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Particulate matter in necropsy activities: experience from a health operators' exposure monitoring campaign

Matteo Scopetti[1], Nicola Di Fazio[2], Martina Padovano[2], Giuseppe Delogu[2], Donato Morena[2], Paola Frati[2], Carmela Protano[3], Matteo Vitali[3] and Vittorio Fineschi[2*]

Abstract

Background Operators in the obituary and necropsy sectors are exposed to various environmental hazards during specific tasks. Despite this exposure, occupational risks have often been underestimated, resulting in a lack of substantial evidence. The primary objectives of this study were to identify sources of chemical risk, establish procedures for monitoring and quantifying exposure during necropsy activities, and recommend adjustments to regulatory guidelines to protect the health of the operators. The study was conducted at the Legal Medicine Unit of the Umberto I General Hospital in Rome, focusing on the quantitative measurement of particulate matter (PM) exposure among at-risk operators during necropsy activities. Environmental levels of total suspended particles, PM10, PM4, PM2.5, and PM1 were assessed by evaluating the average, minimum, and maximum instantaneous indoor concentrations using an airborne analyzer.

Results The monitoring activities revealed that the PM concentrations were significantly lower than the recognized reference values. However, bone sawing, body removal, and cleaning were identified as high-risk maneuvers for dust suspension.

Conclusions Our study highlighted specific risks associated with necropsy activities, particularly concerning timing and certain maneuvers. These results may lead to interventions for improving current prevention procedures, implementing good practices, and developing specific guidelines to enhance operator safety.

Keywords Risk management, Investigative techniques, Forensic medicine, Environmental pollution, Particulate matter

Background

Morgue and necropsy activities involve various professional roles, such as medical examiners, autopsy room technicians, nurses, and support staff. The primary tasks performed in these occupational settings include external examinations, autopsies, and the collection of tissue samples for chemical fixation. Consequently, workers in this sector are exposed to biological (Miller et al. 2012; Nolte et al. 2021), chemical (Pathak et al. 2008; Gwenzi 2021), and physical (Del Fante et al. 2021) hazards associated with contact with body fluids and tissues, sharp instruments, fixative agents, and embalming substances.

*Correspondence:
Vittorio Fineschi
vittorio.fineschi@uniroma1.it
[1] Department of Medical Surgical Sciences and Translational Medicine, Sapienza University of Rome, Rome 00189, Italy
[2] Department of Anatomical, Histological, Forensic and Orthopaedic Science, Sapienza University of Rome, Rome 00185, Italy
[3] Department of Public Health and Infectious Diseases, Sapienza University of Rome, Rome 00185, Italy

Furthermore, during autopsies, operators may be involuntarily exposed to drugs and other chemicals present in the corpse for various reasons (Chiu et al. 2020). Regarding chemical risks, limited evidence is currently available in the scientific literature. However, particulate matter (PM), primarily generated during bone sawing (Wenner et al. 2017), has been identified as a major hazard. The definitions of PM refer to a mixture of solid particles and liquid droplets dispersed in the atmosphere, spanning a dimensional range from nanometers to hundreds of micrometers. Particle size is the most important parameter for describing their behavior and origin. The chemical composition, removal, and residence time in the atmosphere are all characteristics related to particle size. Since particles generally have non-homogeneous density and non-spherical shapes, the definition of particle diameter refers to an "equivalent" diameter, known as the aerodynamic diameter. This is defined as the diameter of a spherical particle with a unit density that has the same sedimentation rate as the particle under consideration (Independent Particulate Matter Review Panel et al. 2020).

Particulate matter has distinctive characteristics both physically and chemically. It is typically categorized based on the aerodynamic diameter of the particles (Asgharian et al. 2001): greater than 2.5 µm (coarse mode particles), between 0.1 and 2.5 µm (accumulation mode particles), and less than 0.1 µm (ultrafine particles). This classification is because smaller particles can penetrate deeper into the respiratory system (Manigrasso et al. 2018). The chemical composition of PM determines its specific toxicity, related to the substances present in the particles, which can cause harmful effects both locally (at the area of the respiratory tree where the particles are deposited) and systemically (in organs and tissues reached by the chemicals released into the bloodstream from the particles) (Avino et al. 2016).

Due to its adverse effects on human health, outdoor PM air pollution has been classified as carcinogenic to humans by the International Agency for Research on Cancer (IARC 2015). The international literature shows a limited number of studies on PM exposure during necropsy activities, primarily focused on the microbiological risk potentially associated with the suspension of bone dust (Pluim et al. 2019).

Despite bone sawing is an unavoidable procedure during autopsies, to date, only limited data are available on the specific occupational settings involved. Therefore, it is essential to identify, characterize, and measure such risks to develop specific procedures to protect the health of exposed professionals.

The main objective of the present study was to assess the potential occupational exposure of healthcare workers involved in necropsy and morgue activities to PM. Specifically, the exposure assessment was based on identifying potentially exposed job duties, determining exposure levels through environmental and personal monitoring, and comparing the risk assessment with regulatory limits and guidelines.

Methods

The monitoring campaigns took place at the premises of the Legal Medicine Unit of the Umberto I General Hospital in Rome. The research was conducted in a hospital complex equipped with:

– A dissection hall with three accessorized autopsy tables;
– A refrigerated area with 90 spaces, including single cells and refrigerated rooms maintained at 5 °C;
– An air ventilation system with High-Efficiency Particulate Air (HEPA) filters capable of 12.5 air changes per hour;
– A histology laboratory equipped with ventilated cabinets for sample storage, a hood with an image acquisition system, a vacuum tissue processor, a semi-automatic microtome, an automatic stainer, and a microscope.

Surveys were carried out during scheduled autopsy activities, including cadavers destined for judicial or clinical autopsy. Several groups of operators involved in necropsy activities were identified as being at risk of exposure to PM. These operators included medical examiners, residents, students, autopsy room technicians, auxiliary personnel, magistrates, and police officers.

The monitoring was designed by determining activities at risk based on available scientific evidence and the professional experience of the investigators. A critical review of technical maneuvers performed during autopsies was conducted to identify activities posing the greatest risk. Monitoring activities aimed at assessing individual risk included tasks such as autopsy procedures, tissue sampling, washing of stretchers and instruments, hygienic and conservative treatments, and the conservation and treatment of samples.

Measurements were conducted using an airborne analyzer (DustTrak DRX 8534, TSI Incorporated, Shoreview, MN, USA) equipped with dedicated software that provided data as precise values expressed in micrograms per cubic meter (µg/m^3). The analyzer was positioned at a representative location within the monitored environment.

Once the instrumentation was activated and readings stabilized, monitoring was performed with measurements taken at 15-s intervals. Measurements began approximately 30 min before the start of activities each day and continued until the end of operations, including tidying up, cleaning, and sanitization.

The following parameters were collected:

- average of instantaneous indoor concentrations;
- minimum of instantaneous indoor concentrations;
- maximum instantaneous indoor concentrations.

Surveys included five types of particle size fractions (Brown et al. 2013; Pluim et al. 2018):

- total suspended particles (TSP) (according to the American Conference of Governmental Industrial Hygienists, ACGIH);
- PM10 (chest fraction according to ACGIH);
- PM4 (breathable fraction according to ACGIH);
- PM2.5;
- PM1.

Results

Results relating to TSP, PM10, PM4, PM2.5, and PM1 detected during the surveys are presented below (Table 1; Figs. 1,2, 3, 4, and 5).

The PM detection on day 1 revealed increases in dust concentration at several key points: when the autopsy table was activated and the autopsy began (2:46 p.m.), during the opening of the ribcage with shears (3:05 p.m.), and when the cranial cavity was opened with the oscillating saw (3:15 p.m.), as well as during the post-procedural cleaning phase.

On day 2, PM measurements confirmed elevated dust concentrations during the use of the oscillating saw across the three sequential autopsies.

Detection on day 3 and day 4 reinforced these findings, showing peaks in particulate concentrations at the time

Table 1 Total suspended particles (TSP) and particulate matter (PM) concentrations in indoor air during the monitoring campaign

	Average (min–max)					Reference limit (mg/m^3)
	Day 1	Day 2	Day 3	Day 4	Day 5	
TSP	0.012 (0.010–0.091)	0.017 (0.010–0.238)	0.003 (< 0.001–0.059)	0.049 (0.017–0.895)	0.040 (0.007–0.529)	10[a]
PM10	0.012 (0.010–0.033)	0.016 (0.010–0.211)	0.003 (< 0.001–0.057)	0.037 (0.017–0.458)	0.030 (0.007–0.186)	0.050[b]
PM4	0.012 (0.010–0.025)	0.015 (0.010–0.154)	0.003 (< 0.001–0.051)	0.033 (0.017–0.231)	0.027 (0.007–0.162)	3[a]
PM2.5	0.012 (0.010–0.023)	0.015 (0.010–0.138)	0.003 (< 0.001–0.048)	0.032 (0.016–0.198)	0.027 (0.006–0.158)	0.025[b]
PM1	0.012 (0.010–0.022)	0.014 (0.010–0.128)	0.003 (< 0.001–0.046)	0.032 (0.016–0.187)	0.026 (0.006–0.157)	NR

[a] TLV-TWA, ACGIH, 2016 (Kozlovac and Hawley 2017)

[b] Italian Legislative Decree 13 August 2010, n. 155 "Implementation of Directive 2008/50/EC on ambient air quality and cleaner air in Europe"

NR not reported

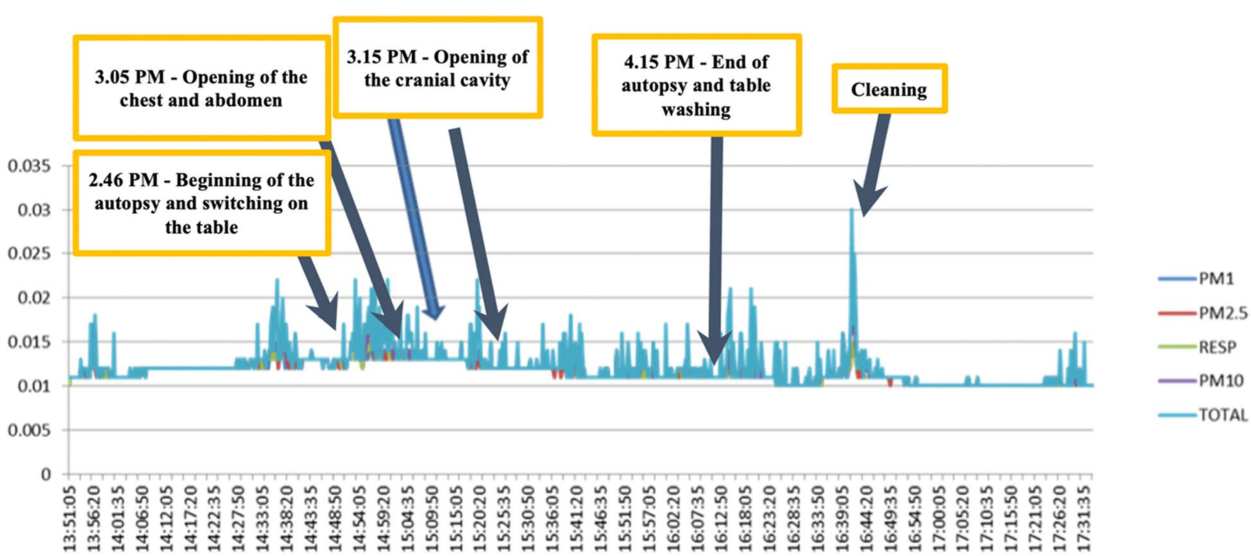

Fig. 1 Graphic representation of results of measurements performed on day 1. The ordinate shows the quantity of particulate matter expressed in mg/m^3; the abscissa plots the time of measurements in hours:minutes:seconds

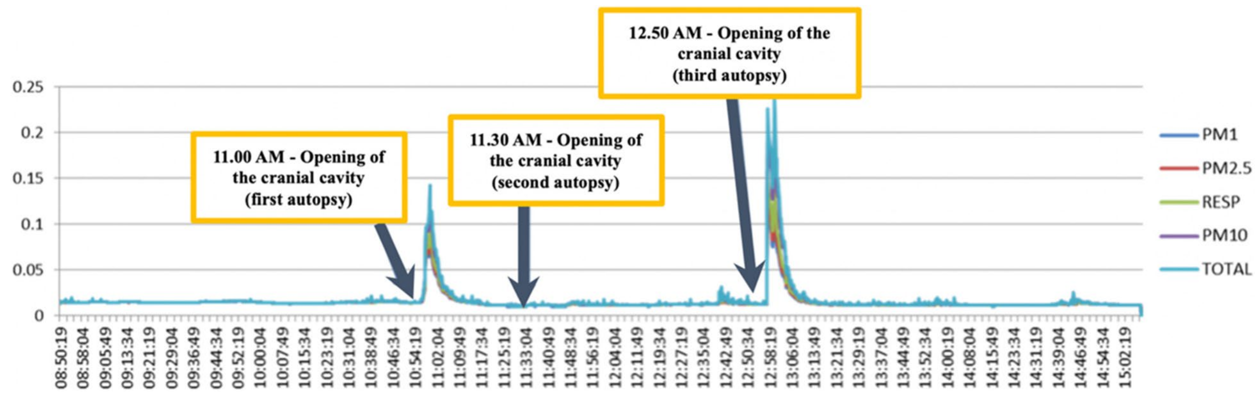

Fig. 2 Graphical representation of results of measurements performed on day 2. The ordinate shows the quantity of particulate matter expressed in mg/m^3; the abscissa plots the time of measurements in hours:minutes:seconds

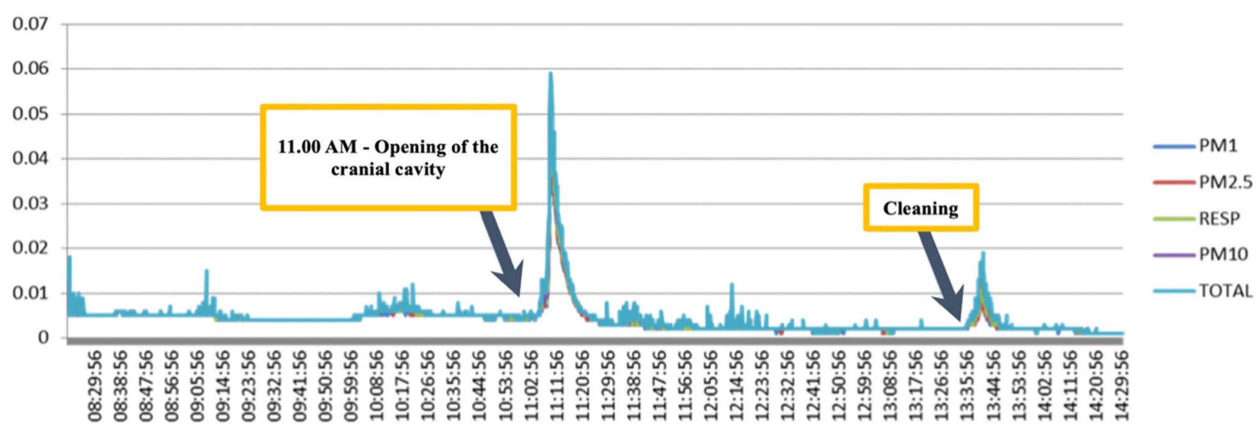

Fig. 3 Graphical representation of results of measurements performed on day 3. The ordinate shows the quantity of particulate matter expressed in mg/m^3; the abscissa plots the time of measurements in hours:minutes:seconds

of the oscillating saw's operation and during the cleaning of the autopsy table.

Finally, measurements on day 5 confirmed that the use of the oscillating saw for cranial cavity opening and bone sampling resulted in peak particulate concentrations in instantaneous indoor measurements.

Overall, the monitoring campaigns indicated that TSP and PM10 concentrations were below the established limits. For non-industrial indoor environments (such as offices, schools, homes, and healthcare settings), lower concentration limits are considered (approximately one-tenth of those for industrial settings). Even when considering levels of concern, dust levels were found to be reduced in all monitored environments.

Examination of the point concentration trends of PM fractions over time revealed several notable features. Higher background levels of PM were observed when more people were present in the dissection hall and when multiple autopsies were performed simultaneously. This highlights the issue of resuspension caused by operators' movement and underscores the need to limit simultaneous autopsies based on available space.

The use of an oscillating saw for cranial cavity opening and bone sampling generated the highest PM levels, approaching 1 mg/m^3. In comparison, the use of a manual saw resulted in PM emissions only slightly above the background level.

Peaks in PM concentration were also documented following post-procedural cleaning and the restoration of the dissection hall. These activities caused the resuspension of PM generated during autopsies and its subsequent deposition on surfaces.

Regarding the dimensional composition of PM, background levels were predominantly attributed to PM particles smaller than 1 µm. During peak concentrations, particularly when using the oscillating saw, more than 50% of the PM was larger than 10 µm, while approximately 40% was smaller than 1 µm. A similar particle size

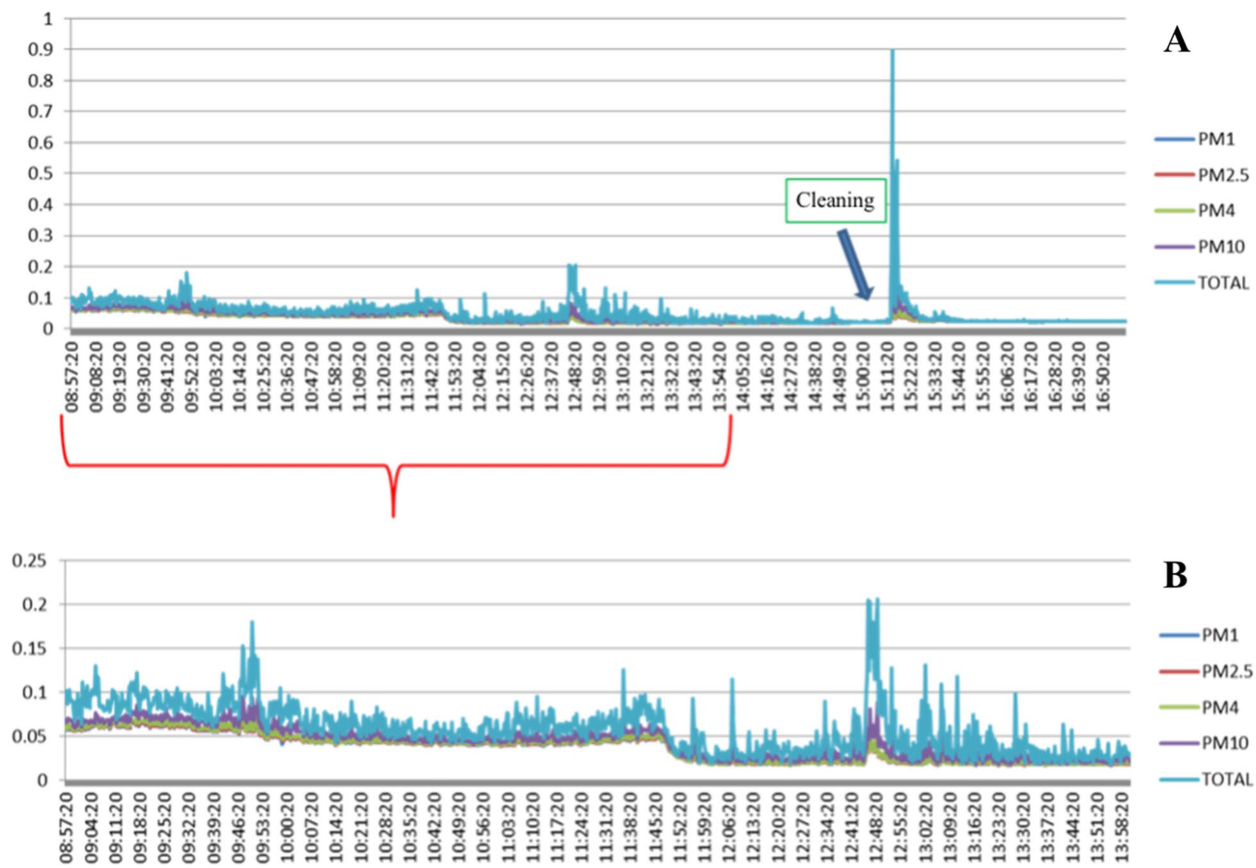

Fig. 4 Graphical representation of results of measurements performed on day 4. **A** Description of particulate matter air concentration peak observed during cleaning. **B** Time window restricted to 5 h in the morning. The ordinate shows the quantity of particulate matter expressed in mg/m^3; the abscissa plots the time of measurements in hours:minutes:seconds

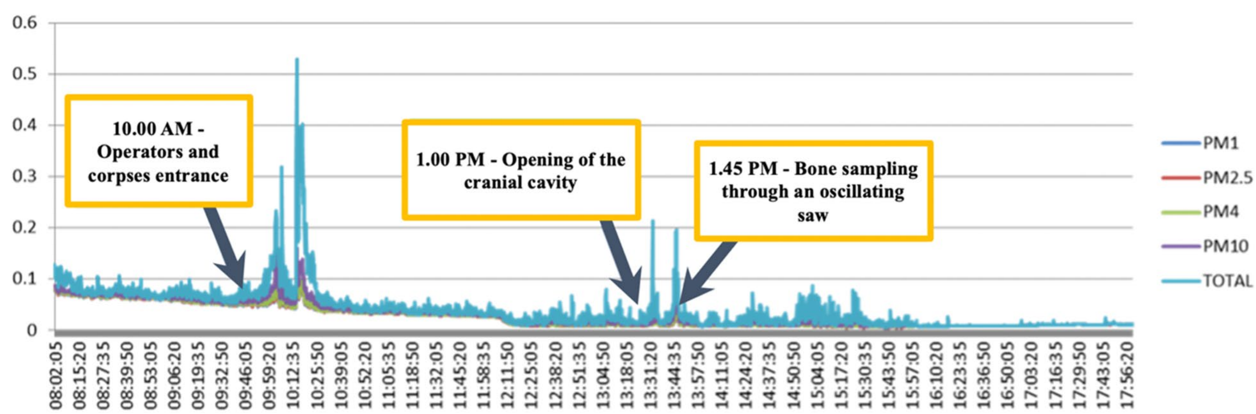

Fig. 5 Graphical representation of results of measurements performed on day 5. The ordinate shows the quantity of particulate matter expressed in mg/m^3; the abscissa plots the time of measurements in hours:minutes:seconds

distribution was observed in PM generated during cleaning and restoration activities.

Discussion

The results obtained in the present study, according to the available evidence, document that the chemical risk associated with necropsy and morgue activities is closely related to the production of PM during several specific activities, highlighting the occupational risks inherent in these settings. Health dangers arising from the inhalation of organic dust due to work exposure encompass both acute respiratory diseases, such as bronchitis or pulmonary edema from high concentrations of irritants (Gorguner and Akgun 2010), and chronic respiratory diseases (Khaltaev and Axelrod 2019), such as pneumoconiosis, extrinsic allergic alveolitis, lung cancer, and mesothelioma.

The risk assessment procedure is based on studying the work cycle, the chemical, physical, and toxicological characteristics of the substances and/or mixtures used or produced, the working environments, the characteristics of the operator, and the job performed. Similarly, characterizing and quantifying the exposure is fundamental. Risk assessment is not always feasible in exposure situations difficult to assess through a quantitative-analytical approach (e.g., scenarios with low dispersive actions, high control, variable frequency, short duration, or involving many chemicals in limited quantities). In such cases, a forecasting approach, such as generating "exposure scenarios", may be necessary. For assessing occupational exposure to chemical agents, the preferred method remains instrumental and analytical approaches, including environmental and/or biological monitoring surveys. These methods compare exposure assessment results with appropriate exposure threshold limit values and/or conduct specific investigations.

During autopsy procedures, in addition to risks associated with physical activities, there are also risks related to the exposure of operators to PM. Specifically, in our study, the most relevant moments for this risk include the use of the oscillating saw, the opening of the cranial cavity, and bone sampling, other than the cleaning activities.

The oscillating saw, as well as the use of rib shears to open the chest cavity, release large quantities of potentially contaminated bone dust, posing an inhalation risk.

Moreover, body removal and cleaning the autopsy tables are risky activities due to dust resuspension, exposing not only health professionals but also other operators.

Considering innovative aspects related to identifying possible chemical risk factors during necropsy activities and subsequent development and application of preventive measures, our findings demonstrate the need for procedural adjustments in necropsy and morgue activities. The subsequent step is planning risk reduction measures and/or surveillance. This objective can only be achieved through monitoring campaigns and indicators useful for quantifying risk control-related performance (Baylina et al. 2018). Indicators allow operators to monitor a set of elements or some of them quickly and effectively, activating specific interventions as necessary with scientific validity, applicability, measurability, and reproducibility (Donabedian 1988; Lee et al. 2015).

The main limitation of the present study is the lack of assessment of exposure to chemical agents according to the specific activities of the different operators involved. This limitation is primarily due to the difficulty in estimating the specific working time within individual environments for each worker during monitoring. However, this issue could be investigated in future studies. Similarly, it may be appropriate to compare workplace results with those obtained in the open air outside the morgue on the same days. A proper evaluation must consider the great variability of tested parameters based on climate, season, and geographic location. Unexpectedly, on only one of the monitoring days were mean concentration values higher than external ones.

Conclusively, necropsy and morgue activities are characterized by significant heterogeneity of tasks and related exposures in terms of times and doses (D'Errico et al. 2021). Therefore, consequent risk assessment cannot ignore the careful and timely examination of procedures carried out in each individual setting (Scopetti et al. 2021).

Conclusions

Our study underscores that autopsy practices expose operators to dust particles of various sizes, representing both chemical and biological risks. By highlighting the most hazardous moments during autopsy activities, these findings can inform the decisions of the National Health System, health facilities, and regulatory bodies, driving improvements in prevention procedures and workplace guidelines. Although monitoring surveys show that the environment largely meets recommended values, the presence of particles originating from human tissues, posing potential biological and chemical risks, necessitates specific risk assessments.

Abbreviations

PM	Particulate matter
IARC	International Agency for Research on Cancer
HEPA	High-Efficiency Particulate Air
TSP	Total Suspended Particles
ACGIH	American Conference of Governmental Industrial Hygienists
PM in Figs. 1–5	Postmeridiem
AM in Figs. 1–5	Antemeridiem

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Authors' contributions
Conceptualization: V.F. and M.V.; methodology: D.M., M.S., and V.F.; software: N.D.F. and G.D.; investigation: C.P. and M.P.; resources: V.F.; data curation: P.F.; writing—original draft preparation: D.M., M.P. and C.P.; writing—review and editing: M.S. and M.V.; visualization: P.F.; supervision: V.F.; project administration: V.F. and M.V. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials
All data used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was conducted according to the guidelines of the Declaration of Helsinki and with the ethical guidelines of the Polyclinic Umberto I and "Sapienza" University of Rome in which the study was performed. Informed consent was obtained from all subjects involved in the study.

Consent for publication
All co-authors of the present manuscript can certify that it has not been submitted to more than one journal for simultaneous consideration and that the manuscript has not been published previously (partly or in full). The authors also can certify that our main study is not split into several parts to increase the number of submissions, that none of the data presented here have been fabricated or manipulated, and that we present our data/text/theories/ideas. All authors and authorities have explicitly provided their consent to submit the present manuscript; in general, we all agree with the ethical responsibilities of the authors of the journal.

Competing interests
The authors declare that they have no competing interests.

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