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IDENTIFYING THE NATURAL AND ANTHROPOGENIC SOURCES OF PARTICULATE MATTER: AN ANALYSIS OF POLLUTION ORIGINS AND ENVIRONMENTAL IMPACT

Elena-Denisa PREDESCU, Carmen Otilia RUSĂNESCU, Roxana-Elena FRÎNCU, Sabrina Maria BĂLĂNESCU, Daniela MIHAI, Ionela Alexandra ION

National University of Science and Technology POLITEHNICA Bucharest,
313 Splaiul Independenței, District 6, Bucharest, Romania

Corresponding authors email: denisa.predescu23@yahoo.com

Abstract

This study focuses on the origins of particulate matter (PM), an important air pollutant with significant effects on the environment and human health. PM comes from a variety of sources, including anthropogenic ones such as industrial emissions, traffic, and construction activities, as well as natural processes like wildfires and volcanic eruptions. The paper also examines how these particles are released into the atmosphere and how their behaviour is influenced by their size and chemical composition. In addition, the study discusses the transport and dispersion of particulate matter in the atmosphere, highlighting the factors that affect its concentration and persistence. Understanding these processes is essential for improving air quality management, reducing pollution levels, and protecting both ecosystems and public health.

Key words*: air pollution, environmental health, monitoring, particulate matter (PM), PM sources.*

INTRODUCTION

Air pollution is a major environmental concern, with particulate matter (PM) being one of the most significant atmospheric pollutants due to its complex origin and widespread presence. PM originates from both natural processes and anthropogenic activities, including traffic emissions, industrial processes, construction activities, biomass burning, and secondary atmospheric formation.

This study focuses on the characterization of PM sources and the importance of source identification for air quality management and emission control strategies.

Understanding PM source contributions is essential for the development of effective air pollution mitigation policies. This topic has been widely addressed in the scientific literature, particularly in studies focusing on source apportionment and atmospheric pollution dynamics (Durbacă, et al., 2020).

This review is based on peer-reviewed articles indexed in ISI Web of Science and Scopus databases, published mainly over the last 10-15 years (2010-2025), including systematic reviews and source apportionment studies of particulate matter.

The aim of this study is to identify and analyse the main natural and anthropogenic sources of particulate matter based on recent scientific literature, to provide an overview of their relative contributions and environmental relevance.

MATERIALS AND METHODS

This study is based on a narrative review of scientific literature regarding particulate matter (PM) sources and origins. Relevant peer-reviewed articles were selected from ISI Web of Science and Scopus databases, focusing on publications from 2010 to 2025.

The literature search included studies addressing PM source identification, source apportionment, and emission characterization. The collected information was critically analysed and synthesized to provide an overview of the main natural and anthropogenic sources of particulate matter and their environmental significance.

RESULTS AND DISCUSSIONS

This section synthesizes findings from recent literature on particulate matter (PM) sources and source apportionment studies. The reviewed studies consistently identify both natural and anthropogenic contributions to ambient PM levels, with variability depending on location, seasonality, and local emission profiles.
Anthropogenic sources, particularly traffic emissions, industrial activities, construction processes, and biomass burning, are generally reported as the dominant contributors in urban and industrial areas, while natural sources such as dust resuspension and sea salt are more relevant in rural or coastal environments.

SOURCES OF PARTICULATE MATTER (PM)

Particulate matter (PM) is divided into primary and secondary sources. Primary PM originates directly from natural events such as marine aerosols, volcanic activity, wildfires, and bioparticles, as well as anthropogenic sources including transport, industry, construction, and domestic practices.
Secondary PM forms in the atmosphere from chemical reactions involving precursors gases.
As shown in Figure 1, the main sources of PM pollution are presented. This study also highlights the main sources of PM in Bucharest, where urban and traffic-related emissions are dominant.

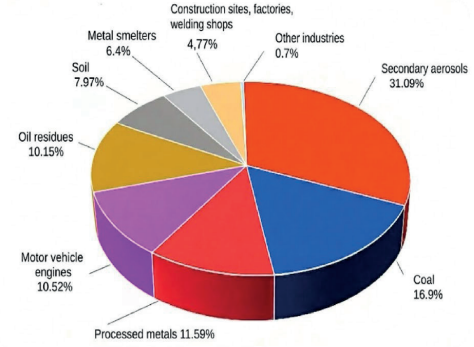


Figure 1. Sources of PM pollution (Lee et al., 2023)

Natural sources of particulate matter (PM)

Aeolian dust and soil erosion **r**elease fine mineral particles into the atmosphere, contributing significantly to PM10 and PM2.5 concentrations. These processes are driven by wind action over exposed or disturbed soils, where the breakdown of soil aggregates facilitates particle detachment and suspension. Emissions increase strongly in dry, bare or agricultural lands, especially under high wind speeds and low soil moisture conditions. Once uplifted, particles can remain suspended for extended periods and be transported over long distances, influencing air quality at both local and regional scales (Katra, 2020).
Marine aerosols are a major natural source of $PM_{2.5}$ and PM_{10} in coastal regions, formed mainly from sea spray processes. They consist predominantly of sodium (Na^+), chloride (Cl^-) and other sea-derived ions such as magnesium, which are commonly used as chemical tracers for marine origin. In atmospheric measurements, these ions are also used in source apportionment studies to distinguish marine contributions from anthropogenic inputs and to assess aerosol aging processes in coastal environments (Wu et al., 2024).

Shipping emissions from maritime transport represent an important source of particulate matter, particularly in coastal and port areas. Ship engines, often using heavy fuel oil, emit SO_2 and primary PM2.5, while also contributing to secondary particle formation in the atmosphere through oxidation processes. These emissions can significantly affect air quality in major ports and coastal urban zones, making maritime transport a relevant contributor to regional PM pollution in Europe (Thunis et al., 2015).
Volcanic activity is a major natural source of particulate matter, releasing ash, fine particles, and gases that affect aerosol chemistry. These emissions vary in intensity and composition and can impact air quality at local, regional, and global levels. Volcanic particles contain silica, aluminium and iron oxides, and sulphides, and can be transported over long distances (Wu et al., 2023).
Figure 2 illustrates volcanic emissions including solid particles (ash and dust) and secondary aerosols formed from gas condensation.

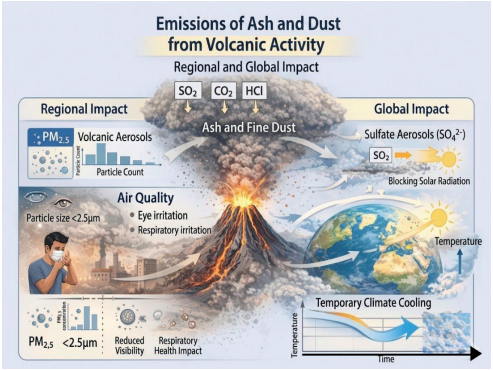


Figure 2. Emission of Ash and Dust from Volcanic Activity (image generated with AI)

Fine particles ($PM_{2.5}$) can remain in the atmosphere and travel long distances, increasing PM levels. At a global scale, volcanic aerosols, especially sulphates from SO_2, can reflect solar radiation and temporarily cool the climate (Zhang et al., 2022).

Wildfires release a complex mixture of gases and particulate matter, including $PM_{2.5}$, PM_{10}, VOCs, CO, and NOx. Fine particles can travel long distances and significantly increase PM concentrations, often exceeding air quality limits. This leads to large-scale air pollution and impacts both local and distant regions, as shown in Figure 3 (Hadiwijoyo et al., 2025).

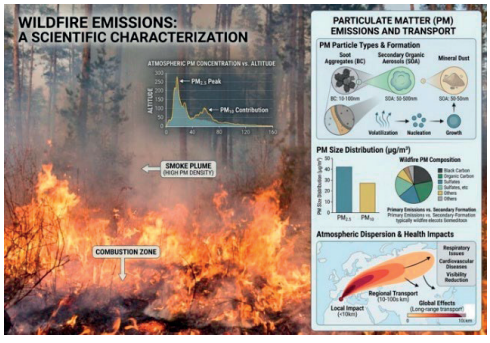


Figure 3. Wildfire emissions (image generated with AI)

Wildfire smoke acts as an atmospheric aerosol, affecting solar radiation and cloud formation. As a result, $PM_{2.5}$ and PM_{10} can influence weather patterns and climate at regional and global scales (Vaezi et al., 2025).

Recent studies show that pollen and fungal spores are dispersed in the atmosphere as part of bioaerosols and can contribute to particulate matter, particularly in the PM10 fraction and, in some cases, in the fine fraction below 10 µm. These particles are of biological origin and can become incorporated into airborne particulate matter through mechanical release and atmospheric transport processes. Bioaerosols also contribute to the organic fraction of PM, highlighting their relevance in the overall composition of atmospheric particulate matter in both indoor and outdoor environments (Sikoparija et al., 2025).

Vegetation reduces wind-driven soil erosion by stabilizing the soil structure and limiting the detachment of fine particles through root systems and surface cover. In contrast, exposed or bare lands act as important sources of dust emissions, with the number of resuspended particles strongly dependent on wind speed, soil texture, and moisture content. Under dry conditions and high wind intensity, these surfaces can significantly contribute to atmospheric PM10 levels through enhanced dust emission and transport processes (Labiadh et al., 2023).

Seasonal variability and meteorological conditions significantly influence the concentration, transport, and spatial distribution of marine aerosols. Wind speed plays a key role in the generation and emission of sea spray particles, while atmospheric humidity and temperature affect their hygroscopic growth and chemical evolution in the atmosphere. Atmospheric stability conditions determine the vertical mixing and dispersion of these particles, controlling how efficiently they are transported from coastal zones towards inland continental areas. As a result, marine aerosol concentrations can vary considerably depending on seasonal weather patterns and large-scale atmospheric circulation, which modulate both their intensity and persistence in the atmosphere (Zhu et al., 2025).

Particulate matter emissions and PM10 and PM2.5 concentrations exhibit significant seasonal variability, with higher levels typically observed during dry and warm periods. In these conditions, soils are more exposed and susceptible to wind-driven resuspension, while reduced moisture content increases the ease of particle detachment from surfaces. In contrast, during wet seasons, precipitation and higher humidity contribute to the removal of airborne

particles through wet deposition and limit dust generation from soils. Seasonal dynamics therefore affect both natural emissions from soil surfaces and ambient PM levels in urban environments, leading to higher concentrations during dry, stagnant atmospheric conditions compared to rainy periods. This variability highlights the importance of meteorological factors and seasonal climate patterns in assessing particulate matter emissions and identifying periods of increased environmental risk (de Souza et al., 2025).

Lightning is a natural source of nitrogen oxides (NOx) in the atmosphere, produced during high-temperature electrical discharges. These emissions contribute to the formation of ozone and secondary particulate matter through atmospheric oxidation processes involving NOx-derived compounds. Although lightning-induced emissions are episodic and spatially variable, they represent an important natural pathway for atmospheric chemical reactions that can influence the formation of secondary aerosols, including PM2.5, at regional scales (Bender et al., 2006).

Table 1 presents the main environmental factors influencing PM emissions and their effects on PM_{10} and $PM_{2.5}$ concentrations.

Table 1. Factors which influence PM emissions
Source: compiled by the author based on literature data

Factor	Effect on PM emissions
Arid- semi-arid climate	Increases PM10 and PM2.5 concentrations
Exposed soil/intensive agriculture	Increases PM10 concentration (>10%)
Low humidity	Increases particle mobilization and intensifies turbulence
Precipitation	Reduces PM (through particle deposition)
Reduced vegetation	Increases the risk of PM10 and PM2.5 emissions
Green zones/tree shelterbelts	Reduces PM10 and PM2.5 concentrations

Anthropogenic sources of particulate matter (PM)

Vehicle exhaust emissions are a major anthropogenic source of $PM_{2.5}$ and PM_{10} in urban environments, originating mainly from incomplete combustion of fossil fuels in internal combustion engines. These emissions are characterized by high concentrations of carbonaceous particles, particularly organic carbon (OC) and elemental carbon (EC), which significantly influence both the mass and toxicity of particulate matter. Diesel engines generally produce higher particulate emissions compared to gasoline engines due to differences in combustion efficiency and fuel composition. In addition to exhaust emissions, non-exhaust sources such as brake wear, tire abrasion, and road surface wear also contribute substantially to urban PM levels through mechanically generated particles. Elevated OC and EC fractions are typically associated with inefficient or incomplete combustion processes and varying operating conditions (Shi et al., 2023).

Aviation contributes to particulate matter emissions mainly in airport areas, especially during landing and take-off cycles. Aircraft engines emit PM2.5 and ultrafine particles, including black carbon and sulphate-related particles formed during fuel combustion. Although its global contribution to PM mass is relatively limited compared to road traffic and industry, aviation can significantly affect local air quality near airports due to concentrated emissions at low altitudes (Dadvand et al., 2011).

Residential heating is an important anthropogenic source of particulate matter, with emissions strongly dependent on the energy system used. Domestic heating systems based on solid fuels (wood, coal, biomass) generate significantly higher PM10 and PM2.5 emissions due to incomplete combustion, especially in older and low-efficiency installations. In contrast, centralised district heating systems generally show lower specific emissions because of higher combustion efficiency, better fuel control, and the use of emission abatement technologies. However, in urban areas where individual heating systems still dominate, domestic combustion remains a major contributor to wintertime PM levels, often exceeding emissions from transport in cold seasons (Cincinelli et al., 2019).

Table 2 summarizes the main sources of particulate matter (PM), their predominant particle fractions, and their key characteristics.

Table 2. Main sources of particulate matter (PM)
Source: compiled by the author based on literature data

Source Type	Main PM Fraction	Key characteristics / examples
Natural sources	PM10, 2.5	Marine aerosols, wildfires, volcanic ash
Traffic	PM2.5	Combustion (OC, EC), non-exhaust wear
Construction	PM10	Dust from excavation, demolition
Residential burning	PM2.5	Biomass and waste combustion
Agriculture	PM10	Soil dust, crop residue burning
Industry	PM2.5, PM10	Metal particles, combustion, chemical PM

CONCLUSIONS

The literature review highlights that particulate matter originates from a wide range of natural and anthropogenic sources, with significant spatial and temporal variability. Anthropogenic activities, particularly traffic, industrial processes, and construction, are consistently identified as major contributors in urban environments, while natural sources such as dust and marine aerosols play a more important role in rural and coastal areas.

The reviewed studies emphasize that source apportionment is essential for understanding PM distribution and for supporting effective air quality management strategies.

Overall, the findings underline the importance of targeted emission control measures adapted to local emission profiles.

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