed matter, whose individual aggregates are larger than small molecules in diameter greater than 0.0002 μm but less than 500 μm.

2. Atmospheric pollutants

Atmospheric pollutants can be classified according to their origin and can be classified as: primary, if they are emitted directly by identifiable sources (fixed, mobile, and natural sources), for example: NO_X, SO_X, CO, particulates, hydrocarbons, and metals; secondary, if they are generated in the atmosphere by the reaction between two or more primary pollutants, or by the reaction between the current air constituents, and by photoactivation, hydrolysis or oxidation, for example: O_3, other photochemical oxidants such as peroxyacetyl nitrate and oxidised hydrocarbons (HC). They may also be classified by their chemical composition, being divided by: organic, which include hydrocarbons (HC), alcohols, and esters; inorganic, which include NO_X, SO_X, CO and CO_2, and metals. They can also be classified according to their physical state, which can be: gases (for example: NO_X, SO_X, CO, and CO_2), O_3; particles (solid or liquid), which are usually identified as dispersed material, for example: metal particles, asbestos, carbon (C), resin, nitrate, sulphate, bacteria, dioxins, and furans. There are certain contaminants that normally exist in all urban areas, which are referred to as reference pollutants (CO, NO_X, O_3, SO_2, and PM_{10}). Their concentrations vary and depend on the level of industrial activity and the traffic. In addition to these, hundreds of other compounds specific to each type of industry exist, for example: acrylonitrile, benzene, dichloromethane, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), vinyl chloride, carbon disulfide, 1,2-dichloromethane, styrene, tetrachlorethylene, toluene, trichlorethylene, arsenic, asbestos, and heavy metals.

3. Relation between meteorology and atmospheric pollution

Atmospheric conditions vary from day to day in all locations. The state of the weather at a given location and at a given time is characterised by the cloud cover and its type, the intensity and direction of the wind, the temperature, air humidity, the atmospheric pressure, visibility, and precipitation. This change in local weather is generally associated with the movement and evolution of systems of a certain size, such as depressions and anticyclones, fronts and hurricanes. Meteorological parameters are collected daily in meteorological conditions. This observation of the fact that the atmospheric composition and other characteristics of the planet's surface have been progressively disturbed by human activity has caused worries about the future of global climate, constituting one of the biggest problems today. Concentrations of pollutants in ambient air depend on the emissions of pollutants, which are also influenced by atmospheric phenomena, which play an important role in the processes of transport, transformation, and dispersion of pollutants into the atmosphere. These processes are affected by local topography and by meteorological factors such as atmospheric pressure, temperature, solar radiation, precipitation, and wind. Practically, all the energy intervening in the atmospheric processes comes from the sun and is transferred in the form of electromagnetic waves. A strong solar radiation, associated with high temperatures, contributes to the formation of photochemical pollutants such as ozone (O_3) [3]. Temperature intervenes in the chemical component of pollutants and plays an important role in the vertical dispersion in the atmosphere. During summer, high temperatures promote O_3 formation, and in winter, temperature differences between day and night can cause thermal inversions and pollution peaks [4]. The atmospheric stability determines the local convective processes being characterised by the vertical temperature gradient that limits the vertical mixture of pollutants in case of a thermal inversion. The air temperature tends to decrease in altitude; however, under certain conditions, a thermal inversion may occur, that is, an increase in temperature, creating a layer of hot air that prevents polluted air near the ground from rising and disperse [5]. The general air flow over the planet is induced by large-scale atmospheric pressure variations (macrometeorology). These pressure variations essentially result from the differential heating of the atmosphere. The intensity of these pressure systems, their normal location or their trajectories determine the distribution of winds in a given area. The wind is a meteorological factor with direct and determinant effects on the dispersion conditions of the pollutants. The wind velocity determines the mechanical turbulence production, which is responsible for the local dispersion. The lack of wind favours the concentration of pollutants, and moderate wind conditions favour its dispersion; however, the strong wind can cause the appearance of pollution located in the direction of the prevailing winds. The low-pressure situations generally correspond to a strong turbulence in the atmosphere which favours the dispersion of the pollutants. In high pressure conditions (anticyclone), characterised by low wind, air stability does not allow the dispersion of pollutants, causing pollution to be concentrated near the ground. One way both gases and particles are removed is by dry deposition. This process involves two steps: (1) the downward movement of the molecules or particles of the pollutants until their collision with the elements of the surface; (2) its absorption or adsorption on these elements. In order for dry deposition to occur, there is a need for a downward mass flow of the pollutant to be deposited, the intensity of which depends on its atmospheric concentrations. On the other hand, the efficiency of the vertical transfer process depends on the intensity of the atmospheric turbulence in the layer under consideration, and the efficiency of the adsorption/adsorption depends on the deposited compound and the nature of the surface on which it is located made. Although both the gases and the particles undergo dry deposition, qualitative differences between their deposition processes are expected. In the case of particles of less than 1 μm, it is found that they behave essentially as gases in relation to the diffusion process. In the case of larger particles, its motion is independent of the motion of the air molecules, with each particle reaching a terminal velocity, which increases greatly with its size.

4. Particulate matter

4.1. General characteristics

Particles may be characterised as being a complex set of substances, minerals or organic substances, which are suspended in the atmosphere in liquid or solid form. Its size can range from a few tens of nanometres to a hundred micrometres. Particles are emitted into the atmosphere from a wide range of anthropogenic sources, the most important being the burning of fossil fuels, road traffic, and certain industrial processes. PM may also be emitted from natural sources such as volcanoes, forest fires or are the result of wind erosion on the soil and water surfaces. In urban areas, road transport is considered to be the largest source of PM, with the highest concentration along roadways. These substances are not only the result of direct emissions from vehicle exhaust, but also from tire wear and braking and dust resuspension. In general, diesel vehicles emit a larger amount of fine particles per vehicle than petrol vehicles [5]. The composition of airborne particles is very variable, reflecting the wide variety of emitting sources and the fact that they are continuously altering as a result of their interaction with other constituents of the atmosphere. The coarse fraction contains abundant elements of the earth's crust and marine salts, such as alum, calcium, iron, potassium, and silica, while the fine fraction is mainly composed of sulphates, nitrates or ammonia, carbon, organic compounds, and metals, mainly from the burning of fossil fuels and numerous industrial processes [6]. It is known that the smaller the particles, the greater the likelihood of penetrating deeply into the respiratory tract and the greater the risk of inducing negative effects. The finer particles being smaller than 2.5 μm ($PM_{2.5}$) reach the pulmonary alveoli and interfere with gas exchange. Chronic exposure to particles contributes to the risk of development of respiratory and cardiovascular diseases, as well as lung cancer. Suspended particulates are also an effective transport vehicle for other atmospheric pollutants that attach to their surface, especially hydrocarbons and heavy metals. These substances are often transported to the lungs where they can then be absorbed into the blood and tissues. The effects of soiling on buildings and monuments are the most obvious effects of particulate matter on the environment [5]. Atmospheric particles are associated with various health problems ranging from pulmonary to cardiovascular problems and may even lead to death. One of the effects of prolonged exposures to high particle levels is a significant reduction in the expected life expectancy. The most serious effects are usually among the most vulnerable groups, such as children, the elderly, and asthmatics [3]. The term particle generally refers to a diverse and complex set of organic and inorganic substances. Particles are a considerably large group of airborne pollutants, which may be in the liquid or solid state and originate from distinct sources such as automobiles, steelworks, thermal systems, heating systems, cement plants, volcanoes, deserts, and oceans. In general terms, the term particle may be taken to be any three-dimensional discontinuity in the liquid or gaseous phase in a dispersed system. However, in terms of air pollution, a particle can be defined as a solid, liquid or solid liquid dispersed matter, and the individual aggregates having a diameter between 0.0002 and 500 μm [7]. Thin particles are considered if their aerodynamic diameter is less than 1.0 μm and are mainly emitted from sources of anthropogenic origin as combustion processes, including exhaust emissions of vehicles. The particle classification can be made based on two criteria: the shape mechanism or the physical dimension. In the case of classification according to the mechanism of forming the particulars can be classified as primary

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particles, which are emitted directly, and secondary particles or particles that are those formed from precursor gases existing in the atmosphere, through a mechanism of form-particle. Both the so-called primary and secondary particles are subject to growth and transformation mechanisms, since secondary material may also be formed on the core of the existing particle. In the case of classification according to the physical dimension, which is the most used classification, it ranges from a few nanometers (nm) to tens of micrometers (μm) in diameter. Dimension is a very important feature and has implications for form, physical and chemical properties, transformation, transport, and particle removal, from the atmosphere. Knowing that the particles in suspension in the atmosphere vary considerably in size, composition, and origin, it is important to classify the particles for their aerodynamic properties, since these properties, besides being responsible for the transport and removal of particles from the air, also generate their deposition in the respiratory system, being also associated to the chemical composition and origin of the particles [8]. Thus, particle size is usually characterised by its aerodynamic diameter, which refers to the diameter of a sphere of uniform density and with the same settling velocity of the particle in question [9].

4.2. Classification of the particles

In urban environments, mass and particle composition tend to be confined to two major groups: coarse particles (larger particles) and fine particles (smaller particles). The boundary between these two classes of particles is generally between 10 and 1 μm. However, this limit between coarse and fine particles is generally fixed, by convention, to 2.5 μm of aerodynamic diameter. The standard PM_X (USEPA terminology) refers to particles with a diameter less than x μm, whereby $PM_{2.5}$ refers to particles with a diameter of up to 2.5 μm. Smaller particles (fine particles) include secondary aerosols, formed from gases in the atmosphere through the gas-particle formation mechanism (gas-particle conversion), and also contain particles that result from combustion processes and organic recondensed vapours and metallic. Due to their small size, they are easily inhaled, depositing in the lower respiratory tract and causing numerous, essentially respiratory, health problems. The term 'Total Suspended Particles' (TSP) refers to a mass concentration of particles of less than 50 μm in diameter, and the term 'ultrafine particles' refers to particles of diameter less than 100 nm (0.1 μm). Larger particles (coarse particles) usually contain materials from the earth's crust and dust from roads and industry. In urban environments, the largest number of particles is found in very small sizes, less than 100 nm. However, these ultrafine particles (UFP) often contribute a small percentage to the total mass of the sample, contributing more than 90% of the number of particles. Particles with a diameter of less than 1 μm (PM_1) have a size that allows them to penetrate deeply into the respiratory and circulatory system carrying toxic elements and compounds [3]. Other thermal usually used in black carbon (BC) with a primary aerosol emitted directly at the source from incomplete combustion processes (fossil fuel and biomass burning) and so a several part of atmospheric BC is of anthropogenic origin. Chemically, BC consists of pure carbon in several linked forms.

4.3. Mechanisms of particle formation

Particles with a diameter greater than 2.5 μm (coarse particles) are produced mechanically by the breaking of larger solid particles, which may include dust originating from agricultural processes, glues carried by the wind from the exposed soil, dirt roads, or dust from other processes such as mining or quarrying. In turn, also the road traffic produces dust and turbulence that causes rise and can shake the road dust. Also at coast-to-coast locations, evaporation of the sea water can produce particles of this size. Also, pollen grains, mould and plant spores, and insect parts are included in this larger size range. The amount of energy needed to break down the elements referred to in smaller particles increases as the size decreases. This results in a lower limit for the production of these coarse particles of approximately 1 μm. Minor particles (fine particles) are formed, for the most part, from gases, through two distinct processes according to its size, nucleation and condensation. In nucleation, the smallest particles, less than 0.1 μm, are formed by the condensation of substances formed by vaporisation at high temperature or by chemical reactions in the atmosphere. Particles in this range grow by coagulation, that is, the combination of two or more particles to form a larger particle, or by condensation, that is, condensation of gas or vapour of molecules on the surface of existing particles. Coagulation is more efficient for large particle numbers, and the condensation is more efficient for large surface areas. Therefore, the efficiency of both coagulation and condensation mechanisms decreases with increasing particle size, which effectively produces an upper limit such that the particles do not grow by these processes to more than about 1 μm. Thus, this type of particles tends to 'accumulate' between 0.1 and 1 μm. In condensation, particles below 1 μm can be formed by condensation of metals or organic compounds, which are evaporated in combustion processes, or can also be produced by gas condensation arising from atmospheric areas. For example, sulphur dioxide is oxidised into the atmosphere to form sulphuric acid (H_2SO_4), which can be neutralised by ammonia (NH_3) to form ammonium sulphate. Nitrogen dioxide (NO_2) is oxidised to nitric acid (HNO_3) which in turn can react with NH_3 to form ammonium nitrate (NH_4NO_3). The particles produced by these gases in the atmosphere are called secondary particles. Sulphates and nitrate particles are usually the predominant component of these fine particles [10]. Suspended particles in the environment typically have a modal type distribution with respect to size (diameter), which means that the total mass of the particles tends to be concentrated around one or more distinct points. The modal distribution character in the particle size results from the equilibrium of the particle formation processes on the one hand and on the other side of the particle removal processes from the atmosphere. Thus, this modal distribution of the diameter of the particles around one or two characteristic points varies depending on the age of the aerosol and the proximity of emission sources of particles of different types. Other important aspects in the definition of particle concentrations in the atmosphere are meteorological variables such as wind speed and direction, atmospheric temperature, precipitation, and height of the atmospheric boundary layer. Higher particle concentrations are often recorded during atmospheric weather conditions, especially in thermal inversion situations with low wind speed, and also because the physical and chemical processes of particle formation are governed largely by meteorological variables [11].

4.4. Point sources and area sources

There are several types of source emission related to PM. Particulate sources designated by point sources include various types of facilities such as power plants, industrial plants, municipal waste incineration plants, paper mills, various fossil fuel combustion plants, and domestic heating installations. These sources are often considered as point sources (thermal and industrial plant chimneys), but may also be considered as an area source, such as residential combustion plants. The physical and chemical characteristics of the particles emitted from these source categories depend on the combustion process itself and on the type of fuel burned, presenting quite different physical, chemical, and dimensional characteristics depending on the process combustion. For noncombustion emissions, the main industrial processes that may contribute to the emission of particulate matter to the atmosphere include metal processing and chemical processing plants, processing and handling of building materials or for industry. Particulate emissions originating from this type of source are often derived from fugitive emissions, which are not controlled but are instead released in an inhomogeneous form. The type of particles and their physical and chemical properties also depend on the processes by which they are emitted, and it is not at all possible to generalise their characteristics. The knowledge of the relation of the various dimensions of the particles in a certain sample of atmospheric air is important to try to characterise the origin of the emission sources of these same particles. Some recent studies [12] have devoted themselves to studying this relationship, based on samples collected from 31 locations in Europe, concluding that the diameters relationships showed similarities for all locations [13].

4.5. Remote sources

Particles in the form of dust of natural origin carried by the wind can contribute to the existence of high concentrations of larger particles (coarse particles) and fine particles. In some cases, the particles are found in locations hundreds or thousands of kilometres from their origin. It has been proven the strong contribution of the wind in transporting dust from the desert to remote sites of its origin. For example, in Southern Mediterranean countries, such as Portugal, there are frequent 2–4-day transient episodes of transporting dust from the Sahara desert every year, resulting in levels exceeding 25 $\mu g/m^3$ expected daily concentrations of PM_{10} and $PM_{2.5}$ [14].

Resuspension of particles is the term given to the re-entry, in atmospheric air, of particles previously deposited and their re-entrainment into the atmosphere. It is a complex process that can be triggered by mechanical disturbances, such as wind, traffic-induced turbulence, tire stress, and construction activities. The so-called 'road dust' is an agglomeration of particles originating from various anthropogenic and biogenic sources. On the roads, this dust of diverse origins accumulates on the roadsides, near the sidewalk and along the central divisions. Resuspension, deposition, entrainment on and off the road, and emission of new particulates are a dynamic particle emission 'source' and 'well' mechanism that characterises road traffic. Roads are one of the largest source emitting particles in urban environments. Several studies have also shown that resuspension of this element is the predominant source of larger particles (coarse particles) in locations of intense road traffic causing the impact of resuspension on the concentration of particles in the atmospheric air is of great importance. Road dust may also act as a repository for the various elements of anthropogenic particulate sources, and resuspension may function in certain locations as a re-emission, thereby contributing to the increase in the atmospheric concentration of these elements. The plausibility of this theory is supported by studies where it has been shown that larger particles are more easily resuspended by wind and road traffic, and that deposited materials are more susceptible to resuspend, if associated with larger host particles. Fine particles can remain in suspension for much longer than coarse particles and this may result in a greater spatial impact on atmospheric concentrations of particles, and secondly the fine fraction of resuspended particles is more likely to contain constituents of anthropogenic origin, potentially more toxic, than the fine particles of natural origin [15].

4.6. Contribution of road traffic to PM

In urban environments, 90% of the concentration of atmospheric particles emitted by road traffic corresponds to the fraction of particles smaller than 1 mm (0.001 μm). This fact can affect human health, so it is important to study PM_1 in high traffic areas [16]. Particulate emissions from road traffic are the result of a large number of processes, such as the combustion products of gasoline, diesel, and gas engines, products originating from vehicle oil, tire rubbers, braking system, bearings, car body, road material, and dust release from road and ground [17]. Traffic is in fact an important source of both smaller (fine particles) and larger (coarse particles) particles, but is also a source of condensable organic gas emissions and an important source of nitrogen (NO_X), which subsequently form nitrate (secondary) aerosols. Particles of condensed carbonaceous material are emitted mainly by diesel vehicles, but also by gasoline vehicles with run-down performance [13]. Particulates originating from diesel engines are mainly carbonaceous agglomerates less than 100 nm in diameter, while the particles emitted by gasoline vehicles are mainly smaller carbonaceous agglomerates, ranging from 10 to 80 nm [18]. Although it is not possible to generalise conclusions about the association of the various elements present in atmospheric particles, with their origin in road traffic, some elements have been frequently associated with them. These elements include copper (Cu), zinc (Zn), lead (Pb), bromine (Br), iron (Fe), calcium (Ca), and barium (Ba) [18–20]. However, the emissions of many of the metal elements originating from road traffic are not due to the exhaust emissions but to other sources of the vehicle such as tires, brakes, and other parts of the vehicle [17, 21, 22]. Studies have concluded that $PM_{2.5}$ containing sulphur in their composition is mainly from the combustion of coal and exhaust emissions from vehicles [22]. Polycyclic aromatic hydrocarbons (PAHs) are organic compounds, formed by at least two fused aromatic rings, entirely made up of carbon and hydrogen [23]. They can be found in many urban air components and are a health concern, mainly because of their carcinogenic and mutagenic properties. A negative correlation of PM_1 with the wind speed was obtained due to the wind dispersing the particulate matter from the atmosphere. Regarding relative humidity, it was found to have a positive correlation with PM_1, which can be attributed to the influence of free and clean masses of troposphere air. For the ambient temperature and solar radiation, a negative correlation was calculated, perhaps associated with stagnation and cold fronts. A positive correlation of PAHs with relative humidity and a negative correlation with solar radiation, ambient temperature, O_3 and NO shows that PAHs degrade through photolysis and chemical reactions with these pollutants. Analyses of the composition of PM_1 with PAHs indicated that these had their origin especially in diesel and gasoline emissions, as well as the combustion of wood, lubricating oils, and fossil fuels [16].

4.7. Consequences of PM in atmosphere

Particulate matter (PM) is one of the most relevant air pollutants globally. In humans, adverse effects associated with many cases of exposure to high concentrations of aerosols (mortality, morbidity, respiratory, and cardiovascular problems) are well established. However, the mechanisms involved are still not well known [24]. In recent years, several scientific studies have attempted to correlate the outcome of possible adverse health effects due to the exposure to PM levels in atmospheric air [25]. Numerous epidemiological and toxicological studies have recently been developed to try to understand what kind of particles and which dimensions lead to the most detrimental effects on human health. In chemical terms, some studies indicate that the toxicity of the particles is mainly due to the organic compounds around the particle, and other studies point to the coal core of the particle as the main factor of toxicity. In terms of size, a considerable number of authors correlate the health effects with the mass concentration of particles, and other authors point out the importance of the concentration of ultrafine particles in atmospheric air in the negative consequences for health. Several epidemiological studies have shown the strong correlation between morbidity (or morbidity) and mortality with the concentration of fine particles in urban environment. These refer to particles as the air pollutant with the most detrimental consequences to health, followed by ozone (O_3). Some studies indicate that even concentrations below the current recommended air quality levels may pose a health risk. It is believed that the effects of fine particles on health are caused after their inhalation and penetration into the lungs. Several studies indicate that both chemical and physical interactions with lung tissues can cause irritation or damage to the lungs. The smaller the size of the particles, the more they can penetrate the lungs. Annual mortality levels are associated with the concentration levels of $PM_{2.5}$, which in Europe represent 40–80% of the mass concentration of PM_{10} in ambient air. However, the larger particle fraction (from 2.5 to 10 μm) of PM_{10} also has negative impacts on human health and affect mortality, although increasing evidence points to $PM_{2.5}$ having an adverse impact [11]. Continued exposure to atmospheric particles contributes to the risk of developing cardiovascular and respiratory diseases as well as lung cancer. The mortality associated with air pollution is about 15–20% higher in cities with high levels of pollution compared to relatively less polluted cities. From this air pollution, numerous studies show that the most critical pollutant is the particles. For example, in the European Union (EU) studies indicate that the average life expectancy is 8.6 months lower due to exposure to $PM_{2.5}$ resulting from human activities. Particle pollution (especially fine particles) contains microscopic solids or liquids, which, being too small, can penetrate deeply into the lungs and cause serious health problems. Numerous scientific studies have correlated exposure to particulate matter with a number of health problems, including: increased respiratory problems such as irritation of the airways, coughing or difficulty breathing; decreased pulmonary function; worsening of asthma cases; development of chronic bronchitis and irregular heartbeat; non-fatal heart attacks and premature death in people with heart or lung disease. People with heart or lung disease, children, and the elderly are the groups most likely to be affected by exposure to particulate pollution. As mentioned above, two types of studies have been developed with regard to the health consequences of exposure to air pollutants, so this also applies to particulate matter, epidemiological studies, and toxicological studies. Epidemiological studies are global studies that seek to study the cause-effect relationship of a given disease, most often using statistical analysis tools. In the case of particles, these studies seek to analyse the consequences of exposure of a given population to a particular concentration level or to a particular type of particle. Within this type of studies, two degrees of incidence have been analysed: morbidity, which can be defined as the rate of carriers of a given disease in relation to the total population studied, and mortality. Alternatively, toxicological studies are studies that attempt to analyse the harmful or adverse effects that a certain toxic agent (chemical) has on the organism. There are two types of toxicological studies, experimental toxicology, which uses animals to try to understand the mechanism of action and consequences for the body, and analytical toxicology that aims to identify/quantify toxic elements in organs such as liver, kidneys or matrices such as blood, urine, or saliva [26]. Combustion of biomass by the domestic sector (burning of fuels such as wood and coal) and emissions from road vehicles in urban centres are the sectors that are the main direct sources of particulate emissions. Agriculture is a sector with high contribution to ammonia emissions, which is one of the pollutants that contributes most to the formation of secondary particles. Particles can also affect the climate, promoting heating or cooling of the planet, depending on its chemical composition. One such case is soot containing black carbon, found mainly in fine particles, resulting from the incomplete burning of fossil fuels and biomass, contributes to changes in the climate because it absorbs the energy of the sun promoting the heating of the atmosphere [27].

5. Monitoring networks

National or regional air quality authorities have in their area of jurisdiction a set of fixed sampling points for the continuous measurement of PM concentration. For their realisation, they have stations equipped with automatic analysers of measurement PM concentration. The main objective in the process of selecting the localization of air quality stations is to obtain information with the greatest possible representation of the surrounding area, since the location of the air quality measurement stations can directly affect the conclusions from the analysis of the results. Measuring stations that may be influenced by very particular characteristics of the locations where they are installed may no longer be representative and require the analysis of complementary information from other stations or other assessment methods. This reason makes it necessary for information users to have systematised data on the particular conditions of installation and location of each station. The selection of monitoring sites should take into account the diversity of techniques and materials used in the construction of buildings, as they differ from country to country and in larger countries, differ within the same country, in order to have representative sites in each area. In urban areas, the deterioration of materials is affected by the levels of pollution observed. Three locations can be chosen to represent: the highest level of urban pollution (usually near the centre of the city), an average background level, and a traffic hot spot. In industrial zones, two sites may be selected to represent a medium level and a higher level of pollution. The air quality stations are classified taking into account the area where they are located (surrounding environment) and the type of emission source that influences the air quality levels measured in that location and may be in relation to the type of zone or type of environment encompassing three possible classes: urban, suburban, and rural and as to the type of dominant emission source containing three possible classes: traffic, industrial, and fund. The classification of stations in the various typologies is relevant for analysing the air quality data, as it makes the data comparable at local or global level [28]. Each country develops its plan for monitoring air quality and deposition in order to be representative of ecosystem exposure to air pollution. Since concentrations of air pollution and deposition also vary greatly, a monitoring program is required that includes a large selection of ecosystems, that is, regions and areas within each region [29].

6. Methods of PM measurement

For the continuous monitoring of PM in the air, sophisticated and very sensitive equipment is essential. For the quality control of the information generated, periodic calibrations, corrective and preventive maintenance, and evaluation of the representativeness and validity of the data obtained through the statistical analysis and monitoring of the historical trend of the pollutant at the location in question and of the analyser behaviour are necessary. The estimation of the uncertainties that must be evaluated in the calibration of the equipment for the monitoring of environmental data presents a level of difficulty because the concentration range of pollutants found in an environment is very close to the detection limits of the equipment available in the market and due to the number of factors that interfere with the measurement of the pollutant in question. The assurance of the presented results is based on a good detection of errors and inconsistencies occurred in the procedures and analytical or sampling methods. Failure to do so may lead to misinterpretations or misconceptions [30]. The most common method of PM measurement and monitoring is done by a beta particle analyser by absorption of beta radiation and sampler. This method applies to the automatic measurement of continuous particulate matter, based on the absorption of the β radiation emitted by a radioactive source by the particles deposited in a filter. The particles are deposited on a fibreglass tape, which is traversed by constant flows of ambient air for pre-programmed time periods or cycles. This tape is located between the radioactive source and the Geiger-Muller radiation detector. The uniform distribution of the deposited particles on the surface of the filter allows to obtain the relation between the total mass deposited and the number of counts registered by the detector. Knowing the number of counts recorded with the filter before the aspiration of the ambient air and the number of counts recorded with the filter after the deposition of particles, it is possible to determine its mass in $\mu g/m^3$.

7. Strategic aspects for decision making

Information on atmospheric pollution levels in general and external air quality (AQ) in particular is a widely discussed and developed aspect both in the scientific community and in the general population. However, an effort has been made by the scientific community to develop models that somehow predict and simulate PM concentration in the environment. An even more recent and ambitious step refers to the modelling of the human exposure to this pollutant, relating the activity of the individual and his time of permanence in this space with the environments in which he is in terms of PM concentration [31]. It is therefore essential that mitigation and mitigation measures should be implemented through National and International Plans and Programs that will lead to significant benefits for atmospheric PM levels to be significantly reduced with benefits to health [32]. These measures include:

- Intervening on the effectiveness of air quality and emission legislation by strengthening their implementation;
- Overall and global reduction of PM emissions from industrial and domestic sources;

- Modernization of monitoring and data transmission and control of PM;
- Creation of significant benefits in the acquisition of new vehicles that are less polluting or even non-polluting and more energy efficient;
- Promotion of access to shore-based electricity (preferably from renewable energy sources) by berthed ships;
- Selection of forest species and practices less vulnerable to storms and fires, greater penalties for the fire set;
- Reduction in the use of nitrogen (N) in agriculture due to the excessive use of nitrogen fertilisers and nitrogen content in animal feed;
- Implement improved monetary assessment of impacts on ecosystems and analyse the costs and effectiveness of measures implemented to improve QA;
- Rationalise and optimise the global transport system to reduce CO_2 emissions.

8. Conclusions

Improving global air quality and reducing the atmospheric concentration of PM is essential to achieve greater control of air pollution at source and to minimise its effects in order to preserve human health, the environment, and materials. Legislative measures and other instruments (including Plans and Programs) have been adopted at National and Community levels for several decades. For these measures and instruments to be implemented and enforced, it is necessary to implement the updated air quality policy, making use of the latest scientific knowledge and appropriate management of commitments and synergies between climate and environmental objectives in order to that it cannot only enhance ecological and climatic resilience, but also achieve important socio-economic benefits, including public health.

The control at source of emissions of air pollutants in general and PM in particular can be done through the installation and use of best available non-pollutant techniques and equipment. Also, measures to prevent air pollution include reducing emissions, as switching to cleaner fuels, alternative use of renewable energy sources, and more efficient and cleaner new energy sources (wind, water, solar, and biomass valorisation of agriculture) in response to considerations of the climate or security of supply, the use of less polluting means of transport, leading in particular to a substantial decrease in PM_{10} and dangerous emissions. In this chapter, a general overview of variables and key factors that identify, relate, and understand the diverse and multidisciplinary variables that contribute to PM concentration in urban environments associated with health impacts were identified and described. The main multidisciplinary aspects, namely meteorology, urban geometry, road traffic, industries, air concentration measurements, and health were also presented and discussed. The main strategic aspects for decision making related to airborne PM impact on health were also discussed.

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