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PARTICULATE MATTER EMISSIONS IN URBAN CONSTRUCTION: CHARACTERISATION, HEALTH EFFECTS, REGULATORY BACKGROUND, AND MITIGATION APPROACHES

BY

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Abstract. A significant environmental and public health risks derive from civil construction as a major source of air pollution, particularly through the emission of particulate matter (PM). Demolition, earthmoving, transportation, material handling, and on-site production processes, continue to generate substantial PM emissions, despite technological advances. This work assessed the characteristics and behavior of PM, highlighting the differences between fine and coarse fractions and the associated toxicological implications. The paper aims to revised current European regulations for PM_{10} and $PM_{2.5}$ including proposed updates to align with WHO (World Health Organization) recommendations. Exposure to PM leads to respiratory and cardiovascular diseases, as well as to premature mortality worldwide. The study collects and systematizes several practical mitigation measures applicable to all construction works stages. Reducing PM emissions requires robust planning, constant monitoring, and sustainable construction practices. Implementing an efficient environmental management plan is mandatory to reduce emissions and protect both humans and communities.

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1. Introduction

Civil construction is recognized as one of the barriers to sustainable development, with impacts ranging from local to global scale (Moraes *et al*., 2016). One of the primary environmental impacts caused by construction is the generation of air pollution. Sources of pollution resulting from construction include harmful gases, noise, dust and solid waste (Fang *et al*., 2024; Tah and Abanda, 2011). In contrast, sustainable construction seeks to address these challenges by establishing parameters through national and international policies, as well as through environmental certification methodologies that limit the environmental, economic and social impacts of construction. This approach also considers the building's entire life cycle, from project conception to demolition and recycling (Lima *et al*., 2021).

The greatest challenge for the construction sector is, therefore, to build sustainably, reconciling two important parts: the environmental impact of construction and its economic and social aspects. Building sustainably means improving the quality of life for the present population with extension of the benefits to future generations (Kuklinska *et al*., 2015). Sustainability in construction can be implemented gradually by applying strategic actions to priority items, focusing on the most impactful activities. Furthermore, it is necessary to associate sustainable construction with a dynamic process in which goals must be continually monitored and improved (Tah and Abanda, 2011). For this reason, it is important to investigate environmental impacts to establish priorities based on the context and specific needs of each construction project. By identifying and prioritizing the impacts that need to be reduced or eliminated, appropriate technologies and actions can be defined to minimize or even avoid harmful effects. This approach additionally involves pointing out risks, polluting activities, and the required tools to prevent, control and monitor these activities (European-Parliament, 2008).

One significant environmental impact caused by constructions is the generation of air pollution through the emission of particulate matter (PM), which causes serious damage to physical, biotic and anthropic environments (Commission, 2025). In several countries (such as India, Mexico, United States, China, United Kingdom), construction sites are recognized as major sources of particulate pollution (Yan *et al*., 2023).

Despite technological advances achieved by the construction industry through the use of innovative construction techniques like sensor networks, advanced chemical suppressants and binders, integrated vacuum extraction, these measures alone are not sufficient to reduce the environmental impacts generated by the emission of particulate matter. Effective reduction requires that such practices be correlated with good project management and environmental supervision (European-Parliament, 2008; Tah and Abanda, 2011). The environmental impacts resulting from the emission of particulate matter during various activities on construction sites, such as demolition, earthmoving, transportation, removal of materials and waste, storage, and all construction stages from rough work to finishing – remains a topic little discussed in the literature and face limitations in practical applications.

This work aims to critically discuss the characteristics of particulate matter, highlight its negative effects on human health, and identify the measures that should be implemented in civil construction projects in urban areas to diminish the emissions of these particles into the atmosphere.

2. Characterization of particulate matter

Within the scope of pollution emitted by activities on construction sites, PM in the atmosphere, according to (Morantes *et al*., 2021; USEPA, 2024; Wang, 2004) is define as mixture of solid and/or liquid particles (except pure water) found in the air, with distinct chemical and physical characteristics. These particles are directly emitted by polluting sources, or formed in the atmosphere, and can be responsible for a range of respiratory and cardiac problems, as well as damage to flora and fauna, inconvenience to neighbourhoods, deterioration of soil, water and air quality, among other aspects. Particulate Matter (PM) are divided into 3 groups: $PM_{2.5}$ - respirable particles, particles with an aerodynamic diameter of up to 2.5 µm; PM_{10} - inhalable particles, particles with an aerodynamic diameter between 2.5 µm - 10 µm; and, Total Suspended Particles - TSP, particles with an aerodynamic diameter of up to 100 µm (Fang *et al*., 2024).

PM is defined as the combination of solid and liquid elements, excluding pure water, present in the air, emitted by polluting sources or formed in the atmosphere, with specific physicochemical properties (Wang, 2004). PM consists of particles with diameters varying from 0.001 µm to 100 µm. Its basic composition includes an elementary carbon core to which gases, organic compounds, sulphates, nitrates and metals are aggregated (Fig. 1).

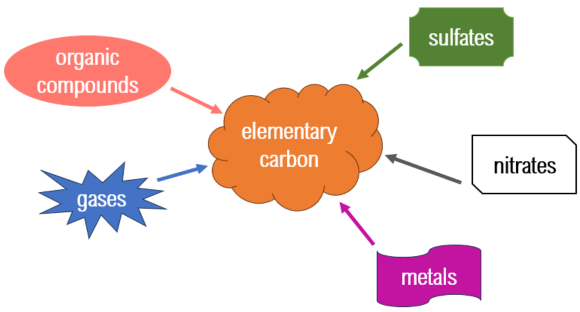

Fig. 1 – PM basic composition.

Numerous air pollutants are absorbed onto this carbon core, whose irritating, toxic or carcinogenic effects are facilitated by the transport of these compounds into the body through the inhalation of particulate matter (Fang *et al*., 2024; Yan *et al*., 2023).

The size of PM particles is classified into two main categories: i) the fine fraction, with a diameter ranging from 0.001 µm to 2.5 µm, which often has a residence time of days to weeks in the atmosphere and can be transported over long distances, ii) the coarse fraction, with a diameter greater than 2.5 µm, which often has high sedimentation rates and remains retained for a short period in the atmosphere (Morantes *et al*., 2021; WHO, 2006). Most of the literature mentions PM and uses the terms PTS, PM_{10} and $PM_{2.5}$, which are also known as total suspended particles, coarse particles and fine and ultrafine particles, respectively (Fang *et al*., 2024; WHO, 2006)

3. The levels of PM emissions across Europe and the limits imposed by European legislation

According to 2008/50/EC Directive on ambient air quality and cleaner air for Europe, as well as the European Commission's proposal COM (2022) 542 for the new Air Quality Directive (expected to be adopted in 2025), the limits for PM_{10} and $PM_{2.5}$ in Europe are presented in Table 1:

Table 1
Current limits and proposals for PM limits (µg/m^3)

Pollutant	Daily / annual limit	Current legal threshold (Directive 2008/50/EC)	New proposals (2024 revision, aiming to align with WHO)
PM_{10}	Annual average	40 µg/ m^3	20 µg/ m^3 (proposed)
	24-hour average	50 µg/ m^3 – May not be exceeded more than 35 days / year	45 µg/ m^3 – max. 18 Days/year (proposed)
$PM_{2.5}$	Annual average	25 µg/ m^3	10 µg/ m^3 (proposed)
	24-hour average (no current legal limit in force)	-	25 µg/ m^3 (proposed)

Figures 2 and 3 show the evolution of average PM_{10} and $PM_{2.5}$ concentrations in several European countries, as reported by European Environment Agency (Targa *et al*., 2025). The presentation aimed to include data from both developed and emerging European countries.

As can be seen, the average levels of PM_{10} and $PM_{2.5}$ emissions in recent years generally fall within the current limits established by European legislation, although in certain cases maximum levels may exceed the regulations in force.

Slightly higher concentrations (between 20–40 μg/m^3) are reported in countries in Central, Southern, and Eastern Europe. The findings presented in Figs. 2 and 3 aligns with outcomes reported in other works that detailedly analyzed the generation of PM_{10} and $PM_{2.5}$ in Romania in the context of European legislation (Toma and Volf, 2023).

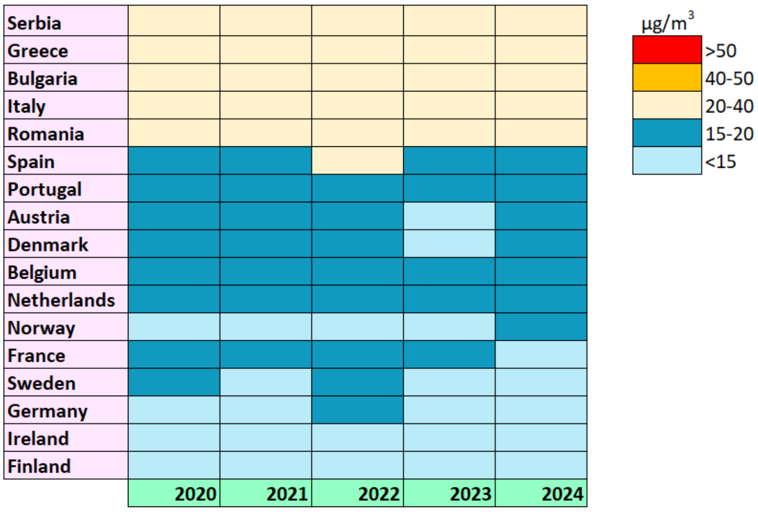

Fig. 2 – Evolution of annual average PM_{10} concentrations by country between 2020–2024.

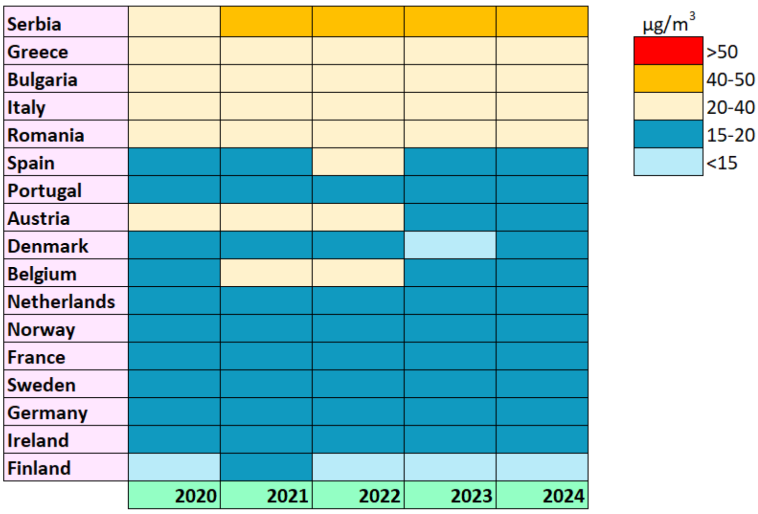

Fig. 3 – Evolution of annual average PM $_{2.5}$ concentrations by country between the years 2020–2024.

4. The effects of particulate matter on human health

The USEPA (USEPA, 2006) defines any substance present in the air that can cause harm to humans and the environment as an air pollutant. Of these, PM is the air pollutant most consistently related with harmful effects on human health. When these particles enter the respiratory system, they cause several diseases, such as silicosis, asthma, bronchitis, allergies, cardiac arrhythmia and heart attacks (Fang *et al*., 2024; Yan *et al*., 2023). Some of these particles can be observed at a macroscopic level (dust or smoke), but others can only be observed using electronic microscopes, as is the case of particles with diameters equal to or less than 10 µm.

Worldwide, it is estimated that air pollution by particles smaller than 2.5 µm is responsible for approximately 0.8 million premature deaths and 6.4 million years of life lost per year (Cohen *et al*., 2005). According to (Teinilä *et al*., 2022; Yan *et al*., 2023), particle size is directly associated with its potential to cause health problems, and the smaller the particle, the greater the effects. Its toxicity is related not only to its size, but also to chemical composition. Generally, defense mechanisms are adequate to remove inhaled particles larger than 10 µm. Particles smaller than 2.5 µm cause serious harm to the health of humans and animals, as they can lodge deeper in the respiratory system (Godish *et al*., 2015).

In 2006, the World Health Organization (WHO, 2006) published new air quality standards for PM. The limit values are suggestions to be adopted by countries, based on research by several global institutions on the harmful effects of PM on human health. This organization establishes standards for PM_{10} and $PM_{2.5}$ for annual average concentration and 24-hour concentration, as shown in Table 2.

Table 2

Air quality reference and interim objectives for PM in terms of annual average concentration according WHO 2026

	PM_{10} (µm/m^3)	$PM_{2.5}$ (µm/m^3)	Considerations for the selected level
Level I	70	35	These levels are associated with a long-term mortality risk about 15% higher than reference air quality levels.
Level II	50	25	These levels reduce premature mortality by approximately 6% in relation to level I.
Level III	30	15	These levels reduce premature mortality by approximately 6% in relation to level II.
Air quality reference	20	10	These are the lowest levels at which mortality from lung cancer or heart disease was reduced by 95% with long-term exposure to PM.

Construction activities are major potential sources of PM emissions into the atmosphere, at all stages of their life cycle, so their interference in air quality must be monitored, controlled and mitigated.

5. PM emission mitigation measures

The main recommended measures to be implemented to reduce PM emissions into the atmosphere during civil construction projects are pointed out in Table 3.

Table 3
PM emissions reduction measures

Activity	Good practices to be implemented	
Demolition activities	- Surround the construction site or emission points with fine-mesh polyester screens or wooden sheets; - Demolition waste must be removed as soon as possible from the construction site, avoiding its exposure to wind and rain. When this is not possible, it must be fenced, moistened and covered; - Avoid demolition activities when wind speeds are high; - Keep the area moist after the demolition is complete; - Spray water with high-flow hoses before and during the demolition activity.	(Commission, 2024) (EPA, 1998) (Neuroject, 2024) (Zumrut *et al*., 2024)
Earth moving	- Existing vegetation should be removed as earth moving activities progress; - Excavation services should be avoided during very dry periods and with strong winds; - Removal of soil from the work site should preferably be done immediately after excavation/movement; - Moisten the soil periodically and provide physical barriers around the work site or work areas; - Keep the excavation areas moist and covered during periods of standstill; - Control the height of the earth release during loading and unloading work. Empty the bucket slowly, avoiding the formation of dust clouds.	(Commission, 2024) (EPA, 1998) (Neuroject, 2024)
Removal of materials and waste	- All types of biological material present in the building that pose a risk to the environment must be removed before demolition begins. The material must be prevented from becoming an aerosol when removed; - Materials must not be burned, except as a last resort. Send for incineration;	(Commission, 2024) (EPA, 1998) (GLA, 2005) (Kunak, 2023)

	- Identify the types of waste produced (reduce, reuse and recycle); - Materials must be stored away from sensitive areas.	
Transportation	- Arrange vehicles and equipment for transporting elements to prevent the dispersion of PM (protect with physical barriers such as tarps, wooden sheets and screens, moisten materials); - When unloading, reduce the height of release, avoid doing so under strong winds; - Perform periodic cleaning of vehicles and equipment, avoiding the accumulation of dust; - Reuse waste to avoid unnecessary transportation; - Prefer materials in silos transported by pipelines rather than bagged materials; - Vehicles should be loaded up to a limit of 15 cm below the top of the bucket/truck; - Limit vehicle speed to avoid particle suspension. It is recommended to be below 30 km/h.	(Commission, 2024) (EPA, 1998) (GLA, 2005)
Storage	- Keep materials and waste stored for the shortest possible time on the construction site; - Store materials and waste protected from wind and rain; - Piles of materials should be arranged at angles that prevent constant collapse; - Large piles of materials and waste can be protected by chemical stabilizers or constantly moistened. Limit the height of the piles to 2.50 meters; - Perform periodic cleaning of storage areas; - When there is a large generation of PM at the storage site, install exhaust fans with filters; - Store materials and waste away from boundaries and environments sensitive to PM (watercourses, hospitals, schools, homes, places with crowds of people and others); - Store suction and cleaning equipment in case of accidental “leaks”.	(Commission, 2024) (EPA, 1998) (Fang *et al.*, 2025) (Kunak, 2023)
Construction	- Use a sawdust dust collection device attached to the equipment; - In the event of large amounts of emissions, carry out the activity in an environment with an exhaust hood and filter; - Cut/drill with and in a place protected from the wind and inside a collection box; - Whenever possible, avoid the production of concrete and mortars, on site and when produced on	(Commission, 2024) (EPA, 1998) (Neuroject, 2024) (Fang *et al.*, 2025) (Zumrut *et al.*, 2024)

	site. Do so in a place protected from the wind and rain; - When the mixtures are left overnight, cover them with tarps; - Whenever possible, avoid carrying out activities that require surface wear, replacing the construction technology; - Perform wet sweeping or vacuuming frequently; - Rationalize the production process in order to reduce the loss of mortars and concretes due to falls; - Check the tightness of the equipment used to transport concretes and mortars; - Create physical barriers to prevent mortar and concrete from being thrown outside a controllable space (screens on facade scaffolding, hoardings, tarps, among others); - Burning services should be avoided whenever possible on construction sites, as they release PM and gases; - When burning materials, for some reason, is unavoidable, try to do it in public incinerators; - Whenever possible and applicable, carry out the excavation in parts, trying to maintain the existing layer of plant protection for as long as possible; - Compact the surface or plant vegetation as soon as possible after finishing the services; - Use physical barriers (hoardings, screens, tarps, among others) around the service areas, avoiding or reducing the action of wind and rain; - Develop the physical planning of the work, trying to optimize the duration of this activity, so that the surfaces can be finished as soon as possible; - Perform cleaning as frequently as possible to prevent the accumulation of particles.	

6. Discussion

Ensuring control of particle emissions depends on adequate planning that identifies the risks involved, emission-producing activities, and proper prevention, control, and monitoring tools. In addition, it depends on an adequate transfer of this information to the production teams, as well as continuous control to ensure proper implementation (European-Parliament, 2008). All these factors only become viable if a comprehensive management plan is in place, ensuring that the actions are correctly applied through the project completion, when the site is dismantled and the building is released to residents, ending the construction phase and beginning the building's operation phase (European-Parliament, 2008).

A unique challenge on construction sites, in relation to other types of emission sources, is that the building evolves throughout its construction, not only in the type of emission, but also in its shape and size, causing different behaviors in the face of meteorological influences, among other variables that need to be analyzed and correlated with PM emissions (Fang *et al*., 2024).

Furthermore, distinct attention should be paid to the production stage of construction, since construction sites can generate large volumes of emissions and waste that are harmful to workers and, to a large extent, to the surround environment and residents (European-Parliament, 2008).

7. Conclusions

Environmental sustainability in civil construction requires compliance with good practice policies regarding air pollution, such as mandating of mitigating activities for PM emissions, the requirement of measuring and controlling these particles using appropriate equipment, and the dissemination of information regarding emissions and the necessary precautions within the construction site and its surroundings. To reduce harmful environmental impact, it is necessary to promote measures that are applied through periodic field monitoring, permitting timely interventions to prevent and control PM emissions throughout all activities on construction sites.

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STADIUL ACTUAL AL EMISIILOR DE PARTICULE ÎN CONSTRUCȚIILE URBANE: CARACTERIZARE, EFECTE ASUPRA SĂNĂTĂȚII, CONTEXT LEGISLATIV ȘI ABORDĂRI DE DIMINUARE

(Rezumat)

Construcțiile civile generează riscuri semnificative pentru mediu și sănătatea publică, acestea reprezentând o sursă majoră de poluare a aerului, în special prin emisiile de material particulat (PM). Activitățile de demolare, săpături, transport, manipulare a materialelor și procesele de producție la fața locului continuă să genereze emisii considerabile de PM, în ciuda progreselor tehnologice. Această lucrare oferă o evaluare a caracteristicilor și comportamentului PM, evidențiind diferențele dintre fracțiile fine și grosiere și implicațiile toxicologice asociate. Lucrarea își propune să revizuiască reglementările europene actuale privind PM_{10} și $PM_{2.5}$, inclusiv actualizările propuse pentru alinierea la recomandările OMS (Organizația Mondială a Sănătății). Expunerea la PM conduce la boli respiratorii și cardiovasculare, dar și la mortalitate prematură la nivel global. Studiul colectează și sistematizează mai multe măsuri practice de reducere a PM aplicabile tuturor etapelor lucrărilor de construcții. Reducerea emisiilor de PM necesită o planificare riguroasă, monitorizare constantă și adoptarea unor practici de construcție durabile. Este obligatorie implementarea unui plan eficient de management de mediu pentru a diminua emisiile și pentru a proteja atât lucrătorii, cât și comunitățile adiacente.