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Indoor air quality in offices: strategies for monitoring chemical and biological pollutants

G. Settimo, M. Arpaia, M. Cerasa, S. Della Libera, M. Gherardi, M.G. Grollino, E. Guerriero, M. Inglessis, R. Mari, F. Ravaioli, F. Regina, F. Scaini, L. Tofful
for the National Indoor Air Study Group

AMBIENTE E SALUTE

ISTITUTO SUPERIORE DI SANITÀ

Indoor air quality in offices: strategies for monitoring chemical and biological pollutants

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2025, x, 67 p. Rapporti ISTISAN 25/15

Purpose of this document is to provide correct *indoor* air monitoring strategies in offices, both for proper measurement, acquisition, verification and evaluation of chemical and biological pollutants, and to support Individual specifications and collective prevention protocols, with the aim of improving health workers, in particular reiterating the central role of responsibility for the promotion and protection of workplaces, as provided by the World Health Organization and the achievement of the Sustainable Development Goals set in the United Nations 2030 Agenda. The main factors to be considered in order to plan the monitoring activities in relation to the internal environments and the sources are reported. The general principles and characteristics of the methods of sampling and analysis of Volatile Organic Compounds (VOC_S), particulate matter (PM_{10} and $PM_{2.5}$), organic micropollutants (PAH, PCDD/F and PCB) and inorganic (metals and metalloids), biological (virus, bacteria, moulds and allergens) are described.
Key words: *Indoor* air; Schools; VOC; PM_{10}; $PM_{2.5}$; Metals; PAH; PCDD/F; PCB; Bacteria; Virus; Allergens; Sampling; Analysis

Istituto Superiore di Sanità
Qualità dell'aria *indoor* negli uffici: strategie di monitoraggio degli inquinanti chimici e biologici.
Gaetano Settimo, Margherita Arpaia, Marina Cerasa, Simonetta Della Libera, Monica Gherardi, Maria Giuseppa Grollino, Ettore Guerriero, Marco Inglessis, Roberto Mari, Francesca Ravaioli, Francesco Regina, Federica Scaini, Luca Tofful per il Gruppo di Studio Nazionale Inquinamento *Indoor*
2025, x, 67 p. Rapporti ISTISAN 25/15 EN (in inglese)

Obiettivo di questo documento è fornire delle corrette strategie di monitoraggio dell'aria *indoor* negli uffici sia per un'adeguata attività di misura, acquisizione, verifica e valutazione degli inquinanti chimici e biologici, sia per supportare adeguatamente specifici protocolli di prevenzione individuale e collettiva, con l'obiettivo di migliorare lo stato di salute del personale, e per ribadire il ruolo centrale di responsabilità nella promozione e tutela della salute da parte dei luoghi di lavoro così come previsto dalla World Health Organization e dagli obiettivi di sviluppo sostenibile fissati nell'Agenda 2030 delle Nazioni Unite. Si riportano i principali fattori da considerare per pianificare le attività di monitoraggio in relazione agli ambienti e alle sorgenti *indoor*. Vengono descritti i principi generali e le caratteristiche dei metodi per il campionamento e l'analisi dei Composti Organici Volatili (COV), del materiale particellare (PM_{10} e $PM_{2,5}$), dei microinquinanti organici (IPA, PCDD/F e PCB) e inorganici (metalli e metalloidi), biologici (virus, batteri, funghi e allergeni) con riferimento alle norme elaborate a livello europeo.
Parole chiave: Aria *indoor*; Uffici e ambienti similari; COV; materiale particellare PM_{10}; $PM_{2,5}$; Metalli; IPA; PCDD/F; PCB; Batteri; Virus; Allergeni; Campionamento; Analisi

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National Study Group Indoor Pollution

The ISS National Indoor Pollution Study Group was appointed with notes of December 16, 2015 (Prot. 372571), February 10, 2016 (Prot. 3880), July 27, 2023 (Prot. 35562), June 5, 2024 (Prot. 24534) and March 20, 2025 (Prot. 0012487) by the President of the Istituto Superiore di Sanità.

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ACRONYMS

CEN	European Committee for Standardization
CFU/cm^2	Colony Forming Units/cm^2
CFU/m^3	Colony Forming Units/m^3
ECHA/RAC	European Chemicals Agency/Risk Assessment Committee
HSE	Health, Safety and Environment
HSO	Health and Safety Officer
HVAC	Heating, Ventilation, and Air Conditioning
IRP	Infectious Respiratory Particles
ISO	International Organization for Standardization
LCI	Lowest Concentration of Interest
NHS	National Health Service
NPP	National Prevention Plan
OEL	Occupational Exposure Limit Values
OEL-STEL	Occupational exposure limit values – Short-Term Exposure Limit
OEL-TWA	Occupational Exposure Limit values – Time-Weighted Average
OELV-VLEP	Occupational Exposure Limit Values
PAH	Polycyclic Aromatic Hydrocarbon
PCB	PolyChlorinated Biphenyls
PCDD	PolyChlorinated DibenzoDioxins
PCDF	PolyChlorinated DibenzoFurans
PCR	Polymerase Chain Reaction
PM	Particulate Matter
ppmv	parts per million-ppm volume/volume
PPSO	Prevention and Protection Service Officer
RAD	Risk Assessment Document
STEL	Short Term Exposure Limit
SVOC	Semi Volatile Organic Compound
TLV®	Threshold Limit Value
TLV®-C	Threshold Limit Value – Ceiling
TLV®-STEL	Threshold Limit Value – Short-Term Exposure Limit
TLV®-TWA	Threshold Limit Value – Time-Weighted Average
UNI	Italian Standards Body
VOC	Volatile Organic Compound
VVOC	Very Volatile Organic Compound
WHO	World Health Organization
WSR	Workers' Safety Representative

PRESENTATION

The great importance of the problems connected with indoor air quality in public and private buildings where staff are mainly employed in office work, from institutions and administrations to banks, from insurance companies to post offices, from consulting offices of the liberal professions to the services and administrative spaces of companies and other similar places, urged the National Study Group Indoor Pollution (GdS), established at the Istituto Superiore di Sanità (ISS), to draw up a document describing the main strategies to be used for the definition of indoor air quality monitoring, control and assessment plans, recalling the indications present in the documents already published by the same GdS as volumes of the series *Rapporti ISTISAN*. The GdS Indoor Pollution aims to help refine knowledge and the broadest possible assessment of indoor air concentration levels of the main chemical and biological pollutants that can affect the health of staff, users as well as customers and suppliers. This requires the development and implementation of effective plans and tools for managing indoor air quality, identifying and preventing health risks in advance.

The document contains a number of references for the adoption of a dedicated, integrated and coherent "big vision" action plan to protect and promote health and, at the same time, a decent work environment for all, as described in Sustainable Development Goal n. 8 of the United Nations 2030 Agenda. The workplace must increasingly be seen as a context in which to develop primary health prevention activities, not only to prevent exposures, but also to assess and improve the overall health of staff.

Offices represent a category of heterogeneous spaces in which a multiplicity and diversity of activities and functions such as administrative, financial, business and customer service activities take place. They can include rooms, spaces and modular spaces adapted according to needs, *open space*, or delimited by partition panels, meeting rooms, conference rooms, training rooms, archives, reception/desk reception for visitors in the immediate vicinity of the entrance, and relaxation spaces.

Buildings, environments, utilisation and occupation of space have undergone profound and continuous changes in recent years (mostly during the pandemic period), generating new behavioural and cultural models very different from traditional face-to-face and centralised work (hybrid or remote work, agile work and home office teleworking).

Today, many offices see the presence of the majority of staff only on certain days of the week, transforming working environments into increasingly specialised, functional, shared spaces designed using standards, technologies and technical regulations that create new challenges in the labour market and in primary prevention activities. The pursuit of a plan for constant and continuous improvement of indoor air quality in offices will result in significant health benefits for staff, who spend most of their time inside the office, and necessarily implies the full involvement of the corporate community of employers, management, executives, staff and suppliers, who must also include indoor air quality among the company's values.

In office environments, specific interventions on primary health prevention are mandatory and necessary, considering that whatever the risk, the exposure of staff in indoor environments takes on a particular significance and importance, both because of the vulnerabilities of the subjects (e.g. staff with more or less complex susceptibility and different disabilities, or with respiratory diseases, asthmatics and allergy sufferers, or altered immune systems, older staff, clients, visitors, etc.), and because of the high length of time they spend there (e.g. office environments and spaces represent after the home the places where staff spend the most time, on average about 8-10 hours a day for at least five days a week) affecting performance, productivity, service quality,

relationships and staff satisfaction, as well as reducing health and care costs borne by the worker and the National Health Service (NHS). It is estimated that we spend over 65,000 hours in the workplace during our working lives.

In Italy, in relation to indoor air quality, there is an evident legislative delay that must be compulsorily and rapidly filled, with the issuance of a specific act according to an integrated viewpoint that contains appropriate references for chemical and biological pollutants in line with those elaborated and updated with the state of knowledge by the World Health Organization (WHO), with the protocols and operating procedures for detection and control provided for and published in the *Rapporti ISTISAN* of the GdS Indoor Pollution.

The current system of laws on health prevention and protection (Legislative Decree 81/2008) has also led to a confusion of language, difficulty, ambiguity of interpretation, and even inconsistencies in the scope of application, which has disoriented technicians, NHS operators and other stakeholders such as personnel managers, administrative managers, HSO, PPSO, WSR, competent doctors, municipal and provincial technical offices, policy makers, building owners, etc, in guiding the development of plans, operational programmes and assessments. There is an urgent need to bridge the obvious gap, through a concrete revision and update of Legislative Decree 81/2008, which is still lacking and not exhaustive in this regard of suitable references on indoor air quality both as definitions, as reference concentrations of the main pollutants, and on the sampling and analysis methods to be adopted for verification in order to allow the best interpretation of the results, consistent with the indications and health-based guideline values already established by the WHO and contained in the *Rapporti ISTISAN* of the ISS Indoor Pollution Study Group.

It is mandatory for the Risk Assessment Document (RAD-DVR) to include indoor air quality among the risk factors, in order to adopt and/or maintain measures and interventions to protect health, anticipate, eliminate or mitigate its effects and control its risk.

It should be remembered that in offices, in the case of chemical pollutants, it is not possible to use occupational-industrial derived standards – e.g. the Occupational Exposure Limit Values (OELV) of Annex XXXVIII and XVIII of Legislative Decree 81/2008 or the threshold limit values (*Threshold Limit Value*, TLV®, *Occupational Exposure Limit*, OEL ECHA/RAC) prolonged in time or short term TLV-TWA®, OEL-TWA (*Time-Weighted Average*) or TLV®-STEL, OEL-STEL (*Short Term Exposure Limit*), TLV-C® (*Ceiling*), etc.

The National Prevention Plan (NPP) 2020-2025 contains central Support Lines, also called NPP Central Actions, aimed at improving the capacity of the health system to promote and govern prevention and to facilitate the achievement of the NPP objectives. Among the 13 Lines of Central Actions of the NPP, there is Line n. 8 “Definition of a National Plan for Indoor Air Quality (IAQ)”, which provides for the adoption of a National Plan through institutional coordination.

In the National Strategic-Operational Plan for Influenza Pandemic Preparedness and Response (PanFlu) 2021-2023, improving indoor air quality is among the most effective preventive measures. Therefore, among the Plan's crucial measures is the adoption of a simple and effective indoor air quality prevention plan, which must be supported by short-, medium- and long-term action planning of monitoring, assessment, information and staff training to involve and empower the community in the proper management of indoor air quality.

In the draft of the “New Strategic Operational Plan for Preparedness and Response to a Pandemic from Respiratory Transmitted Pathogens with the Highest Pandemic Potential 2024-2028”, the central role of improving indoor air quality is once again confirmed among the key guiding principles to be adopted as public health prevention and response measures.

On the whole, many of these aspects are reported in the “Air Pollution Strategy of our Country Profile” published by the WHO in 2017, which emphasises the need for a governance system on indoor air quality based on a legislative framework that allows for the revision and updating of

Legislative Decree 81/2008, taking into account the ongoing changes in the world of work, activities, indoor environments and personnel, in order to strengthen the search for primary prevention solutions for healthy living, with mutual and shared responsibility between the organisation and staff.

Considering the need to respond to the crucial issues of primary health prevention, pollutant and infection control, risks of epidemics or pandemics caused by emerging or re-emerging pathogens, reduction of carbon emissions from materials and equipment, improvement of the energy performance of buildings (see Energy Performance of Buildings Directive, EPBD) and the impact of climate change, a new cultural attitude of continuous and continuous improvement of indoor air quality in offices is needed.

With this document, the GdS Indoor Pollution wants to contribute to developing and consolidating full awareness of a primary prevention approach to safeguard and improve health, which is based on the quality of the air breathed in offices that represent typical indoor environments. In particular, it applies to:

– *chemical pollutants*
  - organic compounds (VVOCs, VOCs) [*], which are the most frequently used pollutants in indoor air quality studies;
  - suspended particulate matter (PM_{10} and $PM_{2.5}$[**]), and where chemical characterization of PM_{10} e $PM_{2.5}$ in terms of the content of selected semi-volatile organic compounds (SVOC)[*] such as PAH, PCDD, PCDF, PCB and metals is deemed necessary;
– *biological pollutants*
  - bacteria, fungi, viruses-*Infectious Respiratory Particles* IRP[***] and allergens.

These pollutants are all potential sources of risk, present in the different environments, spaces or areas of office buildings used by staff, customers and suppliers. It should be remembered that the methodologies proposed in this document are already commonly used in numerous national and European survey and assessment initiatives and refer to the main methods developed on indoor air quality by the International Standard Organization (ISO) and implemented by the European Committee for Standardization (CEN) and in part in Italy by the Italian Standardization Body (UNI).

In these fifteen years of activity, the ISS GdS Indoor Pollution, in which the various ministerial components (Ministry of Health, Ministry of the Environment and Energy Security, Ministry of Labour and Social Policies), regions and research institutes (ISS, National Research Council-CNR, National Institute for Insurance against Accidents at Work-INAIL, Italian National Agency for New Technologies, Energy and Sustainable Economic Development-ENEA, Italian Institute for Environmental Protection and Research-ISPRA, National System for Environmental Protection-SNPA), drew up a series of reference documents, and carried out training and information activities to raise awareness, in order to enable and implement harmonised actions unified at national level.

The documents of the ISS GdS Indoor Pollution, already published as *Rapporti ISTISAN* and dissemination documents, are intended to promote and foster the design and development of a national strategy on indoor air quality, which still represents a priority that our country must support and achieve.

[**] PM_{10} and $PM_{2.5}$ are particulate matter that penetrates through a size-selective inlet in accordance with the reference method for sampling and measurement according to EN 12341.

[***] IRPs (Infectious Respiratory Particles) is the new WHO terminology for pathogens that are transmitted through the air, dividing the process into: airborne transmission, which occurs when IRPs enter the respiratory tract through inhalation, over short or long distances; direct deposition, which occurs when IRPs follow a short-range, semi-balistic trajectory, depositing on the surface of the facial mucosa.

Below is a list of the documents:

- *Rapporti ISTISAN 13/4*
  "Monitoring strategies for Volatile Organic Compounds (VOCs) in indoor environment";
- *Rapporti ISTISAN 13/37*
  "Monitoring strategies for indoor air pollution of biological origin";
- *Rapporti ISTISAN 13/39*
  "Workshop. Indoor pollution issues: current situation in Italy. Istituto Superiore di Sanità. Rome, June 25, 2012. Atti";
- *Rapporti ISTISAN 15/4*
  "Workshop. Indoor air quality: current national and EU situation. The experience of the National Indoor Pollution Study Group. Istituto Superiore di Sanità. Rome, May 28, 2014. Atti";
- *Rapporti ISTISAN 15/5*
  "Monitoring strategies to determine the concentration of airborne asbestos and man-made glass fibres in indoor environments";
- *Rapporti ISTISAN 15/25*
  "Microclimatic parameters and indoor pollution";
- *Rapporti ISTISAN 16/15*
  "Presence of CO_2 and H_2S in indoor environments: current knowledge and literature";
- *Rapporti ISTISAN 16/16*
  "Monitoring strategies for PM_{10} and $PM_{2.5}$ in indoor environments: characterization of organic and inorganic micropollutants";
- *Rapporti ISTISAN 19/17*
  "Indoor air quality in healthcare facilities: monitoring strategies for chemical and biological pollutants";
- *Rapporti ISTISAN 20/3*
  "Indoor air quality in schools: monitoring strategies for chemical and biological pollutants".

In addition, leaflets and podcasts on the topic have been produced that can be downloaded from the institutional webpage https://www.iss.it/podcast:

— Leaflet entitled "The Air in Our Home".

— Leaflet entitled "Carbon monoxide poisoning. How to protect yourself".

— When there is a bad atmosphere at home - what to do (or not to do) to improve indoor air quality;

— Carbon monoxide, a silent, invisible and deadly gas. We learn how to avoid it.

Gaetano Settimo
GdS Indoor Pollution Coordinator

1. CHEMICAL POLLUTANTS: INDOOR AIR MONITORING STRATEGIES AND METHODS

In order to plan an office air quality monitoring plan, it is very useful to collect basic information on the building, the flat or part of the building or flat occupied/used for this activity, the location, the construction and plant components present in the different rooms.

The processing of this basic information is essential for:

- determine the type and number of pollutants to be searched for (e.g. in the specific case of offices serving craft/industrial production activities, it is necessary to gather information on the possible pollutants produced/derived by the activity itself);
- establish the operational mode with which monitoring is to be carried out (e.g. continuous or fractional detection);
- identifying official survey methodologies (e.g. ISO, EN, UNI, *Rapporti ISTISAN*), for the choice of instrumentation and appropriate sampling materials and for setting the correct duration to adopt (e.g. 30 minutes, 1 hour, 8 hours, 24 hours, etc.);
- finalize the specific objectives of the monitoring programme and for the choice of numerical reference values to be used for interpreting and evaluating the results (e.g. guide values, reference, action values, etc.) found in the WHO *air quality* documents or those found in the specific legislation of other European countries (Appendix A).

It should be remembered that the air monitoring strategy is drawn up and modulated on a case-by-case basis to respond to the objectives, specific aims and goals to be achieved by carrying out monitoring activities, taking into account the nature of the contaminants and their effects on health, the nature of exposure (constant, intermittent, occasional, etc.), the measurement methods and their characteristics, the timing, duration and frequency of measurements, the number of personnel involved, reference values, guide values, etc, to better collect, interpret, evaluate and communicate monitoring data and results (Fuselli, *et al.*, 2013; Settimo, 2015; Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020).

1.1. Basic information required indoor air monitoring

The variety of sources present in offices, together with the size of the rooms, spaces and areas, the type of activity carried out by the staff and the presence of technological systems result in the release of various types of chemical pollutants into the air and possible pollutants produced by transformation reactions. In order to identify and study the main chemical pollutants in indoor air, it is very useful to collect a series of elements and data characteristic of the office environments that are part of the building/apartment, along with basic information detailing the most significant aspects of the activities that take place there (e.g. office hours, frequency and density of use, opening hours to the public, organisational measures, type and method of running facilities, etc.).

In this regard, the information to be acquired from the Personnel Department, the technical offices, the HSE or HSO service, concerns:

– *Physical characteristics of the building/apartment*
  - location (e.g. urban, urban central, urban suburbs, urban industrial, rural) and orientation of the building north, south, east or west;
  - age (e.g. historic building, modern, etc.) and condition of the building (e.g. peeling paint, presence of dirt or debris, water damage stains on walls, ceiling panels, etc., moisture on surfaces (e.g. condensation on windows);
  - number and height of floors;
  - number of rooms per floor;
  - dimensions and layout of rooms and spaces;
  - presence of doors, windows, shape, size, position, opening mode e.g. single leaf, double leaf, sliding, tilt and turn, vasistas/bottom-hung, folding, orientation window and balcony openings: external, internal; north, south, east or west;
  - any adaptations, renovations or energy efficiency (e.g. change of windows, insulation, etc.);
  - presence of solar shading devices integrated in the facades (e.g. sunshades, brise-soleil, etc.), on the window frames (e.g. films, panels, shutters, etc.), or outside (e.g. awnings, sunshades, etc.). Solar shading devices must not obstruct the ventilation of windows and must not favour the inflow of hot air rising from the external wall;
  - characteristics and technical/safety data sheets of the materials used in walls, floors, parquet, wood, ceilings and for each of the other components making up the building, reports, material emission certifications and data on emissions of pollutants from paints, varnishes, etc. (e.g. UNI EN 717:1, UNI EN 16516, ISO 16000, etc.);
  - operation of combustion machines (e.g. gas, wood, pellets, propane, etc.);
  - presence and location of lifts or other facilities, presence of a garage in the building that may cause direct or indirect entry of pollutants from vehicle combustion engines through doors, staircases, windows, etc.;
  - presence of stairs;
  - position of radiators/heating elements; the presence and positioning of air conditioning systems such as heat pumps;
  - bathrooms location;
  - energy performance certification, energy performance certificate-APE, etc.

– *Air exchange*
  - how air exchange is carried out, the ventilation strategy (e.g. natural ventilation through window openings, doors and balconies or air treatment units/controlled mechanical ventilation HVAC);
  - in the case of natural air exchange, it is necessary to know the arrangement, number, shape, size (also with respect to the room) and opening mode of windows, balconies and doors, the opening period and duration in the different seasonal periods. As far as HVAC is concerned, it is of fundamental importance to acquire the technical report of the system containing distribution diagrams for the various rooms served;
  - frequency and calculation of air change-over volumes per hour (h^{-1}), L/s person or m^3/s (e.g. in the calculation it must be remembered that providing a low air change-over value per hour (h^{-1}) in a large room requires more air than a larger air change-over value per hour (h^{-1}) in a smaller room);
  - air flow measurements;
  - air flow distribution measurements;

- CO_2, relative humidity and temperature measurements;
- positioning of supply and extraction inlets in the different rooms;
- type of air filters (e.g. ISO ePM_{10}, ISO $ePM_{2.5}$, ISO ePM_1: UNI EN ISO 16890:2017);
- positioning of air filter systems in the HVAC;
- frequency of air filter replacement;
- type of operation/activation (typical days: weekdays, weekends - public holidays and other specific days, hours of operation per day);
- running registers;
- during cleaning activities characterized by emissions over a period of time;
- during sanitisation characterized by emissions over a period of time;
- purposes of maintenance work;
- intervention reports;
- periodicity and method of control of fixed and mobile air conditioning systems, HVAC and air flow measurement.

– *Furniture, draperies, upholstery, desks, chairs and other furniture*, characteristics and technical/safety data sheets of the materials used for walls, floors, ceilings, furniture including cupboards and bookcases along the walls, reports, material emission certifications and data on emissions of pollutants from furniture, desks, etc. (e.g. UNI EN 717:1, UNI EN 16516, ISO 16000, etc.).

– *Number of staff, main activities carried out, time spent on them, office equipment* used in the work environment (e.g. personal computers, printers, photocopiers[*]*, projectors, paper material, are a common part of office environments).

– *Working environment* (e.g. *open space*, single rooms, multiple workstations, meeting rooms, etc.) and conditions of use of the areas and premises (e.g. continuous activity, daytime, afternoon, public access, opening hours or reception of the public as well as customers and suppliers, etc.).

– *Organizational measures, activities and training programmes* on indoor air quality, required updates for staff, any recommendations produced on how to manage air changes in rooms, spaces and areas, good practices, effective information and promotion programmes on indoor air quality.

– *Cleaning in the different environments and related procedures, protocols, intervention methods, periodicity* (e.g. time of day when the activities are carried out, whether staff is present or not, as pollutants may be emitted/released); list of cleaning products used for the different surfaces (e.g. floors, marble, parquet, tables, chairs, bookcases, etc.), which contain in their composition VVOCs and VOCs that are released into the environment after application the concentrations of use, the sequence in which the products are used, the single or multiple daily passes, the tools used (e.g. type of broom, type of hoover, microfibre cloths), safety data sheet of the products used, technical notes, EU standards such as LCI, record of product condition checks, etc.; HVAC operation (e.g. feasibility of increasing air flow rates) or opening windows, during this activity, etc.

[*] During the functioning of photocopiers and laser printers, ozone, VOCs and PM may be produced. The quantities of ozone released during operation depend on the technical characteristics of the photocopier/printer, the operating time and the maintenance conditions of the devices. Another aspect to consider is the size of the environment/operating space.

- *Behavioural rules and other actions* that staff have acquired through the dedicated training plan and daily experience (e.g. how, when and how often windows, balconies and doors are opened according to the season, smoking ban extended to electronic cigarettes, greater attention to the use of air fresheners (which add VVOCs and VOCs to those already present in the air from other sources. The natural origin of these VVOCs and VOCs does not mean that they have no health effects. In fact, the toxicity of a substance, whether it is of natural or synthetic origin, is intrinsically linked to its chemical nature and not to its origin), cosmetics, times of the day in which to clean the relaxation area and specific methods to be adopted in this phase to increase air changes (e.g. frequency and duration of opening windows and balconies, extractor hood on, increased HVAC air flow rate, etc.).
- *Air purifiers also known as air purifiers*[*], fixed or portable devices (PAC) that use different technologies and mechanisms of action depending on the nature of the chemical and biological pollutants they act on. It is necessary to acquire the report and technical evaluation that led to the choice of the air purifier, the technology and main characteristics, possible releases of reactive and hazardous by-products, flow rate of clean air delivered CADR, positioning, room volume, number of people, activity carried out, mode and duration of operation, performance measurement standards, training, cost of filters and adsorbent materials, frequency and cost of cleaning, frequency and cost of maintenance (to prevent their efficiency from decreasing over time), noise, etc.
- *Procedures and frequency of pest control* (e.g. presence of signs of infestations such as cockroaches, rodents, pigeons, etc.).

In cases where further information is needed, it may be useful to complete survey questionnaires similar to the one proposed in Appendix B. It contains a list of items to be selected and filled in by the technicians, possibly supplemented with specific information to highlight the characteristics of the offices, age of the building, location, design of the rooms/spaces, operating methods of the users, presence of customers, visitors, operators of external companies, level of energy efficiency, air exchange-ventilation strategy, etc.

The information gathered will make it possible, when drawing up the monitoring plan, to guide subsequent choices regarding the pollutants to be searched for, the duration of sampling (hourly, daily, weekly, etc.), the sampling methods (active or passive), the choice of appropriate solid adsorbent materials (activated carbon, silica gel, etc.), the preliminary treatment of the samples and the subsequent chemical analysis procedures to be carried out in the laboratory (an example is given in Appendix C).

1.2. Planning of indoor air monitoring activities in offices

In general, the monitoring of chemical pollutants in indoor air is carried out by senior management to ensure the effectiveness of the health protection measures and procedures adopted to guarantee the air quality and health of staff and the organization. In this process, activities are planned and carried out in different office environments and spaces (e.g., office rooms, studies,

[*] See Annex A2 "Are mobile air purifiers/filters really a solution?" of the *Interim Technical Note. CO_2 monitoring for prevention and management in* indoor *environments in relation to the transmission of SARS-CoV-2 virus infection* published by the Istituto Superiore di Sanità in 2022.

open spaces, meeting rooms, training rooms, archives, reception/desks, reception areas, common areas, relaxation rooms, or other specific areas of the office, etc.) for the following purposes:

- know the levels of pollutant concentration in specific environments, spaces, areas, or rooms of the building during work activities and have a representative picture;
- understand changes in indoor air quality and implement any necessary improvements in order to anticipate health risks;
- Assess individual and collective human exposure levels to indoor pollutants, taking into account the tasks performed, the methods, duration, and frequency (e.g., single exposure, repeated exposure, etc.), the presence of additional unusual activities to which personnel are subject, and especially groups of particularly vulnerable individuals (e.g., staff with specific needs, users, customers, and suppliers, etc.). If it is considered too high compared to the references used, action must be taken to reduce it;
- verify and confirm over time compliance with the indoor air quality values identified by the employer or established by the competent authorities in relation to the permanence and vulnerability of personnel;
- contribute to identifying and reducing, as far as possible, the emission levels of specific indoor sources (site-specific, ubiquitous, dominant, minority, etc.), in certain environments, areas, or premises during the performance of activities in the presence of staff, users, customers, and suppliers and in the absence of staff, users, customers, and suppliers;
- knowing the variations over time in the concentrations of pollutants in indoor air in certain areas or rooms in the presence of staff, users, customers, and suppliers and in the absence of staff, users, customers, and suppliers, in order to anticipate health risks;
- timely and punctual verification of indoor air quality in terms of space and time, aimed at satisfying requests or resolving issues brought to attention by staff, users, customers and suppliers with specific needs (e.g. allergy sufferers, asthmatics, etc.);
- verification and assessment of indoor air quality in specific areas and/or rooms and in adjacent areas during or after cleaning, maintenance or renovation work that may involve emissions of PM, VVOCs, VOCs and other substances, in order to protect staff, users, customers and suppliers. In this case, it is necessary to obtain a detailed description of the type of intervention/work carried out, the premises concerned, the technical data sheets, safety data sheets of the products used, etc.;
- assessment of the impact and effectiveness of the preventive and remedial measures identified and adopted in the various areas;
- know the levels of pollutant concentration in particular events or emergencies (e.g. exceptional external pollution linked to fires, accidents at production sites near the office, etc.);
- evaluate data sharing by explaining the main results.

In offices and other similar locations (rooms, studies, *open spaces*, meeting rooms, training rooms, reception/welcome desks, common areas, archives and executive areas dedicated to management), areas can be identified:

- where staff are present for the entire working day (approximately 8 hours a day, 5 days a week);
- where staff stay for only short periods (one, two or three days) during the week;

- where public access and presence are limited to periods when the premises are open to the public or when users, customers and suppliers are received (one or more hours/periods/days) during the week;
- where staff are only present for short periods (one or more hours/days) during the week;
- where staff are only required to be present during the day or afternoon, or both.

The chemical pollutants that may be of greatest interest are those derived from the basic information collected (*see* Appendix B) and from the conditions of use of the various office environments/spaces, or more generally those already identified by the WHO and the ISS GdS Indoor Pollution in the various documents produced, which offer a broad overview (Settimo, 2015; Settimo *et al*., 2016; Settimo *et al*., 2019; Settimo *et al*., 2020a; Settimo *et al*., 2020b; Settimo *et al*., 2023), such as:

- VVOCs and VOCs, which play a crucial role in determining indoor air quality, whose effects on health are very varied and can be more or less serious; some are classified by the *International Agency for Research on Cancer* (IARC) as Group 1 carcinogens (known to be carcinogenic to humans) (e.g. benzene, formaldehyde and trichloroethylene), Group 2A carcinogens (probably carcinogenic to humans) (e.g. tetrachloroethylene, dichloromethane, styrene);
- $PM_{2.5}$, corresponding to the respirable fraction, and PM_{10}, corresponding to the thoracic fraction of particulate matter (in this case, mass concentration is the minimum approach for assessing indoor air quality): classified by IARC as Group 1 carcinogens (known to be carcinogenic to humans);
- SVOCs, including PAH, such as benzo[a]pyrene + other selected PAH based on carcinogenic properties in PM_{10} or $PM_{2.5}$, classified as Group 1 (known human carcinogen), Group 2A (probable human carcinogen) and Group 2B (possible human carcinogen) according to IARC. In some specific cases, it may also be useful to determine other SVOCs such as PCDD, PCDF and PCB expressed in terms of toxic equivalency (WHO-TE) classified as Group 1 (known human carcinogen), Group 2A (probable human carcinogen) and Group 3 (not classifiable as to carcinogenicity to humans);
- metals (e.g. arsenic, cadmium, nickel, lead, etc.) classified by IARC as Group 1 carcinogens (known to be carcinogenic to humans) (e.g. arsenic, cadmium, nickel) and Group 2B carcinogens (probably carcinogenic to humans) (e.g. lead).

VVOCs and VOCs can be sampled using different types of systems, depending on the specific purpose of the investigation (Fuselli, *et al*., 2013, Settimo *et al*., 2019; Settimo *et al*., 2020a); these are divided into:

- *active samplers* where air sampling, which must be performed at low flow rates, is carried out using pumps with appropriately calibrated suction flow rates (e.g. mL/min) and tubes/vials filled with specific adsorbent materials, generally activated carbon, silica gel coated with reagents and/or stabilisers, or polymer-type systems. Various types of tubes/vials of various sizes are available on the market, containing varying quantities of adsorbent material (e.g. *jumbo*, *medium* and *large*) with different load capacities, to be used according to the expected average indoor environmental concentration level. These sampling systems take up very little space, but the acoustic impact of the pump, which is often not negligible, must be taken into account, even though they can be housed in special soundproof cases, and their visual impact is very limited. They may need to be connected to the mains electricity supply;
- *passive samplers,* e.g. systems based on the phenomenon of gas diffusion; in this case, cartridges or devices made of specific adsorbent materials, generally activated carbon and

silica gel coated with reagents and/or stabilisers, are used. The footprint of these sampling systems is negligible, and they have no acoustic impact and very limited visual impact. They do not need to be connected to the mains electricity supply. However, they have the disadvantage of requiring long sampling times.

In both active and passive samplers, the choice of capture substrate is crucial for efficient and selective sampling of the analytes of interest; some capture substrates are non-analyte-specific, while others, especially derivatised ones, are analyte-specific. For the correct choice of adsorbent materials to be used for the detection of VVOCs and VOCs, please refer to Appendix C of the *Rapporto ISTISAN* 13/4 (Fuselli *et al*., 2013), which contains a list of the main solid adsorbent materials.

Another type of sampler that can be used for VVOCs and VOCs is the *canister*, e.g. glass bottles, cylinders, or stainless-steel cylinders with passivated walls and non-hermetic closures, in which a vacuum can be created by connecting them to pumps; by adjusting the air inlet flow, the devices can be used for both instantaneous and short- to long-term sampling. *Canisters* involve sampling small volumes of air, which allows the level of environmental contamination to be "photographed" during the sampling period. The maximum volume that can be sampled with these systems corresponds to the volume of the *canister*. *Canisters* take up very little space and have no acoustic impact; they do not need to be connected to the mains. Alternatively, inflatable bags made of inert material can be used, in which the air is sampled inside the bags using pumps with a suitably calibrated suction flow.

The number of VVOCs and VOCs to be included in the monitoring plan may vary significantly based on the basic information acquired, for example, on the materials and specific characteristics of the construction, furnishings, finishes, cleaning, technical and safety data sheets of the products present, methods of use and occupation of the environments, operating conditions, activities and tasks performed by staff, users, as well as the presence of customers and suppliers, any reports or complaints collected and, above all, the purpose of the monitoring activity programme developed (*see* Appendix B).

PM_{10} and $PM_{2.5}$ can be sampled using active sampling systems equipped with a selective sampling head compliant with UNI EN 12341, capable of selecting the desired size fraction by inertial impact. The air sample is drawn through the PM_{10} or $PM_{2.5}$ sampling head and collected on filters consisting of a porous substrate made of fibreglass, quartz or polytetrafluoroethylene (PTFE); the concentration of PM_{10} or $PM_{2.5}$ is determined gravimetrically. The physical size and acoustic impact of these samplers are often not negligible (e.g., it must be assessed whether it is possible to position the pump outside the environment under investigation) and may require connection to the mains electricity supply. PM_{10} and $PM_{2.5}$ collected on filters can be used for the subsequent characterisation of organic (e.g. PAH, PCDD/F, PCB) and inorganic (e.g. metals) micropollutants (Settimo *et al*., 2016; Settimo *et al*., 2019; Settimo *et al*., 2020a; Settimo *et al*., 2020b). For these pollutants (organic and inorganic) to be included in the monitoring plan, the considerations already made on VVOCs and VOCs apply.

To know the qualitative level of PM_{10} and $PM_{2.5}$ concentration, real-time monitoring using automatic instruments with high temporal resolution, which measure the optical diameter instead of the aerodynamic diameter and perform both the sampling phase and the subsequent concentration measurement phase, can also carry out (Settimo *et al*., 2016). These instruments also provide a numerical count of particles, such as the number of particles/cm³ (UNI EN ISO 16000:42). This type of detection can be particularly advantageous for studying the spatial-temporal trend of PM in the environment under study. The physical size and acoustic impact of these instruments are often not negligible, so silent samplers must be chosen, and they may need to be connected to the mains.

Table 1 lists the ISO 16000 Indoor Air methods, adopted by CEN and partly by UNI, and the other UNI and CEN methods used to select sampling points and analytical techniques to be applied for determining the concentrations of chemical pollutants. Alongside ISO standards, documents drawn up by the ISS GdS Indoor Pollution can be used as references:

- *Rapporti ISTISAN 13/4*
  "Monitoring strategies for Volatile Organic Compounds (VOCs) in indoor environment"
- *Rapporti ISTISAN 13/37*
  "Monitoring strategies for indoor air pollution of biological origin"
- *Rapporti ISTISAN 15/25*
  "Microclimatic parameters and indoor pollution"
- *Rapporti ISTISAN 16/16*
  "Monitoring strategies for PM_{10} and $PM_{2.5}$ in indoor environments: characterization of organic and inorganic micropollutants".

These documents from the ISS GdS Indoor Pollution form the basis of the UNI 11976:2025 standard "Ergonomics of the physical environment. Tools for assessing indoor air quality". The monitoring plan is completed by the continuous long-term measurement and recording of CO_2 and the main microclimatic parameters such as temperature, relative humidity and air velocity.

The main purpose of measuring CO_2 concentrations is to identify environments with poor air exchange and overcrowding, promoting and implementing daily operating procedures to optimise outdoor air exchange either naturally or using mechanical HVAC systems (e.g. frequency and duration of opening doors, windows and balconies, operation and running times of the ventilation system, air flow control, air flow rates, etc.), or by using both methods, to implement effective improvement and control programmes in various areas with a unified vision, before situations of discomfort and poor work productivity arise (Wyron, 2004; Felguerais *et al*., 2023 Morantes *et al*., 2025), symptoms and health problems that commonly fall under those defined as *Sick Building Syndrome* (SBS) and *Building Related Illnesses* (BRI), due to staff exposure to various chemical agents (e.g. VVOCs, VOCs, PM_{10}, $PM_{2.5}$, SVOCs, metals, odours), biological agents (e.g. bacteria, viruses, allergens, filamentous fungi-moulds), physical agents (radon), and humidity and temperature levels.

Some studies on the SARS-CoV-2 virus and its variants highlight the role of CO_2 concentration on the viability and aerostability of bioaerosols, including viral ones, by preserving the pH of the surrounding fluid envelope, further increasing the risk of transmission.

It should be remembered that, in the case of viral bioaerosols, there are other factors that influence the risk of airborne transmission and that this process is complex (the amount of virus present in the air is not necessarily proportional to CO_2 concentrations), such as the type of pathogen, respiratory activity, silent vocalisation, speaking, shouting, singing, etc., with differences in *aerosol* emissions from person to person (e.g. how much infectious virus is exhaled - emission rate), what happens to the virus once it is in the air and how much virus is needed to cause infection, the length of time it remains in the air during the day, the level of occupancy over time, the level of air exchange over time, the volume of the environment, and the type of activity[*].

[*] For the correct use and interpretation of CO_2 concentration measurements, it is useful to apply the information in the document *Interim Technical Note. CO_2 monitoring for prevention and management in indoor environments in relation to the transmission of SARS-CoV-2 virus infection* published by the Istituto Superiore di Sanità in 2022.

Table 1. UNI EN ISO Standards for indoor environments specific to VVOCs, VOCs, SVOCs, PM_{10}, $PM_{2.5}$ pollutants, particle number and CO_2

Standard	Title
UNI EN ISO 16000	Indoor air
Part 1	General aspect of sampling strategy
Part 2	Sampling strategy for formaldehyde
Part 3	Determination of formaldehyde and other carbonyl compounds – active sampling method
Part 4	Determination of formaldehyde - Diffusive sampling method
Part 5	Sampling strategy for volatile organic compounds (VOCs)
Part 6	Determination of organic compounds (VVOCs, VOCs, SVOCs) in indoor air and in the test chamber by active sampling on sorbent tubes, thermal desorption and gas chromatography using MS or MS FID.
Part 12	Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)
Part 13	Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls and polychlorinated dibenzo-p-dioxins/dibenzofurans - Collection on sorbent-backed filters with high resolution gas chromatographic/mass spectrometric analysis
Part 14	Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) – Extraction, clean up, and analysis by high-resolutions gas chromatographic and mass spectrometric analysis
Part 26	Sampling strategy for carbon dioxide (CO_2)
Part 29	Test methods for VOC detectors
Part 32	Investigation of buildings for the occurrence of pollutants
Part 37	Measurement of $PM_{2.5}$ mass concentration
Part 40	Indoor air quality management system
Part 41	Assessment and classification
Part 42	Measurement of the particle number concentration by condensation particle counters
UNI EN ISO 16017	Indoor, ambient and workplace air – sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption capillary gas chromatography
Part 1	Pumped sampling
Part 2	Diffusive sampling
UNI EN 12341	Ambient air – Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter
UNI EN 16450	Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}, $PM_{2.5}$)
UNI EN 14902	Ambient air quality – Standard method for measurement of Pb, Cd, As and Ni in the PM_{10} fraction of suspended particulate matter
UNI EN 15549	Air quality - Standard method for the measurement of concentration of benzo[a]pyrene in ambient air
UNI 11976	Ergonomics of the physical environment. Tools for assessing indoor air quality

The parts of ISO 16000 not yet implemented in Italy by UNI are shown in grey.

Therefore, the measurement of CO_2 concentration must serve as an "indicator" of pollutant accumulation phenomena within environments, spaces or areas (which depend on the context and cannot therefore be generalised because they are not always proportional to pollutant concentrations), and depend on the density and duration of stay and occupation, the size and volume of indoor environments and spaces, the level of activity and conditions of use, the characteristics of staff and customers, which in offices open to the public can be dynamic and high, the frequency, duration and method of partial or complete opening of doors, windows, balconies and air vents, the operating conditions, flow rates and operating times of the HVAC ventilation system (e.g.

continuous, intermittent or at partial power) and the distribution of air flows, in order to take measures to constantly improve the situation of poor or inadequate air exchange.

CO_2 concentrations typically fluctuate over the course of the working day, with levels rising during periods of work activity and falling during breaks. Typically, at the start of the day when the building is unoccupied, concentrations will be around 400 ppmv (often measured, although actual values vary depending on the type of building and the size of the rooms). This value may vary depending on the area/location, and may often be higher, while with the arrival of staff, members of the public and customers, the level will rise rapidly until, after a certain period of occupancy or once a "steady state" has been reached, it exceeds 1000 ppmv. This trend is closely related to the volume of indoor environments and spaces, the number of occupants, and CO_2 generation rates, and is balanced by air exchange. CO_2 concentrations during periods of non-occupation may be slower and, in some cases, minimal due to closed windows and the airtight nature of new buildings. CO_2 concentrations can vary significantly depending on the season, with higher average concentrations during the winter season.

The ISS document "Interim technical note. Monitoring of CO_2 for prevention and management in indoor environments in relation to the transmission of SARS-CoV-2 virus infection" recommends using a maximum CO_2 concentration of 1000 ppmv (approximately 600 ppmv higher than the average CO_2 value in ambient air-outdoors, which ranges between 400 and 500 ppmv with hourly, daily and seasonal variations); This value is valid as an "initial management approach and indicator of pollutant accumulation", recognising the "limitations" of using this value, as CO_2 concentrations are not correlated with and are not indicators of other pollutants. The adoption of this reference value must be followed by a series of actions on specific and significant aspects in order to identify the essential improvement measures with the dilution/reduction of CO_2 concentrations (e.g. occupancy density, type of activity carried out, characteristics of the occupants, frequency of air exchange through the entry of external air obtained naturally or mechanically, etc.), relative air humidity and pollutants accumulated in the air such as VVOCs, VOCs, PM_{10} $PM_{2.5}$, odours, bioaerosols that can carry bacteria, viruses, allergens, filamentous fungi [moulds]), present in all environments, spaces and areas of offices (Allen *et al*., 2016; Cedeño Laurent *et al*., 2021).

Therefore, in indoor environments, it is not correct to use the VLEP of 5000 ppmv specified in Annex XXXVIII of Legislative Decree 81/2008 to assess CO_2 concentrations.

In the case of air replacement systems, whose main task is to renew the air in rooms by bringing in air from outside, the available solutions are linked to the way in which the ventilation is designed and constructed, which can be of the following types:

- *natural*
  (e.g. by opening windows, balconies, doors and air vents that can be opened partially or completely and adjusted according to daily weather conditions) caused by wind pressure differences and "thermal buoyancy";
- *forced or mechanically controlled*
  (e.g. through systems, motors/fans and operating conditions of ventilation units and systems such as flow rates, flow distribution in ducts and grilles, diffusers, vents positioned on the ceiling, walls or floor throughout the environment/space, air filtration, ventilation system operating times, when the office is in use/not in use, size of environments/spaces, occupancy density, room volumes, filtration, etc.).

Ventilation strategies must be adapted and flexible to the needs of staff, the practical use of the rooms (e.g. number of sources, volumes, occupancy density, type of activity, occupancy and non-occupancy times, behaviour, age of the building, presence of windows, balconies, level of energy efficiency of the building, etc.), climatic conditions, seasonal flu periods and emergency events related to exceptional external pollution situations, fires, accidents at production sites. These ventilation strategies allow air exchange to be balanced with thermal comfort and energy

consumption. In the case of offices equipped with specific HVAC ventilation systems, the systems must be designed and sized in accordance with the provisions of UNI EN 16798 or the guidelines "Microclimate, ventilation and lighting in the workplace. Standard requirements. Operational and design guidelines" (Technical Coordination for Workplace Safety of the Regions and Autonomous Provinces, 2006). The measurement of air temperature and relative humidity, in addition to meeting physiological requirements, must also be carried out due to the influence these parameters can have in promoting the release of substances from materials and products, causing mould growth or damage to material surfaces, reducing their durability and causing health problems (Santarsiero *et al*., 2015; Salthammer *et al*., 2022). The reference values for temperatures (°C) and relative humidity (%) for the winter and summer seasons are contained in Table 2.5.2. of the Guidelines "Microclimate, ventilation and lighting in the workplace. Standard requirements. Operational and design guidelines" (Technical Coordination for Workplace Safety of the Regions and Autonomous Provinces, 2006).

1.3. Objectives, methods, timing and frequency of indoor air monitoring

A distinction that must be made right from the start in the planning, selection and duration of air monitoring is the purpose, the aim, the answers that are sought or the objective that is to be achieved by conducting sampling in a specific building or parts of a building used as offices, rooms or areas. If the objective of air monitoring is to acquire preliminary data, the minimum duration of sampling must be at least one week in the warm season and one week in the cold season. If, on the other hand, monitoring is carried out to make comparisons or checks for compliance (e.g. reference values, action, etc.), the minimum duration of sampling activities must be at least two weeks in the warm season and two weeks in the cold season (Fuselli *et al*., 2013; Settimo *et al*., 2016; Settimo *et al*., 2019; Settimo *et al*., 2020a).

In general terms, sampling activities must make it possible to determine the concentration of pollutants in offices, rooms, studies, *open spaces*, meeting rooms, training rooms, reception/welcome desks, common areas, relaxation rooms, archives or other specific areas of the office, etc., in order to then carry out:

- comparison with guideline values, reference values, action values established by the competent authorities (e.g. air quality standards in national and European legislation by the Local Health Authority, LHA), or recommended by international or national bodies (e.g. WHO Air quality guidelines, volumes of the *Rapporti ISTISAN* series edited by the GdS-ISS Indoor Pollution), or identified by the employer (e.g. other references identified for management purposes). In this case, the reasons for the choice of numerical value must be documented (Settimo, 2012; Settimo, 2013, Settimo, 2015; Settimo, 2017; Settimo *et al*., 2016; Settimo *et al*., 2019; Settimo *et al*., 2020a; Settimo *et al*., 2020b; Settimo *et al*., 2023);
- assessment of staff exposure to substances presents in the air with respect to the identified reference values (see previous point) and whether action is needed to reduce it;
- identification of possible actions to be implemented to reduce and/or limit personal exposure over time, and ensure compliance with guideline values, reference values, action values, etc. (Settimo *et al.*, 2020b; Settimo *et al.*, 2023);

- identification, as far as possible, of actions to be implemented over time to resolve any issues in order to anticipate, avoid or prevent the recurrence of risks and problems and improve the working environment (Mendell *et al.*, 2023);
- in-depth analysis or completion of the results of surveys carried out in previous years in the same offices, environments, studies, *open spaces*, meeting rooms, training rooms, reception areas/desks or other specific areas of the office, etc., in order to understand the evolution of indoor air quality over time;
- assessment of progress, or identification and acquisition of new knowledge, conducting targeted and/or more comprehensive thematic investigations, e.g. characterising certain phases or moments of the working day in which the performance of tasks or actions by staff may result in the activation and/or presence of certain types of sources, proposing, suggesting and implementing the correct dissemination of assessment protocols and, above all, promoting an improvement in the prevention and protection measures for staff who frequent the office (Campagnolo *et al.*, 2017; Wallenius *et al.*,2022; Morantes *et al.,* 2025).

Consequently, monitoring strategies must be developed on a case-by-case basis according to the purpose of the monitoring programme, with a focus on the pollutants likely to be present and including short-term, fractional or continuous sampling that takes into account staff work activities, operating methods, length of stay, occupancy status and conditions of use (e.g. room sharing, open space used by several people at the same time, meeting rooms, training rooms, access and presence of the public and visitors), the state of non-occupation, the presence of the public, external contractors engaged in daily cleaning, plant upgrading, energy efficiency or general maintenance to ensure the initial and ongoing performance of such technological systems, activities carried out by suppliers, etc. The duration of the sampling must take into account the various factors mentioned above that influence the representativeness of the monitoring itself.

If the monitoring activity is intended to respond to the first case, it is necessary to carry out measurements of the same duration as the guideline/reference value recommended, for example, by the WHO, the LHA, the ISS Indoor Pollution GdS or the reference or action values identified by the employer (e.g. if WHO guideline values are used for PM_{10}, the duration must be 24 hours; for toluene, the duration must be weekly; for formaldehyde, the duration must be 30 minutes; or if the reference in French legislation is to be used, for example (Settimo *et al*., 2020a; Settimo *et al*., 2020b; Settimo *et al*., 2023), the duration must be weekly, or it is possible to use references from other countries (*see* Appendix A). If the aim is to determine the concentration of pollutants at a specific moment or during a specific activity/start-up (e.g. maximum concentration where the sampling duration is between a few minutes and a couple of hours), short-term measurements can be taken to highlight the presence or use of specific sources, but it must be ensured that the actual conditions of use of rooms, studies, *open spaces*, meeting rooms, training rooms, reception areas/desks, common areas, relaxation rooms, archives, etc., or other specific areas of the office are respected throughout the sampling period, for example, the opening of windows, balconies and doors (it is preferable to open windows facing the interior or unexposed facades and those furthest from busy roads), switching the HVAC system on/off, occupancy levels, etc.

If, on the other hand, you want to know the possible role, contribution or influence on the concentration levels of chemical pollutants due to the use of HVAC systems, it may be useful to implement a monitoring strategy in three different operating states of the HVAC and occupancy/use of rooms, studies, open spaces, meeting rooms, training rooms, reception/reception desk areas, common areas, relaxation rooms, archives, etc. (e.g. HVAC off and no activity, HVAC on and no activity, HVAC on and normal activities taking place).

Based on the above, the main objectives of monitoring chemical pollutants in office environments (e.g. rooms, *open spaces*, studies, meeting rooms, training rooms, reception

areas/desks, common areas, relaxation rooms, archives or other specific areas of the office, etc.) are those that allow for:

- promote and implement an appropriate strategy for primary health prevention and exposure reduction, with particular reference to vulnerable personnel in relation to the duration and frequency of their stay;
- identify possible sources of indoor air pollution during use and when staff are present (e.g. related to building materials, flooring, technical furnishings, fabrics, equipment and the use of appliances, cleaning and detergent products, use of ventilation and air conditioning systems, under normal operating conditions or during public access or in the event of malfunctions, incorrect printer location, etc.);
- know the concentration levels of chemical pollutants in different environments and compare them with guideline values, reference values, action values, etc.;
- verify the correct functioning, operation, management, maintenance, and cleaning of technological ventilation systems (HVAC) and the specific air exchange rates required for different environments, spaces, areas, or rooms;
- verify the correct cleaning procedures for the premises, as per protocol and dedicated training, in order to implement behavioural models (e.g. from the timing of opening windows, balconies and doors to adjusting air flow rates, closing vents and diffusers, or management measures to prevent incorrect use, incorrect applications or sequences of steps);
- identify actions and measures to be taken to resolve any non-conformities.

In office environments where activity continues for several days, daily sampling can therefore be planned based on the actual use of the premises for PM_{10} and $PM_{2.5}$, while for VVOCs, VOCs, measurements can be taken weekly or based on the actual use of the premises during work activities and always based on the duration of time associated with the guideline or reference value that has already been identified and is to be used (e.g. from the WHO or present in the ISS Indoor Pollution Guidelines or in the legislation and guidance documents of other European countries or in national legislation on ambient air quality) (Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020a; Settimo *et al.*, 2020b; Settimo *et al.*, 2023). If the sampling duration is shorter/longer than that specified by the WHO for the guideline value, or than the reference value indicated in the legislation of other European countries for the expected concentration value, the measurement is only an indicative-operational reference (Settimo, 2013; Settimo, 2015; Settimo, 2017; Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020a) (Appendix A).

In all cases, for the same integration period chosen on the basis of the guideline value or, in general, the concentration value taken as a reference, it may be appropriate to divide the samples into shorter time intervals according to the hours of activity and daily occupancy. For example, in the case of office environments where daily use is (e.g. 8 a.m.-4 p.m.), it is necessary to obtain sampling times that are representative of staff presence times and periods of non-use or inactivity (e.g. activity hours 8 a.m.-4 p.m. and non-activity hours 4 p.m.-8 a.m.) and, finally, any continuous sampling for 24 hours. Even if occupation occurs during certain times of the day, it is necessary to organize for fractional sampling, identifying and implementing representative samples of the various uses, covering the time spent by staff on site, but also periods of non-use or periods free from activity (e.g. activity hours 9 a.m.-2 p.m. and non-activity hours 2 p.m.-9 a.m.) and, finally, any continuous sampling for 24 hours.

To give an example, in the case of PM_{10} or $PM_{2.5}$ sampling, where office activities are carried out every day of the week at set times, a series of measurements must be planned to cover the hours when staff are present (e.g. 8 a.m.-4 p.m.) and measurements covering the periods of inactivity, when there is no staff present 24 hours a day (e.g. 2 p.m.-8 a.m.). Once the sampling

period is over, the PM_{10} or $PM_{2.5}$ collection filter used during the active period is removed from the sampling line and replaced with the one used during the complementary inactive period when no personnel are present. The rotation filters are placed in special plastic containers and stored in the refrigerator until they are reused the following day, until the weekly cycle of activities is completed. For PM_{10} or $PM_{2.5}$ filters that must then undergo speciation analysis for PAH content, the maximum sampling period for the two filters (activity filter+non-activity filter) must not exceed 24 hours.

The measurement intervals and their combination make it possible to classify an average trend of pollutants in the environments examined and to describe, as representatively as possible, the conditions of use of the environments, the behaviour of the personnel within them, the number of people/occupancy status, use of windows and/or operation of ventilation systems, cleaning methods, etc. A similar criterion can be used for sampling VVOCs and VOCs, both in the case of active and passive sampling. In this regard, it is important to strictly adhere to the sampling and analysis methods, which also indicate how to store the sample to ensure its stability/integrity until analysis.

For areas equipped with HVAC technological systems, when determining the duration of the measurement, it is advisable to take a quantity of air less than 10% of the volume introduced into the rooms for ventilation during the same period of time for each hour of the measurement interval (e.g. 8 a.m.-2 p.m. or 2 p.m.-8 a.m.). When the ventilation speed cannot be measured or the information is not available, the hourly sampling volume must be adjusted so that it is less than 10% of the room volume (Fuselli *et al.*, 2013; Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020a).

1.4. Choosing pick-up points for monitoring and positioning detection instrumentation

In all office environments, the choice of sampling points where instruments and devices for determining the concentration of pollutants in the air are to be placed is of great importance both for assessing the quality of environmental data and for formulating and implementing appropriate primary prevention measures for office staff.

Therefore, this choice must be made with particular attention to:

- characteristics and dimensions of rooms, *open spaces*, studies, meeting rooms, training rooms, reception area/reception desk, common areas, relaxation rooms and the environments examined;
- workstation positioning;
- management and description of dwell times (of staff, customers, the public, external operators and cleaners, etc.);
- specific conditions of use (activity carried out, behaviour, number of people/occupancy status, use of windows and/or operation of ventilation systems, presence of air purifiers[*], etc.).

In office buildings, it is not necessary to investigate all rooms, but homogeneous areas that are most representative of the objectives of the survey programme can be identified.

When choosing the sampling point for an environment under study or other strategic environmental locations (near desks), if this proves difficult to achieve, the point must be at least

[*] See Annex "A2. Are mobile air purifiers/filters really a solution?" of the *Interim Technical Note. CO_2 monitoring for prevention and management in* indoor *environments in relation to the transmission of SARS-CoV-2 virus infection* published by the Istituto Superiore di Sanità in 2022.

1 m from the nearest wall and at a height of approximately 1.5 m from the floor, as specified in UNI EN ISO 16000-1 and in the *Rapporti ISTISAN* of the GdS-ISS that regulate the matter (Fuselli *et al.*, 2013; Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020a). In the specific case of office environments, where staff work and spend most of their time sitting at their desks, it may be useful to position the sampler at a height of between 1.2 and 1.5 metres from the floor (Fuselli *et al.*, 2013; Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020a).

Furthermore, it is not advisable to place samplers in areas of rooms, studies, open spaces, meeting rooms, training rooms, reception areas/desks and common areas or other specific areas of the office that are subject to natural or forced air currents from walls or ceilings (e.g. HVAC supply vents, split air conditioning systems, heat pumps) that can channel air in specific directions, or near entrance doors, or in direct sunlight (e.g. near windows) or that house heat sources (e.g. near fixed or portable radiators, split air conditioning systems, fixed or portable heat pumps, spotlights, etc.) so as not to compromise the significance of the measurements or the entire detection process for temperature gradients, fluid dynamic flows and concentrations generated within indoor spaces.

1.5. Contemporary measurements in outdoor ambient air

In order to assess the contribution of indoor sources to the concentration levels of the main chemical pollutants (e.g. VVOCs, VOCs, PM_{10}, $PM_{2.5}$, SVOCs, etc.), it is necessary to simultaneously determine the concentrations of these pollutants in the outdoor air (outside the offices examined). In fact, knowledge of the concentrations of the pollutants of interest in the outdoor air allows us to weigh and estimate the pollution situation in the local context of the areas studied, in particular to identify any contributions to indoor concentrations of atmospheric pollutants due to the entry of outdoor air and therefore to air exchange, whether natural or forced (UNI EN ISO 16000-1:2006; Fuselli *et al.*, 2013; Settimo *et al.*, 2016; Settimo *et al.*, 2019; Settimo *et al.*, 2020a).

Sampling of outdoor ambient air should preferably be carried out in the vicinity of the rooms in the building under study, but in any case, no less than 1 m from the external wall and at a height comparable to that of the sampler inside the rooms, studies, open spaces, meeting rooms or areas under examination. If the rooms are equipped with centralised HVAC or air conditioning systems, in order to correctly assess the contribution of outdoor air, a second sampler must be positioned at the same time as the measurements, near the external air intake of the system.

The sampling intervals for outdoor air must be the same as those used for indoor monitoring.

1.6. Activities to be carried out before starting indoor air monitoring

To create the best conditions for effective monitoring, it is necessary to ventilate the various rooms before proceeding with the detection of pollutants. This action allows the removal of substances that have already accumulated in rooms, studies, *open spaces*, meeting rooms, and/or other areas under study, based on their previous use and the continuous or occasional presence of staff, customers, and visitors in numbers and with characteristics that are undefined at that time.

In general, the instructions on how to carry out this preventive action depend on the different types of air exchange and ventilation systems installed in the rooms. If the air exchange and ventilation systems are natural, it is advisable to thoroughly ventilate the rooms, studies, *open*

spaces, meeting rooms or other areas for at least 15 minutes, keeping windows and doors open (preferably windows furthest from main traffic routes facing the interior or unexposed facades), and if possible, also those in the corridor, in the absence of any human activity or presence. After this period of time, the doors and windows must be closed again for about 8 hours (preferably for a whole night) and only then can sampling and measurements begin, keeping the doors and windows of the room closed (this represents the blank data).

Finally, the measures must be repeated, in the same manner, during normal office use with staff present.

If, on the other hand, the rooms in the building are equipped with HVAC systems or fixed or portable air conditioning or heating systems (e.g. heat pumps, radiators, split systems, portable heaters or stoves, wall fans, etc.), these systems will be kept on according to normal operating procedures for at least 3 hours before operating in the absence of any human activity or presence, and only then can sampling begin (this represents the blank data). The measurement will then be repeated, in the same manner, during normal use of the area and/or room with the presence/stay of personnel.

2. BIOLOGICAL POLLUTANTS: INDOOR AIR MONITORING STRATEGIES AND METHODS

Indoor environments, such as offices, are complex contexts from the point of view of health risk assessment, as they can host a diverse population consisting of staff, professionals and regular users, people of different age groups, with different sensitivities and health conditions, as well as occasional visitors. Although the term "indoor pollution" commonly evokes chemical contamination, it is also essential to consider the implications of the presence of airborne biological agents, e.g. inhalable and/or respirable biological particles that can contribute significantly to the onset of infectious, allergic or toxic disorders or diseases (Douwes *et al.*, 2003). Modern offices, often equipped with centralised ventilation and air conditioning systems, energy-saving windows and synthetic furnishings, can be an environment conducive to the accumulation of bioaerosols. In addition, physical activity in offices is generally reduced and occupancy tends to be prolonged and sedentary. This is important because, while reduced pulmonary ventilation limits the instantaneous inhalation of bioaerosols compared to intense physical activity, prolonged exposure in closed and poorly ventilated environments amplifies this lower baseline exposure, increasing the risk associated with cumulative exposure.

Bioaerosol is a heterogeneous mixture of particles of biological origin that spread through the air in the form of solid and liquid components, creating a stable dispersion system. (Zhang *et al.*, 2024). These particles comprise a wide range of biological aerosols, including living entities capable of growing and replicating autonomously, such as bacteria, fungi, archaea, dust mites and other biological entities such as viruses, allergens, toxins, pollen, resistant structures such as fungal spores and bacterial endospores, as well as insect fragments and organic residues (including skin flakes and animal hair) (Zang *et al.*, 2024). These particles can spread through the air and aggregate into formations of varying sizes, remaining suspended in such environments even for prolonged periods. The biological elements contained in bioaerosols are not inert at all, and their biological potential is maintained thanks to the presence of organic matter that promotes their survival. Once suspended in the air, the microorganisms, allergens and toxins present in bioaerosols can spread throughout the environment, leading to exposure to pathogens and potentially harmful substances.

The health impacts associated with bioaerosol particulates vary depending on both the size of the particles, which determines their ability to penetrate the respiratory tract, and their composition and biological activity (Gòrny *et al.*, 1999). The detection of biological contaminants is therefore a key indicator for assessing indoor air quality and identifying any health risks to occupants. (Dacarro *et al.*, 2000; Conferenza Stato Regioni, 2001; Kim *et al.*, 2018).

2.1. Biological risk in offices and similar environments

In office environments, the risk associated with the presence of biological agents mainly concerns infectious and allergic effects, attributable to the presence in the bioaerosol of microorganisms such as bacteria, viruses, fungi, as well as pollen, spores and other organic materials. Exposure to these contaminants can occur mainly through inhalation, but also through contact with contaminated surfaces. There are therefore two modes of transmission: direct airborne transmission over short or long distances, in which the pathogen is transmitted from

person to person, and indirect transmission, which occurs through contact with contaminated surfaces or objects, known as fomites.

In certain work environments, biological risks in offices can be significantly increased by unfavourable environmental conditions, such as overcrowding – for example, during public opening hours or in particularly busy open-plan offices – and a lack of adequate air exchange. These factors contribute not only to a widespread perception of discomfort among occupants, but also to reduced dispersion and dilution of airborne biological agents. In addition, heat accumulation and increased relative humidity create an indoor microclimate that can promote the proliferation of mould and other microorganisms, resulting in poorer air quality and a potential negative impact on staff health and well-being. Prolonged exposure of staff to bioaerosols present in indoor environments has been associated with an increased risk of developing allergic diseases, asthma and respiratory tract infections (Gòrny, 1999; Douwes, 2003; Sharpe *et al.*, 2015). Airborne biological contaminants, such as bacteria, viruses, fungi and allergens, can alter the normal functioning of the respiratory system, triggering inflammatory responses in the nasal and bronchial mucous membranes. These effects can manifest themselves in acute or chronic form, especially in more susceptible individuals, such as those suffering from pre-existing respiratory disorders, allergies or immunocompromised conditions. Furthermore, in work environments where the air is poorly ventilated, repeated and cumulative exposure to low concentrations of these agents can promote the development of persistent symptoms, negatively affecting health and work performance.

Among the various biological agents present in indoor environments, filamentous fungi – commonly known as mould – play a particularly important role. Their presence is not only a sensitive indicator of environmental quality, as it is often associated with high humidity, dust accumulation and insufficient ventilation, but also constitutes a direct health risk. Mould can cause hypersensitivity reactions, allergic respiratory symptoms and infectious diseases. The presence of mould in closed environments – including offices – is significantly correlated with respiratory problems, the onset of asthma, increased sensitivity to chemicals and allergic reactions, giving rise to a wide range of symptoms such as rhinitis (colds), cough, nasal congestion, eye irritation with tearing, shortness of breath, conjunctivitis, and asthma exacerbation.

Prolonged exposure to mould and moisture damage in indoor environments can contribute to the development of *Multiple Chemical Sensitivity* (MCS) in susceptible individuals. A study conducted in Finland showed a significantly higher prevalence of MCS among individuals with respiratory or vocal symptoms associated with moisture damage in the workplace, compared to the general population. Individuals exposed to moisture damage had higher scores in terms of chemical intolerance, symptom severity and impact on daily life (Nynäs *et al*., 2021).

Furthermore, some fungal species produce mycotoxins with carcinogenic, teratogenic and neurotoxic potential (Didwania *et al*., 2013). However, the elimination of allergens from indoor environments leads to a marked reduction in symptoms in allergic individuals.

In offices, measures aimed at improving air quality – while not eliminating the onset of respiratory or allergic diseases – reduce the intensity of symptoms, help prevent acute and even severe episodes, and improve the quality of life of those who regularly frequent these spaces.

2.1.1. Microorganisms in offices and similar environments

Microorganisms are ubiquitous and capable of proliferating on a wide range of substrates. In environments such as offices, their presence is mainly linked to the entry and movement of people and objects; Furthermore, indoor air quality is affected by ventilation movements – including air coming from outside – and, to a lesser extent, by the characteristics of the materials used to furnish

the space (furniture, paints, coatings), which can release substances or particles into the surrounding environment over time.

The microbial load in offices can vary considerably and tends to increase when there is poor air exchange or when water stagnates and humidity levels are high. For most bacteria, fungi and their spores, the inhalation dose capable of causing infections or other adverse effects has not yet been precisely defined; moreover, individual factors – age, immune status, previous illnesses, allergic sensitivity – determine a response that varies greatly from person to person. This combination of scientific uncertainty and marked heterogeneity among individuals still makes it impossible to establish universally accepted exposure limits that can be adopted as operational threshold values. (Macher, 1999).

The complexity of indoor bioaerosols – due to the considerable variety of bacteria, fungi and their spores and the numerous variables that modulate their presence – requires a systematic approach when assessing the microbiological quality of office air. First of all, specific microorganisms, or cultivable aggregates of microorganisms, must be identified that can serve as indicators of the healthiness of the environment. Once these "sentinel microorganisms-aggregates" have been chosen, routine analyses are scheduled to detect the presence of pathogens both in the air and on surfaces, setting up a monitoring plan that considers:

- configuration and characteristics of the areas that make up the office to be examined (rooms, studies, open spaces, meeting rooms, library, archives, common areas, etc.);
- type of visitors (staff, visitors, public, etc.);
- presence of air handling units and/or evaporative dehumidifiers-condensers;
- outdoor environmental conditions that can affect indoor air quality.

The fundamental microbiological parameters for a basic quantitative analysis are:

- *psychrophilic bacterial population*
  bacteria that proliferate at around 22°C (range 15-30°C); they act as indicators of environmental microbial contamination;
- *mesophyte bacterial population*
  bacteria with an optimal growth temperature of around 37°C (range 25-40°C); they indicate contamination of human or animal origin;
- *fungal population*
  includes moulds and yeasts, useful environmental indicators because they are often associated with high humidity, the presence of dust, and, in general, suboptimal air quality.

Appendix A lists the quality references for microbiological parameters of bioaerosols in indoor environments, as proposed by the WHO, certain countries, associations and the *European Collaborative Action* (ECA).

The investigation can then be expanded with a qualitative analysis aimed at identifying specific microbial groups according to the objectives of the investigation itself. In particular, it is useful to note:

- Gram-positive bacteria, belonging to the genus *Staphylococcus* spp. (with particular attention to the presence of *S. aureus*), frequently associated with contamination of human origin, and bacteria of the genus *Streptococcus* spp., associated with the microbial flora of the oral and pharyngeal mucosa, the detection of which indicates poor ventilation of the environment.
- Actinomycetes, an indicator of poor air quality as they are associated with dust, humidity and poor ventilation.

- Gram-negative bacteria, known for producing endotoxins. Among these, the genus *Pseudomonas* spp. – and in particular *P. aeruginosa* – is significant given its ability to survive and multiply even in hostile environments, providing useful information on the microbiological quality of the ambient air. Furthermore, their presence may also suggest the possible coexistence of other Gram-negative bacteria that are difficult to cultivate. Finally, *Enterobacteriaceae*, such as *Escherichia coli* and *Klebsiella* spp., are important indicators of faecal contamination and, more generally, of the hygienic state of an indoor environment; their presence in an office would indicate significant contamination, which is rare unless there are serious problems related to sewage or inadequate cleaning.
- Gram-negative aerobic bacteria with specific characteristics, such as *Legionella*, a ubiquitous genus, mainly found in water, comprising more than 60 species (including subspecies) and approximately 70 serogroups. Not all species have been associated with human disease. *Legionella pneumophila* is the species most frequently found in clinical cases and includes 15 serogroups; *L. pneumophila* serogroup 1 is responsible for 95% of reported infections in Europe and 85% worldwide. The infection is mainly transmitted through inhalation, aspiration or microaspiration of aerosols containing *Legionella*, or particles derived from drying, while human-to-human transmission is extremely rare (currently only one documented case). The danger posed by these particles is inversely proportional to their size, as droplets with a diameter of less than 5 μm reach the lower respiratory tract more easily. Bioaerosols containing *Legionella* can be produced by air conditioning systems, humidifiers and evaporative condensers, humidification sections of HVAC, and drinking water distribution systems, through shower heads, taps and fountains. The term “legionellosis” refers to all forms of disease caused by bacteria of the genus *Legionella*, which can manifest as pneumonia, sometimes severe (with a mortality rate varying between 10-15%), feverish forms of extrapulmonary infections or subclinical infections. The risk of contracting the disease is mainly linked to the susceptibility of the exposed individual and the intensity of exposure, determined by the concentration of *Legionella* present and the duration of exposure. Legionellosis is subject to mandatory notification in class II as established by the Ministerial Decree of 15 December 1990 (since 1983, it has also been subject to a special surveillance system with a specific national register based at the ISS (Ministry of Health, 1991; Presidency of the Council of Ministers, 2015). The legal reference is Title X of Legislative Decree 81/2008 and subsequent amendments and additions: “Exposure to biological agents”; in the case of *Legionella*, its presence in the workplace is not related to a specific activity; therefore, exposure is generally classified as non-occupational; nevertheless, any prevention or protection measures must be implemented by the employer.
  In indoor environments, such as offices, *Legionella* can proliferate inside various components of air handling systems that are subject to humidity and water stagnation, such as HVAC. The latter are devices used to renew (by introducing air from outside), treat and circulate air in rooms, and are part of a HVAC system. These complex systems consist of various components designed to filter, heat, cool, humidify and dehumidify the air, creating optimal conditions for the health and comfort of staff. In addition to developing in HVAC, *Legionella* can proliferate in coils, walls and humidification chambers, fan coil units, air ducts (both supply and return), rotary filters, pocket filters and panel filters. To prevent the proliferation of pathogenic microorganisms such as *Legionella* and the associated health risks, it is therefore essential to carry out regular hygienic maintenance on all parts of the air handling system.
  Particular attention must be paid to components such as humidification trays and ventilation ducts which, designed to prevent excessive dryness of the air, maintain the optimum level

of humidity in a closed environment. In addition, particular attention must be paid to drainage systems designed to remove condensation and/or fluid accumulations which, if not properly maintained and disinfected, can provide an ideal environment for the growth of *Legionella*. The proliferation of this microorganism is in fact favoured by conditions of high humidity and temperatures between 25 and 45°C (Pan *et al*., 2010; Presidency of the Council of Ministers, 2015; UNI EN 13053:2020). HVAC are normally already certified for their performance, but there are also specific versions certified as "hygienic". These HVAC offer the same functions as traditional ones, but are suitable for applications that require a high standard of hygiene, which is certified according to three classification levels, depending on the different applications. Offices fall under Level 1 certification.

2.1.2. Viruses in offices and similar environments

Viruses are one of the main causes of infectious diseases transmitted in closed environments, such as offices, due to their high capacity for spread and, in many cases, their resistance in the environment. Transmission can occur through the air (e.g. IRP), through direct contact between people, especially in high-density environments with limited air exchange, or through contaminated surfaces (e.g. fomites).

Assessing viral contamination in indoor environments is highly complex. In fact, there are no generic indicators for viruses, because:

- there is a wide variety of viral families and species, with very different characteristics in terms of environmental stability, virulence and mode of transmission;
- the presence of one virus does not indicate the presence of others: each virus must be considered a separate entity, with highly variable circulation and concentration dynamics in space and time;
- the pathogenicity of a virus also depends on the host and the epidemiological context, making it difficult to define environmental risk thresholds.

Consequently, it is not possible to define universal parameters for viral contamination in indoor environments, nor to establish exposure limits. For this reason, targeted research into specific viruses is usually only carried out in critical situations that are already known or well established, such as in the case of epidemic outbreaks – the emblematic case of SARS-CoV-2.

Over the last few decades, numerous viruses belonging to different families have been identified both in the air and on surfaces in various types of indoor environments: public and private buildings, means of transport (especially aeroplanes), healthcare facilities, barracks and other places with high occupancy rates (La Rosa *et al*., 2013). Several epidemic outbreaks have been associated with these environments, highlighting how microclimatic conditions, ventilation and population density can facilitate viral transmission.

Among respiratory viruses, SARS-CoV-2 has brought the issue of viral spread in indoor spaces, such as offices, schools, public transport and healthcare facilities, back into the international spotlight. Numerous studies have documented the presence of SARS-CoV-2 viral RNA in offices and other indoor environments frequented by infected individuals (Paton *et al.*, 2022; Masoumbeigi *et al.*, 2020). An analysis conducted in England examined data on SARS-CoV-2 outbreaks in workplaces between 2020 and 2022, finding that many outbreaks occurred in indoor settings such as offices, warehouses and industrial plants (Overton *et al.,* 2024).

A study conducted by the *UK Health and Safety Executive* documented the application of measures to mitigate the risk of SARS-CoV-2 transmission in real work environments, highlighting the importance of ventilation, the complementary role of masks, and the difficulties

of maintaining physical distancing, especially in production facilities and *open space* offices (Sandys *et al.*, 2024).

A systematic review conducted by the *US National Institute for Occupational Safety and Health* (NIOSH) summarised over 270 key studies on SARS-CoV-2 transmission in the workplace, highlighting the central role of enclosed environments, such as offices, in viral spread. The study confirmed that airborne transmission is possible and significant, especially in inadequately ventilated spaces. It also highlighted the limitations of available environmental sampling techniques, which are often unable to detect viable viruses, and the need to develop more effective methods for assessing staff exposure (Cox *et al.*, 2023). The pandemic experience has highlighted the importance of a comprehensive risk management strategy that combines all protective measures such as ventilation, air flow management, sanitisation and workspace organization to contain the spread of infection.

In light of this evidence, numerous health and environmental institutions have published specific recommendations for preventing viral transmission in indoor environments.

The U.S. Environmental Protection Agency (USEPA) and the Centers for Disease Control and Prevention (CDC) have published guidelines on preventing the spread of respiratory viruses in enclosed public spaces, emphasizing the importance of optimal ventilation, the use of high-efficiency filters, and, where necessary, portable air purifiers (USEPA, 2025; CDC, 2024).

The WHO has also published a technical document highlighting the importance of engineering interventions (natural or mechanical ventilation), behavioural measures, and indoor air quality monitoring protocols to reduce the risk of viral transmission in indoor spaces (WHO, 2023; WHO, 2024a; WHO, 2024b).

In Italy, ISS has published several documents in response to the need for greater coordination, recommending an approach based on a set of risk reduction measures that must be part of a comprehensive risk prevention and mitigation strategy and must work simultaneously and complementarily to be effective, as no single measure can reduce risk on its own (such as: control of the various sources that characterize the environment, occupancy density, natural and mechanical air exchange, effective and efficient distribution of air flows in all areas to avoid stratification or lack of mixing and drafts, filtration, CO_2 measurements, temperature, relative humidity, operating times of mechanical ventilation systems, including periodic verification and control of indoor air quality) (ISS Working Group Environment and Indoor Air Quality, 2021; Settimo *et al.*, 2022).

While SARS-CoV-2 is the most recent and relevant example, there are other viral groups that can be transmitted in indoor environments and deserve attention. Scientific literature has documented the presence of viruses such as influenza, adenovirus, rhinovirus, enterovirus, and norovirus in indoor spaces such as offices, schools, transportation, and community facilities (La Rosa *et al.*, 2013). In these contexts, occupancy density, insufficient ventilation, and the persistence of viruses on surfaces and in the air are well-known risk factors (USEPA, 2025).

Despite this, there is still a lack of standardized methods for environmental detection of viruses and shared thresholds for assessing exposure risk, limiting the implementation of effective preventive strategies in workplaces and public environments.

2.1.3. Allergens in offices and similar environments

Exposure to indoor allergens can occur in all enclosed spaces, including offices. It has now been demonstrated that allergic respiratory diseases, such as asthma, are the result of interaction between an individual's genetic predisposition and environmental exposure. Furthermore, there is evidence of a dose-response relationship between environmental exposure to certain indoor allergens and sensitization (presence of specific IgE antibodies), as well as between

environmental exposure and the onset of allergic and asthmatic symptoms in individuals who are already sensitized (Platts-Mills *et al.*, 2007; Ferguson, 2008).

Obtaining information on exposure to indoor allergens is very important because it allows both the risk factors for sensitization and/or the onset of symptoms to be assessed and exposure to the allergens themselves to be reduced.

In this regard, numerous studies have been conducted to determine the level of indoor allergens in both public and private environments, as well as the correlation between their concentration and the onset of symptoms in exposed individuals. A series of studies has also been carried out by the ISS as part of a number of research projects with the aim of developing standardized sampling and analysis methods and obtaining useful information on the presence of indoor allergens in private homes, offices, and especially in schools. In fact, the application of rigorous and standardized procedures at all stages of the process, from sample collection to the measurement of individual allergens, is of fundamental importance in order to obtain reliable information (Brunetto *et al.*, 2009a; Brunetto *et al.*, 2009b).

Standardized ELISA (Enzyme-Linked Immunosorbent Assay) kits using monoclonal antibodies are commercially available for the measurement of some of the most common allergens. The simultaneous availability of special filters for sampling is also a significant aid in standardizing the entire process.

Attention has focused primarily on major allergens, which are the most clinically important, but for each allergenic source there are also other potentially important allergens, known as minor allergens, which may be relevant for individuals sensitized to these allergens.

Since it is unlikely that a person will spend an entire day in a single indoor environment, analysing the relationship between environmental exposure to allergens and sensitization is very complex, as it is not easy to determine where and when sensitization occurs and what concentrations of allergens can induce it. It is easier, however, to estimate whether the allergen load present in the place under examination can cause symptoms in allergic individuals and/or aggravate the allergic condition.

Indoor allergens are defined as “perennial” because, although their concentrations vary, they can be present throughout the year in indoor environments. The most common sources of indoor allergens are mites, cockroaches, mammals, and fungi.

Mites, along with their remains and excrement, are much more abundant in domestic environments, but have also been found in public environments such as offices, where conditions conducive to the development and spread of their allergens can arise.

Among mammals, the main species responsible for allergic diseases are *Canis familiaris* and *Felis domesticus*. Fel d 1, the major cat allergen responsible for acute asthma attacks, is considered one of the most potent indoor allergens. It is produced by the sebaceous glands and squamous epithelial cells of cats, accumulates on their fur, and, because it adheres very easily to clothing, can be carried by humans even to environments where cats are not present, such as offices.

Cockroaches are responsible for a high percentage of severe asthma cases in the United States and Northern Europe, while in Italy the phenomenon of sensitization is still being evaluated. The spread of allergens from this source is considerable, especially in very old buildings with inadequate hygiene standards.

As regards fungi, a commonly adopted distinction is that which provides for the existence of two groups, atmospheric fungi and domestic fungi. Among the former, of particular importance are *Alternaria* spp. and *Cladosporium* spp., which are ubiquitous on the ground together with other environmental fungi and have a seasonal pattern. Among the latter, which may also include *Alternaria* spp. and *Cladosporium* spp., which have penetrated indoor environments, *Aspergillus* spp. is of primary importance.

Diseases caused by fungi are not always IgE-mediated allergic in nature and, moreover, especially in some immunocompromised individuals, they can manifest as serious respiratory infections caused by inhalation of spores from fungi belonging to the genus *Aspergillus*. In the case of true IgE-mediated allergic forms, however, the disease caused by fungi is often difficult to diagnose from an allergological point of view due to the not always optimal quality of the preparations used for diagnosis, which is carried out using commercially available *skin prick tests*.

2.2. Objectives, durability and frequency of indoor air monitoring

2.2.1. Sampling of microorganisms

Sampling and analysing bioaerosols not only allows for the assessment of the biological characteristics of the air, but is also an indispensable tool for preventing health risks for office workers.

The analytical approach is necessarily preceded by an on-site inspection and the collection of all relevant information, as in the case of chemical pollutants (*see* Appendix B).

The characteristics of bioaerosol monitoring are therefore determined by the type of environments to be investigated, the type of contaminants that are expected to be present, and the identified sources of pollution. Some will be typical of the indoor environment, while others will be due to the influx of outdoor air through doors, windows, and any ventilation systems. As we will see later, it will not be necessary to identify all the components of the bioaerosol. In fact, both in indoor and outdoor environments, the most suitable and commonly used criterion is to identify and study the most quantitatively representative species and biological groups.

Before proceeding with sampling in an office, it will be necessary to decide which points to sample, the technique and duration of sampling, the number of samples to be taken, the assessment of possible changes in environmental conditions during sampling, and the instruments to be used. The UNI EN ISO 16000-1 standard establishes the general principles for planning and executing air sampling campaigns in closed environments. It defines the criteria for identifying measurement objectives, choosing the parameters to be monitored, selecting the appropriate sampling techniques, and determining the sampling points and times. The standard emphasizes the importance of considering environmental conditions (temperature, humidity, ventilation, size of spaces, occupancy of spaces) during sampling to ensure representative and comparable data. It also provides guidance on the correct documentation of the activities carried out, in order to ensure the traceability of the results.

The ideal sampling point should be the centre of the room to be monitored, respecting the distances from doors and windows, also considering solar radiation and the possible presence of drafts that could influence the sampling results, as specified in UNI EN ISO 16000-1:2006 and in *Rapporto ISTISAN* 13/37 (Bonadonna *et al*., 2013) by the GdS-ISS Indoor Pollution.

Optimal sampling should allow both the determination of the total number of airborne PM particles, which is not limited to a fraction of particles per unit volume of air (CFU/m^3), and the average number of living cells (ISO 16000 part 16-19, 34). In this case, the choice of analytical technique depends not only on the biological agent to be detected, but above all on its presumed concentration or, better still, its concentration as determined by preliminary sampling.

Table 2 lists the ISO 16000 Indoor Air methods adopted by CEN and, in part, by UNI, and the *Rapporto ISTISAN* 13/37, which can be used to select sampling points and perform sampling, as well as the analytical techniques to be applied.

Table 2. UNI EN ISO standards for indoor environments specific to biological pollutants

Standard	Title
UNI EN ISO 16000	Indoor air
Part 1	General aspect of sampling strategy
Part 16	Detection and enumeration of moulds — Sampling by filtration
Part 17	Detection and enumeration of moulds — Culture-based method
Part 18	Detection and enumeration of moulds — Sampling by impaction
Part 19	Sampling strategy for moulds
Part 20	Detection and enumeration of moulds — determination of total spore counts
Part 34	Strategies for the measurement of airborne particles
Part 40	Indoor air quality management system
Part 41	Assessment and classification
UNI EN 13098	Workplace exposure - measurement of airborne microorganisms and microbial compounds – general requirements
***Rapporto ISTISAN* 13/37**	Monitoring strategies for indoor air pollution of biological origin
UNI 11976	Ergonomics of the physical environment. Tools for assessing indoor air quality

(in gray, the parts not yet adopted in Italy by UNI)

To sample indoor air in offices, as in all indoor environments, there are two different types of methodologies: passive and active sampling.

In passive sampling (by sedimentation or gravimetric methods), microorganisms carried by PM suspended in the air are collected by deposition on the surface of a Petri plate of known dimensions, exposed to the air for predetermined periods of time and containing a suitable culture medium. After appropriate incubation of the plates, at a predetermined temperature and for a predetermined time, the number of colonies grown is counted and the measurement is expressed as the number of PM per unit area (e.g., per m^2, in a unit of time).

Although simple and inexpensive, passive sampling has the undeniable disadvantage of not being a quantitative method, as it does not allow the number of microorganisms collected to be correlated with a known volume of air. It also has the further drawback that, since the deposition rate depends on the mass possessed, the microorganisms contained in larger particles may be overestimated compared to those contained in smaller, lighter particles, which have a slower sedimentation rate and are more likely to be moved elsewhere by convective air motions.

The fundamental property of active, or volumetric, sampling is that it allows volumes of air of known size to be collected, thus making it possible to measure the concentration of microorganisms present in the bioaerosol and to minimize, compared to passive sampling, differences in the distribution of bacteria due to temperature, disturbances caused by air currents, and the size and shape of airborne aggregates. By means of suction, it is possible to convey a specific quantity of air directly onto a solid nutrient substrate suitable for microbial growth or into a liquid medium to be subsequently analysed. In order to overcome any stress conditions suffered by microbial cells during sampling, which can compromise the vitality and therefore the ability

of microorganisms to reproduce in culture medium, and to promote their revitalization, an enrichment phase is sometimes necessary (ISO 16000 parts 16-18, 34).

The nutrient substrates, both solid and liquid, used for analysis must allow for optimal growth of microorganisms, avoiding the establishment of antagonistic effects related to the presence of nutritional or metabolic interference.

The sampling/analysis procedure involves conveying the aspirated air onto a nutrient medium, suitably prepared inside special equipment, and, after an appropriate incubation period, the colonies that have grown can be counted and identified. The degree of microbial contamination is expressed as Colony Forming Units-CFU/m³ of aspirated air.

There are various types of active sampling systems, based on different operating principles: impact samplers, filtration samplers, bubbling samplers, condensation samplers, and laser-induced fluorescence samplers.

Among the active impact samplers, the following stand out: slit samplers, stacked samplers with an external suction system (e.g., the *Andersen* multistage sampler), and single-stage samplers with an integrated suction system; the latter use two different criteria for capturing microbial particles: tangential impact or orthogonal impact of the air on the agarized ground.

Active sampling of suspended PM (using filtration, not limited to a fraction of particles) is commonly used in monitoring chemical pollutants in both indoor and outdoor environments and has only subsequently been adapted for biological monitoring (ISO 16000 parts 16-18, 34). A drawback of this system, in the case of prolonged sampling or in extreme relative humidity conditions, is that stress conditions may arise on the filter membrane that affect the survival of the microorganisms being collected.

Active impinger samplers push the aerosol through a liquid medium (liquid impinger); in this case, sampling, for the removal of particles from the air flow, mainly exploits the force of inertia combined with the diffusion of particles in the liquid medium. This type of sampler may be unsuitable for collecting hydrophobic particles such as fungal spores.

For a more detailed description of how the most common bioaerosol samplers operate, please refer to *Rapporto ISTISAN* 13/37 (Bonadonna *et al.*, 2013).

The most suitable sampling system for monitoring indoor environments is represented by active impact samplers such as the *Surface Air System* (SAS), which are widely used due to their practicality and ease of handling. The SAS is a single-stage orthogonal impact sampler. Using slit filtration, it draws in predetermined quantities of air, with a nominal flow rate that, depending on the model, can vary from 40 to 180 L/min, collecting volumes between 10 and 1000 L, allowing a direct quantitative estimate of viable bacterial cells. The volumes of air to be aspirated can be defined and set according to the presumed levels of microbial contamination. The air is conveyed through an aluminium head with a series of specially designed small holes directly onto the surface of the different agarized nutrient substrates, selective and/or specific for the various microorganisms to be detected, contained in 55 mm diameter Rodac plates, which can be housed directly in the removable and sterilizable head of the sampler itself at the time of sampling. This allows sampling by selecting the microbial groups to be quantified and evaluated at the outset.

This sampler is extremely flexible to use and, thanks to its flow rate, reduces sampling times with the advantage of subjecting the collected microbial cells to less stress from dehydration. The SAS is also commercially available in a model that features two suction heads in a single body that can be operated simultaneously. The advantage of this type of sampler is that it provides statistically representative results using the same type of nutrient medium on both heads; by using two different media, it is also possible to take two samples at the same time using specific nutrient media for two different types of counts (e.g., bacteria and fungi). The possibility of double sampling leads to a real operational advantage as the time required can be halved, which is very important in cases where many rooms need to be monitored, such as in offices.

In order to correlate microbial concentration and the possibility of inhalation during exposure, samplers must be positioned at an average height of 1.5 metres above the ground to simulate the average height of the upper human respiratory tract. Samples must also be taken near the centre of the room to be monitored and at a distance of at least 1 metre from walls, doors and windows (ISO 16000 part 1, *Rapporti ISTISAN* 13/4, 13/37, 19/17 e 20/3) (Fuselli *et al.*, 2013; Bonadonna *et al.*, 2013; Settimo *et al.*, 2019; Settimo *et al.*, 2020a).

Active condensation samplers can be widely used for the detection of stress-sensitive microorganisms such as particular bacterial strains and viruses. This type of aspirator consists of a series of mechanical devices, such as a vacuum pump, humidifier, heating source, liquid source, amplifier, cooling source, etc., which are engineered into a transportable mechanical body.

Condensation draws air into the sampler via a vacuum system and a humidifier equipped with a heat source that vaporises the liquid, preventing the deactivation of microorganisms and viable particles. The air saturated with water vapour is then subjected to a condensation process in the presence of supersaturated vapours. The temperature is reduced and dissipated within the cooling system of the amplification section. The important feature of this technique is that the entire process takes less than a second, increasing recovery efficiency (Walls *et al.*, 2016). This equipment is designed to simulate the human respiratory system and lung function, allowing the sampling of respirable bioaerosols. Sampling efficiency is significantly improved compared to other types of suction samplers because the particle size range is wider, varying from less than 10 nm to larger than 10 μm. Furthermore, by reducing oxidative stress on the sampled particles, the viability and potential infectivity of the sample remain unchanged, as does the DNA/RNA for possible genomic analysis (Pan *et al.*, 2016; Lednicky *et al*., 2016). Commercially available condensation equipment can be fitted with dedicated vials for liquid substrates or Petri plates for agarized culture substrates, allowing the cultivation of sampled microorganisms.

Laser-Induced fluorescence (LIF) technology allows the presence of viable microorganisms in the air to be detected in real time, identifying molecular characteristics and enabling the discrimination of certain selective species. Although active impact air samplers provide information about contamination and also allow the identification of the detected microorganism, they do not allow the precise moment of contamination to be established in real time or the source to be traced directly. The new LIF-based biological detection devices overcome these limitations by providing real-time measurement of viable airborne particles and displaying the data directly on a local display or integrating it into a Facility Monitoring System (FMS).

This approach allows for continuous monitoring, reducing response times and improving the ability to intervene in the event of contamination. The environmental samples collected are excited by a laser beam of a specific wavelength (Zare, 2012). The microbial species present are de-excited and emit light in a fraction of a second, which is then detected by a photomultiplier tube or photodiode, allowing accurate and immediate quantification.

A further technological development in the field of laser detection is represented by the technique of Laser-Induced Breakdown Spectroscopy (LIBS). During this process, a high-energy laser is focused on a specific area of the sample, causing localised ablation that generates a plasma at temperatures of around 10^5 K (Anabitarte *et al*., 2012). At such high temperatures, the ablated materials decompose into excited and ionic states, allowing the identification of microbial taxa and species through analysis of the emitted spectrum.

The commercialisation of this technology for detecting biological contamination in indoor air is widespread in pharmaceutical production systems, thanks to its obvious advantages: it allows for the timely analysis of the causes of contamination, the optimisation of production processes and the adoption of rapid corrective actions.

2.2.2. Viruses sampling

As regards methods for detecting viruses in indoor environments, based on current knowledge, there are no standard protocols describing detailed sampling methods and analytical techniques to be used. In fact, there is a lack of standardization both for sampling (multiple instruments and techniques) and for virus identification (use of cellular systems, molecular methods, others). Studies comparing the various sampling methods often show contradictory results and therefore no guidelines are available for choosing between them. This is confirmed by a recent review which highlights how the variety of sampling and genetic analysis techniques for bioaerosols leads to significant variability in results, making it difficult to evaluate the collected data in a uniform and comparable manner (Pogner *et al.*, 2024).

In general, the instrumentation used for virus sampling is similar to that used for collecting other types of airborne particles described above.

The most commonly used samplers for collecting viruses in indoor environments are liquid impingers, which allow large volumes of air to be drawn in at a controlled flow rate. The most commonly used devices for virus sampling are AGI (All-Glass Impingers) impingers, such as the AGI-30 and AGI-4 systems.

Other systems used to collect viruses from *aerosols* are devices such as Biosamplers, which involve adsorption in liquid (sterile physiological solutions, selective culture media) with centrifugal movement and a pre-set suction flow. Biosampler devices have been used to sample influenza viruses in various indoor environments. Compared to AGI samplers, Biosamplers allow sampling for longer periods of time without the risk of damaging the adsorbed bioparticles; the risks of re-aerosolisation of the particles themselves are also reduced.

Different types of filters can be used to collect viruses in indoor environments using the filtration method: cellulose filters made of polytetrafluoroethylene (PTFE) or polycarbonate (Regan *et al*., 2022). However, their use is limited by the possibility of structural damage due to the air flow impacting the captured viral particles. In recent years, gelatin filter membranes contained in sterile capsules have been used as an alternative, as they are less traumatic for viral integrity. Since they maintain a humid environment during sampling, gelatin filters also allow for greater operational flexibility because they can be dissolved in physiological solution.

Another emerging technology is represented by electrostatic precipitators (ESP) (Fukuda *et al.*, 2023; Kim *et al.*, 2021; Lee *et al*., 2024), which use an electric field to capture airborne viral particles. This technique avoids the mechanical stress typical of other methods, preserving the integrity of the collected particles and improving recovery efficiency. Recent studies have shown that electrostatic precipitators are effective in capturing respiratory viruses and other pathogens present in indoor aerosols, with a reduced risk of particle damage during the sampling process.

Based on a recent 2024 review, it has emerged that airborne virus sampling technologies are evolving rapidly, with the introduction of more powerful devices and more effective methodologies. In particular, new-generation cyclonic and bioaerosol samplers represent a significant step forward compared to traditional methods (Riesenberger *et al*., 2024). These devices allow for greater concentration of viral particles, preserving their integrity during the sampling process and improving recovery efficiency.

2.2.3. Sampling of allergens

Indoor air sampling in the field of allergology is mainly used for outdoor monitoring, where the primary focus is on determining the quality and quantity of airborne pollen. Indoor air sampling has been used rarely, mainly to highlight the presence of mould and spores and, only occasionally, to assess the presence of pollen.

The two traditional methods for air sampling, normally also applied in office environments, are those described above: active gravimetric method by suction and passive method by sedimentation.

In recent years, a new method for sampling airborne allergens has been validated. It is based on the use of a device called Inspirotec, which, together with the Multiplex Array for Indoor Allergens (MARIA) allergen dosing system, facilitates the detection of a wide range of airborne allergens. In addition, a further air sampler has recently been developed that uses specific filters and can be used in conjunction with MARIA or ELISA dosing systems, with the possibility of detecting, again, a wide range of airborne allergens. Currently, due to the novelty of these samplers, there is insufficient data available in the literature to allow for a comparison with data obtained using previous methods.

In cases where it is decided to carry out air sampling, either on its own or in parallel with sedimented PM sampling, there are numerous factors that must be considered, similar to those relating to microbiological sampling and chemical substances detection. It is therefore important to choose the location of the sampler, assess the variation in environmental parameters (such as temperature and humidity) and the duration of sampling, the number of samples to be taken and, finally, the techniques used to identify and quantify allergens. Furthermore, when critically evaluating the various sampling methods, air and surface, the former has the undeniable advantage of providing a more accurate picture of actual exposure, as it is able to provide information on the concentration and type of airborne allergens. However, this method has some disadvantages which, especially in the past, have limited its application. the most significant being the availability of standardised air samplers capable of collecting a wide range of allergens in a reproducible manner and, secondly, the fact that in environments where the air is static and therefore not subject to movement or exchange, the quantity of airborne allergens dispersed is reduced and therefore more difficult to detect.

Regardless of the type of sampling used, it is important to collect useful information during sampling in order to better analyse any cause/effect relationships between the quantity/quality of indoor allergens and allergic and asthmatic respiratory diseases. This information includes not only the date and duration of sampling, but also data on temperature, relative humidity and the premises where sampling was carried out (size, number of occupants, ventilation and heating systems). In addition, any events found to be abnormal, such as visible traces of moisture inside the premises, should be reported. This information is important for properly analysing the actual conditions of environments in which, for example, concentrations of allergens are found that are considered potentially hazardous to the health of the people staying there. Furthermore, it can provide useful information for improving the current situation, both by intervening on the structure and by optimising the microclimate (e.g. natural and mechanical air exchange, heating and cooling) and cleaning procedures in the environments affected by sampling and measurement operations.

2.3. Sampling from surfaces

In indoor environments, surfaces can provide an ideal substrate for the development of bacterial flora. In this context, the microorganisms and nutrients necessary for their sustenance can be supplied either through direct contact or through the sedimentation of PM particles suspended in the indoor air. Bearing in mind that poor or even non-existent air exchange increases the deposition of bioaerosols and that the occurrence of air currents due to the movement of people or the opening of doors and windows raises and disperses part of the deposited particles back into the air, it is clear how important surface sampling is for accurately determining the conditions of

the environments under examination. There are three methods for assessing the hygienic condition of surfaces: microbiological, chemical and biochemical.

According to the microbiological method, microorganisms can be detected and summarily identified in 24-48 hours; on the contrary, both the chemical method (which does not require instrumentation) and the biochemical method (which requires the purchase of a data reading instrument) are able to provide results in a few minutes.

For a quick assessment of the hygienic condition of a surface, various rapid biochemical or chemical systems can be used to detect the concentration of adenosine triphosphate (ATP), a molecule that is ubiquitous in microorganisms and in animal and plant cells, on the surfaces to be tested.

The microbiological method can be applied using different techniques which, in general, refer to the sponge method, flexible slides, contact plates and swabs.

The simplest basic method, which is more suitable for sampling larger surfaces than swabs or contact plates, is the sponge method, which involves using sponges soaked in sterile saline solution and any neutralising agents, which are rubbed on the surface to be tested and then subjected to homogenisation/elution treatment. The sample obtained in this way is seeded on a culture medium using the agar inclusion technique.

Flexible, ready-to-use slides are another quick method available on the market; this technique makes use of the simultaneous presence of two different types of soil on both sides of the same slide, thus allowing two different tests to be carried out at the same time.

In Italy, there are no guidelines for assessing hygiene quality in indoor environments. Therefore, to evaluate the level of contamination on office surfaces, we recommend using two analytical procedures that are already used in other fields to determine the presence of microorganisms on surfaces: the contact plate technique (e.g., Compact Dry, Rodac Weight, Maxi Contact Plate) and the swab technique.

In the first method, special contact plates are used, prepared with a culture medium suitable for the growth of the parameter to be researched. The sample is taken by placing the plate on the surface to be sampled; it is advisable to identify at least three significant points to be sampled on the same surface in order to obtain the average contamination data and to take each sample twice in order to have a greater chance of recovery and better representativeness of the data. After a suitable incubation period, the colonies that have grown on the surface of the culture media are counted. The degree of microbial contamination is expressed as CFU/cm^2.

The contact plate method is not suitable for determining pathogenic species, as it requires pre-enrichment and enrichment stages.

The swab technique is mainly used for sampling irregular surfaces. Swabs, consisting of a rigid stem (made of plastic, wood or aluminium) and a soft head (made of cotton, synthetic fibre or alginate), are widely used due to their versatility of application on multiple surfaces. Unlike the contact plate method, sampling does not take place at the same time as inoculation of the growth medium, which occurs later, in the laboratory, after transport in refrigerated conditions in special containers. Therefore, it must be borne in mind that during this period, the viability of all organisms present in the sample must be maintained, trying to minimise any possible change in the original concentration. For this purpose, both buffered physiological solution and commercially available media that exclude the presence of carbon, nitrogen and organic growth factors can be used to prevent microbial multiplication (e.g., Stuart's Transport Medium and Ames' Transport Medium). Prepared kits are also commercially available with a transport solution containing neutralising agents that inactivate the most common disinfectants or sanitising agents that may be present on the surfaces to be sampled, thus protecting the microorganisms collected until the time of analysis.

The sampling consists of swabbing the surface to be tested with sterile swabs. Calcium alginate swabs (or similar) are very effective because they dissolve completely in suitable solutions, allowing total recovery of the microorganisms collected. The solution obtained can then be used directly for the enumeration and identification of the various microorganisms. This method is useful in cases where a high level (>100 CFU/cm^2) of surface contamination is expected. The analysis is carried out using the agar inclusion technique. The number of microorganisms grown on culture media is expressed as UFC/cm^2.

For further information on sampling and surface analysis methods, please refer to *Rapporto ISTISAN* 13/37 (Bonadonna *et al.*, 2013).

2.3.1. Viruses sampling from surfaces

The systems used for sampling viruses from surfaces are the same as those used for bacteriology, e.g. swabs, sponges and slides, which, after sampling, are subjected to subsequent elution (Julian *et al.*, 2011; Ganime *et al.*, 2015; Turnage *et al.*, 2017).

The most commonly used swabs are cotton (60% of studies) and polyester (16%), followed by *rayon* and other antistatic swabs. The most commonly used eluents are broth (beef extract, minimum essential medium, tryptose/phosphate broth) and *Ringer's* solution. The most suitable and effective method for virus recovery was found to be pre-moistened polyester swabs eluted with *Ringer's* solution (¼ concentration).

2.3.2. Sampling of allergens from surfaces

Surface sampling allows for the assessment of indoor allergens derived from dust mites, cockroaches, pets, rodents, and mould, enabling the verification of accumulation due to deposition over time, as opposed to the instantaneous value found with indoor air sampling, which only measures the quantity of allergens suspended in the volume of air sampled at that moment.

The decision to also sample surfaces is more demanding but ensures a better understanding of the hygiene status of the environment and the origin of the allergens that may be found there. If an employee has pets (cats and dogs), it will be possible to verify how allergens can be carried (carry over) from one place to another, including via clothing, from the home to the office. The importance of surface sampling is also linked to the size of the PM on which the allergens are transported. Those with sizes ranging from 5 to 40 μm can settle more quickly, as they cannot travel far from the source, while those of smaller sizes can remain suspended in the bioaerosol for longer and be transported further.

A standard vacuum cleaner with a maximum power of 1800 W is generally used to collect settled PM dust from surfaces. The total power of the appliance must be higher than the operating power, which is usually 1600 W, to prevent the appliance from operating continuously at maximum power. Plastic nozzles are also available on the market that can be adapted to the end of the suction tube of almost all vacuum cleaner models. These nozzles have a special space inside which specific filters are fitted to trap the PM dust collected from surfaces. The filter must be inserted into the adapter nozzle mounted at the end of the vacuum cleaner tube. It is necessary to check that there is optimal contact between the adapter nozzle and the surface being sampled and that air dispersion is not encouraged during collection.

The aspiration must be strictly standardised in terms of both the duration of the sampling and the surface area involved.

When the specific objective of sampling is to determine the concentration of allergens present in a given environment/area/space in the office, it is advisable to select the appropriate

environment/area/space for sampling where allergens could potentially accumulate based on the room being examined and express the result in µg of allergen per gram of dust -PM collected in a specific filter (µg/g) or µg/m^2 of sampled surface area per minute.

One of the most critical stages of the entire process is choosing the rooms/areas/spaces to be sampled, as these must be representative of the allergen load actually present in the PM dust that has settled in the sampled room/area/space of the office. After the PM dust has been vacuumed, the adapter nozzle is detached from the vacuum cleaner tube and the filter inside it is removed. The filter containing the PM dust is placed in the appropriate container (plastic bag). The adapter nozzles can be washed with common detergents, thoroughly rinsed with running water, and reused for other PM dust samples.

It is good practice to transport samples at a controlled temperature (5°C±3°C) from the place of collection to the place of analysis. If laboratory testing is not carried out immediately and the extraction phase is postponed, the filters can be stored at -20°C until the time of analysis.

2.4. Methods of analysis

2.4.1. Analysis methods for bacteria and fungi

Another key parameter for assessing indoor air quality is the concentration of microorganisms collected in the environment in viable conditions, e.g. cultivable using analytical techniques which, with targeted incubation times and temperatures, are able to highlight and distinguish bacteria and fungi of a specific environmental nature (25-30°C for t > 24 h), or of more restricted human origin (30-37°C for t = 24 h).

In office environments, where there are high levels of relative humidity and a large amount of paper material, in addition to environmental bacteria and fungi, actinomycetes can also be found. These organisms have optimal growth temperatures between 15°C and 37°C, and their presence can contribute to the overall assessment of air quality in monitored indoor environments.

The most important methods for investigating bioaerosol samples include direct culture methods and biological, biochemical, immunological and molecular analyses. Considering that many species of microorganisms of typically environmental origin are difficult to cultivate in the laboratory and that their development times on culture media can be very long, it would be very important to be able to use molecular biology techniques that can detect and distinguish specific microorganisms, even in the absence of growth. The most commonly used techniques are based on in vitro amplification of nucleic acids using Polymerase Chain Reaction (PCR). After amplification, a confirmation phase is required, involving sequencing of the amplified fragments or hybridisation with labelled probes. However, although molecular techniques have the advantage of being able to detect even microorganisms that are difficult to culture, these techniques are not yet standardised and are rarely used in air monitoring.

With the direct enumeration method, viable microorganisms collected from the air are highlighted and counted on a plate as CFU and then, after appropriate isolation, can be identified by performing biochemical or molecular tests. This analytical method can be used not only after air sampling with filter and suction samplers from the liquid or agar collection medium with which the sampler is equipped, but also for samples collected by bubbling and after elution of the filter membranes, or to analyse dust and swabs taken directly from surfaces.

The direct counting method is also suitable for detecting the presence of infectious agents such as staphylococci and pathogenic fungi, where the analytical investigation goes beyond the simple enumeration of airborne microbial flora. It should be noted here that agarized culture often underestimates the actual density of microorganisms present in the air, and that this can be

attributed to various causes: the requirement for specific nutritional or growth conditions by certain microorganisms, the release of inhibitory substances that can slow down or halt the development of surrounding cells, a situation that also occurs in the presence of an excessive density of microorganisms on the agar culture medium, where so-called "contact" inhibition due to adjacent growth can be observed.

In the bioaerosol sampled in offices, the search for saprophytic bacteria and fungi involves the use of non-selective culture media that allow the growth of a wide variety of microorganisms, as is the case with microbiological analyses of environmental samples of any origin, not just indoor air. The search for specific microorganisms, such as staphylococci, enterobacteria, actinomycetes, *Pseudomonadaceae*, *Enterobacteriaceae*, and *Legionella*, requires the use of selective methods and culture media suitable for their detection and subsequent quantification and identification.

For the growth of microorganisms detectable in offices, both selective and non-selective culture media are widely available on the market, with complete formulations to be handled, prepared and set up according to the manufacturer's instructions. However, it is also possible to use ready-made plates with commercially available culture media as an alternative.

Both the enumeration and subsequent identification of colonies grown on the culture medium should be carried out according to the specific instructions provided by the manufacturer of the medium itself. To test the efficiency and sterility of the media used, it may be useful to employ control microorganisms.

When it comes to identifying and classifying fungi, proven and specific experience in the field is essential in order to be able to identify the different morphologies, fruiting bodies and structural elements that distinguish the different species. The recognition of fungi must take into account both the macroscopic morphological characteristics of the colony, such as appearance, shape, colour and texture, and the microscopic characteristics, consisting of the morphology of the reproductive structures and the type of spores produced, as well as the development and growth times of the colonies themselves.

There is no standardized procedure for detecting *Legionella* in bioaerosols. The reference culture method is ISO 11731, the international standard for detecting *Legionella* in water, which, however, does not provide guidance on air volumes, types of samplers, or optimal collection times. This method can be applied to the collection liquid of the bioaerosol, but the isolation of the microorganism from this matrix is complex and may require large volumes of air and prolonged sampling; for this reason, it is generally preferable to test for *Legionella* in the water of humidifiers or in the condensate water of ATUs rather than directly in the air.

For a more detailed and in-depth description of the analytical methods relating to bioaerosols, the choice of culture substrates, temperatures and incubation times, please refer to *Rapporto ISTISAN* 13/37 (Bonadonna *et al.*, 2013).

2.4.2. Analysis methods for viruses

For virus detection in offices, as in other indoor environments, the procedures following sampling (air or surfaces) vary depending on the objective of the analysis: the identification of viable viruses requires culture methods, while the search for viral genetic material is based on molecular techniques.

Isolation on cell cultures is the traditional diagnostic method for detecting viable viruses. The presence of viruses manifests itself through cellular alterations (cytopathic effect) such as loss of shape, enlargement, cellular inclusions and necrosis. However, this technique has some limitations: there are no cultures suitable for all viruses (e.g. norovirus, HAV, HEV) and growth times can vary from 1 to 4 weeks. Molecular techniques, on the other hand, based on the search

for viral genome sequences, are increasingly used for the identification of viruses in indoor environments, thanks to their greater sensitivity compared to culture methods.

The most commonly used techniques are based on in vitro amplification of nucleic acids using PCR. After amplification, a confirmation phase is required, involving sequencing of the amplified fragments or hybridisation with labelled probes. *Real-time* PCR represents an evolution of classic PCR, as it allows simultaneous amplification and quantification of the target DNA. New multiplex *Real-Time* PCR platforms enable simultaneous analysis of multiple respiratory viruses, increasing the effectiveness of environmental monitoring (Zhou *et al.*, 2025; Li *et al.*, 2023; Zhang J *et al.*, 2022). Finally, digital PCR (dPCR) technologies are emerging as the *gold standard* for absolute quantification of viral particles in environmental sampling. The ability of dPCR to provide absolute quantification and greater sensitivity makes it a promising technique for air quality monitoring and risk assessment of exposure to viral pathogens in various indoor environments, especially for low-concentration viruses (Kim *et al.*, 2023; Li *et al.*, 2022; Zhou *et al.*, 2025). In addition to traditional PCR and *digital* PCR (dPCR), the use of viral metagenomics has recently emerged (Hall *et al.*, 2013; Kwok *et al.*, 2022). This approach significantly expands the capacity to detect and identify airborne viruses, overcoming the limitations of target-specific methods, which require prior knowledge of the virus to be searched for.

2.4.3. Analysis methods for allergens

The procedures for analysing allergens present in offices consist of several stages, which are briefly described below. For a detailed description and in-depth analysis of the analytical methods, please refer to the *Rapporto ISTISAN* 13/37 (Bonadonna *et al.*, 2013).

Extraction

After collecting the sample for the analysis of detectable allergens in dust, the extraction procedure first requires the dust sample to be sieved using a n. 45 *mesh* filter.

The fine powder obtained in this way must be weighed in order to determine the volume of buffer to be used for the quantity of powder in question. The method currently most widely used involves extracting samples based on the following ratio: 100 mg of fine powder (after sieving) in 2 mL of Phosphate Buffered Saline (PBS) Tween 0.05%. After adding the appropriate volume of buffer, the tube must be shaken on a shaker under the conditions specified in the protocol. All operations must be performed with great care and the shaking must be set to the minimum power of the instrument so as not to create foam in the sample. The tube should then be centrifuged and the supernatant should be divided into aliquots and stored at -20°C until analysis. As mentioned above, the concentration of allergens measured using the surface sampling method is expressed in terms of μg of allergen per gram of dust (μg/g) or μg of allergen/m^2 per minute, depending on the sampling protocol applied.

Allergen dosages in dust samples after extraction

Following the extraction phase, any allergens present in the extracted samples are measured. Together with the sampling procedure, allergen analysis is one of the most critical aspects of the entire process.

The most widely used and most suitable method for quantitatively determining specific allergens in dust extracts is the ELISA assay. If you want to develop and validate this method in-house, the starting material required is a sample to be used as a standard, with a known concentration, for preparing a standard curve on which to interpolate samples with unknown concentrations. Generally, the standard is represented by the allergen of interest. In addition,

monoclonal or polyclonal antibodies specific to the allergen in question and extracts of dust collected from the environments to be tested are required. Currently, for the most common indoor allergenic species, monoclonal/polyclonal antibodies and their respective allergens for use as standards are commercially available, as are all other necessary reagents (secondary antibody, washing buffers, chromogenic substrate). The availability of all reagents makes it easier than in the past to develop and validate an in-house method. The principle of the method involves coating the wells of an ELISA plate with the monoclonal antibody specific for the antigen to be measured, in a phase called coating, which involves incubating the plate to bind the antibody to the wells. This is followed by a series of steps consisting of three or four washes to remove unbound antibody, incubation of the plate with a bovine serum albumin solution or another solution containing molecules that saturate the plastic portions to which the primary monoclonal antibodies did not bind during the coating phase.

After a further washing phase, the antigen (allergen) present in the standard at a known concentration (standard curve) and any antigen contained in the dust sample extracts are introduced at different concentrations into the individual wells. If present in the extracts, the antigen binds to the specific adsorbed antibody. All allergens may be present simultaneously in the dust samples, for example, the major allergens from cats, dogs, mites, etc. Obviously, the binding of each antigen will be determined by the specificity of the antibody adsorbed onto the plate. All other antigens will be eliminated during the subsequent washing phase. In fact, after appropriate incubation, the washes performed serve to eliminate excess and/or non-specific antigens. At this point, a second antibody, monoclonal or polyclonal, is introduced, which is also specific for the antigen under examination, but for an epitope different from the one recognised by the antibody used for the coating. This antibody is typically conjugated with a specific enzyme (peroxidase or phosphatase) that will bind to the Fc portion of the second antibody. The reactivity of the individual wells of the entire system (consisting of the specific antibody used for coating, the allergen, and the second antibody conjugated with the enzyme) is then visualised with a suitable chromogenic substrate, depending on the enzyme used. As mentioned above, an appropriate reference standard with a known concentration is essential for obtaining a standard curve on which to interpolate the optical densities obtained with the tested dust extract samples, in order to determine their concentration.

A range of ELISA systems are currently available on the market in the form of kits for detecting and quantifying the presence of indoor allergens using monoclonal antibodies specific to individual allergens. It is also possible to produce these reagents independently, purify them and use them to measure individual allergens. In any case, regardless of the nature of the reagents and their origin, as mentioned at the beginning of this paragraph, a crucial aspect is not only the development but also the validation of the quantitative ELISA method in accordance with the requirements of the ICH Q2 (R2) guideline "Guideline on validation of analytical procedures" (Committee for Medicinal Products for Human Use, 2023).

Naturally, even in the case of a method that has already been validated, e.g. by another laboratory or by a company that markets it, in order to be able to provide reliable results, the laboratory using the method is required to carry out further validation, albeit reduced, to demonstrate that the method is suitable for use in its own laboratory and with the personnel performing it. This aspect is fundamental in order to provide real support to the scientific community and regulatory authorities. In fact, it is important to obtain reproducible data that is as realistic as possible in order to assess air quality and establish corrective actions to limit the presence of allergens in indoor environments. In order to provide reliable data, it is also extremely important to always include one or two reference samples as positive and negative controls in each ELISA assay. The control data must obviously be reproducible and the standard curve must always be within the parameters established during the method validation phase. It is also advisable to perform at least

four or five twofold dilutions for each sample to be assayed (each dilution repeated in duplicate or triplicate). This provides at least three points that can be interpolated in the linear portion of the standard curve, providing the allergen concentration of the sample after appropriate statistical calculations. Therefore, the values obtained, corrected by the calculation system for the dilution factor, and based on the experimental results obtained for at least the three dilution points, will be reliable and consistent with modern concepts of analytical method validation.

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APPENDIX A
WHO guide and reference values used in some European countries for chemical and biological pollutants

A1. MAIN POLLUTANTS: unit risk* and indoor air quality guidelines/reference values set by the WHO and some European countries**

Pollutant unit of measure	WHO	France	Germany	Netherlands	United Kingdom	Belgium Flemish Region	Finland	Austria	Portugal	Norway	Lithuania	Poland
Benzene µg/m^3	**No GV** **UR/lifetime** 0.17 (10^{-6}) 1.7 (10^{-5})	30 (24 h) 10 (1 y) **RA** 10 **LP** 2 from 1/1/2018 **UR/lifetime** 0.2 (10^{-6}) 6 (10^{-5})	**No GV** **UR/lifetime** 4.5 (10^{-6}) (temporary)	20	**No GV** **UR/lifetime** 0.17 (10^{-6}) 1.7 (10^{-5})	0.4 if **EC** ≤0.4 µg/m³ in any other case **EC**: **IV**	–	–	5 (8 h)	--	10 (24 h)	20 (8 h)
Nitrogen dioxide µg/m^3	25 (24 h) 10 (1 y)	200 (1 h) 20 (1 y)	**RW I** 80 (1 h) **RW II** 250 (1 h)	200 (1 h) 40 (1 y)	200 (1 h) 40 (1 y)	20 (1 y) **IV** 40	–	–	–	200 (1 h) 100 (24 h)	85 (1 h) 40 (24 h)	–
Dichloro-methane µg/m^3	3000 (24 h) 450 (7 dd)	–	**RW I** 200 (24 h) **RW II** 2000 (24 h)	200 (1 y)	–	–	–	–	–	–	8800 (1 h) 3000 (24 h)	–
Formaldehyde µg/m^3	100 (30 min)	10 (1 y) **RA** 100 **LP** 10	100	120 (30 min) 10 (1 y) **LP** 1.2	100 (30 min) 10 (1 y)	**IV** 100	100 (30 min) 50 (1 y)	100 (30 min) 60 (24 h)	100 (8 h)	100 (30 min)	100 (1 h) 10 (24 h)	100 (8 h)
PAH (BaP) **ng/m^3**	**No GV** UR/lifetime 0.012 (10^{-6}) 0.12 (10^{-5})	**No GV**	**No GV** **UR/lifetime** 0.80 (10^{-6}) (temporary)	1.2	**No GV**	0.012 (1 y) **IV** 0.1	–	–	–	–	1 (24 h)	–
Carbon monoxide mg/m^3	4 (24 h) 7(24 h)	100 (15 min) 60 (30 min) 30 (1 h) 10 (8 h)	100 (15 min) 35 (1 h) 10 (8 h) 4 (24 h)	100 (15 min) 60 (30 min) 30 (1 h) 10 (8 h)	100 (15 min) 30 (1 h) 10 (8 h)	8 (24 h)	7 (1 min)	–	10 (8 h)	96 (15 min) 25 (1 h) 10 (8 h)	5 (1 h) 3 (24 h)	10 (8 h)
Naphtalene µg/m^3	10 (1 y)	10 (1 y)	**RW I** 10 (7 dd) **RW II** 30 (7 dd)	25	3 (1 y)	3 (1 y) **IV** 31	10	–	–	–	3 (1 h) 3 (24 h)	150 (8 h)

Pollutant unit of measure	**WHO**	**France**	**Germany**	**Netherlands**	**United Kingdom**	**Belgium Flemish Region**	**Finland**	**Austria**	**Portugal**	**Norway**	**Lithuania**	**Poland**
Ozone µg/m^3	60 (8 h) *if **EC** maximum daily half-yearly average* 100 (8 h) *if **EC** moving half-yearly average*	-	–	25	100 (8 h)	40 (8 h) **IV** 78	–	60 *4 times/d 15 min a 1h intervals permitted* 70 (24 h)	–	–	160 (1h) 30 (24 h)	150 (8 h)
PM_{10}	45 (24 h) 15 (1 y)	50 (24 h) 20 (1 y) **RA** 75 **LP** 15	–	50 (24 h) 20 (1 y)	–		50 (24 h)	–	50 (8 h)	90 (8 h)	50 (24 h)	–
$PM_{2.5}$	15 (24 h) 5 (1 y)	25 (24 h) 10 (1 y) **RA** 50 **LP** 10	15 (24 h)	25 (24 h) 10 (1 y)	–	10 (1 y)	25 (24 h)	–	25 (8 h)	40 (8 h)	40 (24 h)	–
Styrene µg/m^3	260 (7 dd) 70 (30 min)	–	**RW I** 30 (7 dd) **RW II** 300 (7 dd)	900	850 (1 y)	260 (1 y) **IV** 2500	40	40 (7 dd) 10 (1 h)	–	--	40 (1 h) 2 (24 h)	30 (8 h)
TVOC µg/m^3	–	–	–	200 (1 y)	300 (8 h)	300 (1 y) **IV** 1000	400	<250 (1 y) *Upon delivery of construction works*: 500-1000 *→ likely specific sources* 100-300 *→ present specific sources* 300 *→ after completion*	600 (8 h)	400	400	–

Pollutant unit of measure	WHO	France	Germany	Netherlands	United Kingdom	Belgium Flemish Region	Finland	Austria	Portugal	Norway	Lithuania	Poland
Tetrachloro-ethylene µg/m^3	250 (1 y) 8000 (30 min)	1380 (1-14 dd) 400 (1 y) **UR/lifetime** 40 (10^{-5})	–	250	40 (24 h)	4 (1 y) **IV** 38	–	250 (7 dd)	–	–	500 (1 h) 60 (24 h)	–
Toluene µg/m^3	260 (7 dd) 1000 (30 min)	20000 (1 y)	**RW I** 300 (1-14 dd) **RW II** 3000 (1-14 dd)	200 (1 y)	15000 (8 h) 2300 (24 h)	5000 (1y) **IV** 14000	–	75 (1 h)	–	–	600 (1 h) 600 (24 h)	250 (8 h)
Trichloro-ethylene µg/m^3	**No GV** **UR/lifetime** 2.3 (10^{-6}) 23 (10^{-5})	**RA** 50 **UR/lifetime** 10 (10^{-5})	**UR/lifetime** 20 (10^{-6})	–	**No GV** **UR/lifetime** 2.1 (10^{-6}) 21 (10^{-5})	0.2 (1 y) **IV** 2.5	–	–	–	--	4000 (1 h) 1000 (24 h)	200 (8 h)

* **Unit Risk/lifetime**. For the correct use of these data, it is recommended to consult the air quality guidelines (AQG) provided by the WHO in the original work; the estimate of the unit risk increase is understood as the additional risk of cancer that may occur in a hypothetical population in which all individuals are continuously exposed, from birth and throughout their entire lifetime, to a concentration of the risk agent in the air they breathe.

** Indoor air quality guidelines indicate the levels of pollutant concentration in the air, associated with exposure times, at which no adverse health effects are expected for non-carcinogenic substances.

y: year; **d:** day; **dd:** days; **min:** minutes

RA: Rapid Action
EC: External Concentration
LP: Long Period
No GV: No Guide Value
IV: Intervention Value
RW I: Richtwert I. concentration of a single substance below which, based on current knowledge, no damage to health is expected. The guideline value RW I is derived from RW II.
RW II: Richtwert II. concentration of a substance whose exceedance requires immediate action; it is an operational value.

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A2. BIOLOGICAL POLLUTANTS: Indoor quality standards for bioaerosols set by the WHO, some international associations and European and non-European countries.

Biological agents UFC/m³	WHO[a]	ECA[b]	ACGIH[c]	IAQA[d]	China[e]	Russian Federation[f]	Germany[g]		Poland[h]	Poland[i]
	R	UP	R	R	R	R	R	PO	R	PO
Gram positive bacteria	-	-	-	-	-	-	>1000 → *health risk*		-	-
Total bacteria	-	<50 (**VL**) <100 (**L**) <500 (**I**) <2.000 (**H**) >2.000 (**VH**)	<100 (**VL**) <500 (**L**) <2500 (**I**) <10.000 (**H**) >10.000 (**VH**)	-	<2500	-	-	-	≤1000	≤7000
Total fungi (moulds)	0 *(patogens)* >50 *(if only one species is present)* → *corrective procedures* ≤150 *(if there are several species)* → *acceptable* >500 *(if Cladosporium or other plant fungi are present)* → *acceptable*	<25 (**VL**) <100 (**L**) <500 (**I**) <2.000 (**H**) >2.000 (**VH**)	<50 (**VL**) <200 (**L**) <1000 (**I**) <10.000 (**H**) >10.000 (**VH**)	>300 *(if common fungal species)*	-	1000-10.000 *(in relation to the species)*	>500 *(if even a single pathogenic species is present)* → *health risk* >10.000 → *health risk*	>100 → *uncontaminated* Concentration ratio *indoor/outdoor* <1 *(if present same species/genus)* → *uncontaminated*	10	10.000

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R: residential; **PO**: public offices
Pollution: very low (**VL**); low (**L**); intermediate (**I**); high (**H**); very high (**VH**)

APPENDIX B
Questionnaire for the collection of basic information on offices environments for indoor air assessment

Questionnaire on the construction characteristics of building/flats/office environments for the assessment of indoor air quality

(fill in a form for each environment to be assessed)

A - General characteristics of the individual environment

Area surface ..... m^2

Height ..... m

Door/entrance width ..... m

Floor ❑ ground
❑ no. floor .....

Sealed doors: ❑ yes ❑ no

Doors ❑ close ❑ open

Window exposure: ❑ south ❑ north ❑ west ❑ east

Window that can be opened without any obstacles ❑ yes ❑ no

Window opening mode	vasistas/bottom-hung	❑ yes	❑ no
	single-leaf hinged	❑ yes	❑ no
	double hinged	❑ yes	❑ no
	hinged and vasistas/bottom-hung	❑ yes	❑ no
	sliding	❑ yes	❑ no
	“intelligent” automatic	❑ yes	❑ no

Window(s) with insulating glass ❑ yes ❑ no

Sealed windows ❑ yes ❑ no

Single window width ..... m

Multiple window width ..... m

Presence of shielding (e.g. sun blinds, etc.) ❑ yes ❑ no

Balcony exposure: ❑ south ❑ north ❑ west ❑ east

Openable balconies ❑ yes ❑ no

Balconies that can be opened without any obstacles ❑ yes ❑ no

Balcony opening mechanism	vasistas/bottom-hung	❑ yes	❑ no
	single-leaf hinged	❑ yes	❑ no
	double hinged	❑ yes	❑ no
	hinged and vasistas/bottom-hung	❑ yes	❑ no
	sliding	❑ yes	❑ no

Balconies with insulating glass	❑ yes	❑ no
Presence of external shielding (e.g. sun blinds, etc.)	❑ yes	❑ no
External walls exposed to:		
❑ south ❑ north ❑ west ❑ east		
Presence of general mechanical ventilation system	❑ yes	❑ no
Presence of an autonomous mechanical ventilation system in every work area	❑ yes	❑ no
Presence of vents, diffusers or intake and exhaust grilles	❑ yes	❑ no
Conditioned environment	❑ yes	❑ no
Air deflectors on vents or supply grilles of ventilation systems or on fan coils or split systems	❑ yes	❑ no
Energy Performance Certificate	❑ yes	❑ no
Visible moisture	❑ yes	❑ no
Visible leaks	❑ yes	❑ no
Visible mould on the walls	❑ yes	❑ no
Presence of photocopiers, laser printers	❑ yes	❑ no
Presence of a garage integrated into the building	❑ yes	❑ no
Presence of pests (rodents, insects, etc.)	❑ yes	❑ no
Presence of Smoking areas	❑ yes	❑ no
Presence of toilets/showers	❑ yes	❑ no
Presence of kitchen	❑ yes	❑ no
Presence of flowers	❑ yes	❑ no
Presence of internal curtains	❑ yes	❑ no
Presence of air purifiers	❑ yes	❑ no
Presence of smokers	❑ yes	❑ no
Presence of air fresheners	❑ yes	❑ no
Presence of vegetation/plants	❑ yes	❑ no

Information about the building and the area where the office is located

Age of building: ❑ < 6 months
❑ < 2 years
❑ < 10 years
❑ 10-20 years
❑ > 20 years

Type of area: ❑ rural
❑ urban (suburban)
❑ urban (center)
❑ industrial
❑ other *(specific)* .....

Characteristics of the area
Traffic: ❑ light ❑ heavy
Industrial: ❑ heavy ❑ chemical ❑ traditional
Distance from major external sources of pollution in km: .....
Presence of trees or green ❑ yes ❑ no if yes, of what type .....
Regular pruning ❑ yes ❑ no
Regular maintenance ❑ yes ❑ no

Water and/or moisture damage

Is there damage from water infiltration? ❑ yes ❑ no
If so, how long? .....
Type of damage: .....
Location: .....

Visible molds are present? ❑ yes ❑ no
If so, how long? .....
Type of mold: .....
Location: .....

Reorganization interventions are in progress? ❑ yes ❑ no

Walls and floor

Tile floor: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Terracotta floor: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Linoleum floor: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Wallpaper: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Plastic coatings: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Stucco: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Covered panels: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Wooden panels: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Parquet floor: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Carpets: ❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Other materials (*specific*): .....
❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Windows

The windows are present:

❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Window opening mode	vasistas/bottom-hung	❑ yes	❑ no
	single-leaf hinged	❑ yes	❑ no
	double hinged	❑ yes	❑ no
	hinged and vasistas/bottom-hung	❑ yes	❑ no
	sliding	❑ yes	❑ no
	"intelligent" automatic	❑ yes	❑ no
Non opening window		❑ yes	❑ no

The windows are opened regularly

During activities ❑ no ❑ yes how many hours, ...
At what moment/during what period of the day
……

During public opening hours ❑ no ❑ yes how many hours, ...
At what moment/during what period of the day
……

During breaks ❑ no ❑ yes how many hours, ...
At what moment/during what period of the day
……

Balconies

Balconies are present:

❑ yes ❑ no if yes, age (years) .....
in poor condition ❑ yes ❑ no

Balconies opening mode	vasistas/bottom-hung	❑ yes	❑ no
	single-leaf hinged	❑ yes	❑ no
	double hinged	❑ yes	❑ no
	hinged and vasistas/bottom-hung	❑ yes	❑ no
	sliding	❑ yes	❑ no
Non opening balconies		❑ yes	❑ no

Balconies are opened regularly:

During activities ❑ no ❑ yes how many hours, ...
At what moment/during what period of the day
……

During public opening hours ❑ no ❑ yes how many hours, ...
At what moment/during what period of the day
……

During breaks ❑ no ❑ yes how many hours, ...
At what moment/during what period of the day
……

Internal openings, e.g. doors

❑ yes ❑ no if yes, age (years) .....
Open regularly ❑ yes ❑ no
How many hours,.....
At what moment/during what period of the day
……

Information on the HVAC and/or air conditioning system

What type of system is present?

❑ centralized HVAC ❑ non-centralized air conditioning ❑ either

If yes, ❑ with what type of air filter: ……
❑ without filter

Is the system operating with % recirculation? ❑ yes ❑ no
If yes, what is the recirculation %?.....

The system has been in operation since: …… to: ……
Is the system equipped with structures for monitoring the main parameters? ❑ yes ❑ no
If so, which ones?.....
Are there intake and discharge vents? ❑ yes ❑ no
Is the air path known? ❑ yes ❑ no

Can the HVAC system be regulated by staff during both the cold and hot seasons?

❑ yes ❑ no

Are the intake and exhaust vents positioned correctly so that the "clean air" flows through the entire office, environment or space before being extracted? ❑ yes ❑ no
Have the intake and exhaust vents been cleaned? ❑ yes ❑ no
If yes, on what date? |_|_|_|_|_|_|_|_|
who performs the intervention:……..
Is the system equipped with humidification? ❑ yes ❑ no
Has the absence of water stagnation/mould in the condensate collection tank been verified? ❑ yes ❑ no
Is there rust on the system? ❑ yes ❑ no
Is there water leaking from the outside of the unit? ❑ yes ❑ no

Have the system's air speeds and flows been checked? ❑ yes ❑ no
If yes, on what date? |_|_|_|_|_|_|_|_|
who performs the intervention:

Has maintenance been carried out on the system? ❑ yes ❑ no
If yes, on what date? |_|_|_|_|_|_|_|_|
what type? ❑ total
❑ partial
what was serviced and/or replaced during the intervention? .....
who performs the intervention:

Is there a logbook for the system? ❑ yes ❑ no

Information about the air conditioning system

What type of system is present?

❑ centralized HVAC ❑ non-centralised split/heat pump ❑ either

If yes, ❑ with what type of air filter: ……..
❑ without filter

Is the system operating with % recirculation? ❑ yes ❑ no
If yes, what is the recirculation %?.....

Can the air conditioning system be regulated during both the cold and hot seasons?

❑ yes ❑ no

Do the air outlets directly affect staff? ❑ yes ❑ no

The system has been in operation since: …… to: ……
Is the system equipped with structures for monitoring the main parameters? ❑ yes ❑ no
If so, which ones?.....
Are there intake and discharge vents? ❑ yes ❑ no
Have the intake and exhaust vents been cleaned? ❑ yes ❑ no
If yes, on what date? |_|_|_|_|_|_|_|_|
who performs the intervention:……..
Is the system equipped with humidification? ❑ yes ❑ no
Has the absence of water stagnation/mould in the condensate collection tank been verified? ❑ yes ❑ no
Is there rust on the system? ❑ yes ❑ no
Is there water leaking from the outside of the unit? ❑ yes ❑ no

Have the system's air speeds and flows been checked? ❑ yes ❑ no
If yes, on what date? |_|_|_|_|_|_|_|_|
who performs the intervention:

Has maintenance been carried out on the system? ❑ yes ❑ no
If yes, on what date? |_|_|_|_|_|_|_|_|
what type? ❑ total
❑ partial
what was serviced and/or replaced during the intervention? .....
who performs the intervention:

Is there a logbook for the system? ❑ yes ❑ no

Renovations in recent months

Restorations were carried out? ❑ yes ❑ no
if yes, what has been renovated?
- ❑ Entire building
- ❑ Entire floor
- ❑ Hallway

There have been other changes in the office
or in its immediate vicinity? ❑ yes ❑ no

New windows/doors/balconies in recent months

Have the windows/frames/doors been replaced? ❑ yes ❑ no
If so, in which rooms? .....

In every room ❑ yes ❑ no
What type, e.g. vasistas/bottom-hung window?.....

At the time of purchase, an assessment of the emission load was carried out ❑ yes ❑ no

New furniture in recent months

Has new furniture been added? ❑ yes ❑ no
If so, which ones? .....

At the time of purchase, an assessment of the emission load was carried out ❑ yes ❑ no

Furniture certifications: ❑ yes ❑ no

In poor condition ❑ yes ❑ no

Cleaning products used in rooms/open spaces/meeting rooms

Al momento dell'acquisto o del disciplinare di gara è stata fatta una valutazione delle emissioni di COV
❑ yes ❑ no

❑ Floor cleaning

Treatments performed and sequence of operations: .....
.....
frequency: ❑ rarely ❑ often
Name and brand of cleaning products used: .....
❑ diluted ❑ concentrate ❑ super-concentrate
Product certification and characteristics ❑ yes ❑ no
Label concentration of VOCs: .....
Who performs the intervention: .....
Latest intervention |_|_|_|_|_|_|_|_|

❑ Windows cleaning

Treatments performed and sequence of operations: .....
.....
frequency: ❑ rarely ❑ often
Name and brand of cleaning products used: .....
❑ diluted ❑ concentrate ❑ super-concentrate
Product certification and characteristics ❑ yes ❑ no
Label concentration of VOCs: .....
Who performs the intervention: .....
Latest intervention |_|_|_|_|_|_|_|_|

Cleaning products used for furniture

Treatments carried out and sequence of operations: .....
.....
frequency: ❑ rarely ❑ often
Name and brand of cleaning products used: .....
❑ diluted ❑ concentrated ❑ super-concentrated
Product certification and characteristics ❑ yes ❑ no
Label concentration of VOCs: .....
Who performs the cleaning: .....
Last cleaning |_|_|_|_|_|_|_|_|

Cleaning products used for the kitchen/relax areas

❑ Floor cleaning

Treatments performed and sequence of operations: .....
.....
frequency: ❑ rarely ❑ often
Name and brand of cleaning products used: .....
❑ diluted ❑ concentrated ❑ super-concentrated
Product certification and characteristics ❑ yes ❑ no
Label concentration of VOCs: .....
Who performs the cleaning: .....
Last cleaning |_|_|_|_|_|_|_|_|

❑ Cooking surface and table cleaning

Treatments performed and sequence of operations: .....

.....

frequency: ❑ rarely ❑ often

Name and brand of cleaning products used: .....

❑ diluted ❑ concentrated ❑ super-concentrated

Product certification and characteristics ❑ yes ❑ no

Label concentration of VOCs: .....

Who performs the cleaning: .....

Last cleaning └ ┴ ┴ ┴ ┴ ┴ ┴ ┴ ┘

Cleaning products used for fixed and mobile air system

❑ Cleaning of HVAC systems

Treatments performed and sequence of operations: .....

.....

frequency: ❑ rarely ❑ often

Name and brand of cleaning products used: .....

❑ diluted ❑ concentrated ❑ super-concentrated

Product certification and characteristics ❑ yes ❑ no

Label concentration of VOCs: .....

Who performs the cleaning: .....

Last cleaning └ ┴ ┴ ┴ ┴ ┴ ┴ ┴ ┘

❑ Cleaning of air conditioners and/or heat pumps

Treatments performed and sequence of operations: .....

.....

frequency: ❑ rarely ❑ often

Name and brand of cleaning products used: .....

❑ diluted ❑ concentrated ❑ super-concentrated

Product certification and characteristics ❑ yes ❑ no

Label concentration of VOCs: .....

Who performs the cleaning: .....

Last cleaning └ ┴ ┴ ┴ ┴ ┴ ┴ ┴ ┘

❑ Cleaning of air purifiers

Treatments performed and sequence of operations: .....

.....

frequency: ❑ rarely ❑ often

Name and brand of cleaning products used: .....

❑ diluted ❑ concentrated ❑ super-concentrated

Product certification and characteristics ❑ yes ❑ no

Label concentration of VOCs: .....

Who performs the cleaning: .....

Last cleaning └ ┴ ┴ ┴ ┴ ┴ ┴ ┴ ┘

Information on heating/cooling/split/heat pump type

What type of heating is available?

❑ centralized ❑ non centralized ❑ either

If centralized, what type is it?

❑ radiator
❑ fancoil unit
❑ other *(please specify)*.....

If non centralized, what type is it?

❑ split
❑ heat pump
❑ other *(please specify)*.....

Can the ventilation/air conditioning system be regulated in both cold and hot weather? ❑ yes ❑ no

Do the air vents directly affect staff? ❑ yes ❑ no

Has maintenance been carried out on the split units/heat pump/other? ❑ yes ❑ no

If yes, on what date? |_|_|_|_|_|_|_|_|

and what type? ❑ total
❑ partial

what was serviced and/or replaced during the intervention?.....

who performs the intervention: .....

Type of heating fuel

❑ natural gas (city distribution)
❑ diesel
❑ biomass *(please specify)*.....
❑ other *(please specify)*.....

Information on the type of air fan present

What type of fan is present?

❑ mobile ❑ tableware ❑ other

Has maintenance been carried out on the fan? ❑ yes ❑ no

If yes, on what date? |_|_|_|_|_|_|_|_|

and what type? ❑ total
❑ partial

what was serviced and/or replaced during the intervention?.....

who performs the intervention: ……..

Is there a logbook for the system? ❑ yes ❑ no

Information on the type of air purifier present

What type of air purifier is present?

❑ mobile ❑ tableware ❑ other

Position in the workplace……..

What technology does it work on?.....

Is there a record of operating modes and hours throughout the day? ❑ yes ❑ no

No. of operating hours ……

Has maintenance been carried out on the air purifier? ❑ yes ❑ no

If yes, on what date? |_|_|_|_|_|_|_|_|

and what type? ❑ total ❑ partial

what was serviced and/or replaced during the intervention?.....

who performs the intervention: ……..

Pest control and/or rodent control for environmental pests or insects

Are pest control and/or rodent control measures carried out for environmental pests? ❑ yes ❑ no

If yes, how frequently?

❑ rarely ❑ often

Was consideration given to the best time to carry out rat extermination so as not to affect staff?

❑ yes ❑ no

Who performs the intervention:

Last intervention ⌊_____⌋

Type of products used:

❑ insecticide
❑ pesticide
❑ other *(please specify)* .....

Product certifications: ❑ yes ❑ no

Concentration of products used:

❑ diluted
❑ concentrate
❑ super-concentrate

Home fragrances and insect repellent products

Are fragrances/air fresheners used? ❑ yes ❑ no

If yes, which ones?

❑ spray
❑ gel
❑ candles
❑ incense sticks
❑ essential oils
❑ other *(please specify)* .....

How frequently?

❑ often
❑ rarely

Last use ⌊_____⌋

Are insect repellents used? ❑ yes ❑ no

If yes, which ones?

❑ spray
❑ stick/plasters
❑ candles
❑ essential oils
❑ other *(please specify)* .....

How frequently?

❑ often
❑ rarely

Last use ⌊_____⌋

If so, when is the work expected to be completed? .....

B - Characteristics of office areas

Reception area

Single workstation ❑ yes ❑ no

Administrative area

Office with single workstation ❑ yes ❑ no

Office with multiple workstations ❑ yes ❑ no
no. of single workstation offices.....
no. of multiple workstation offices.....

Meeting rooms ❑ yes ❑ no

Common areas ❑ yes ❑ no

Other spaces (e.g. relax area) *(please specify)*: .....
.....

Kitchen area

Gas hob ❑ yes ❑ no
Induction hob ❑ yes ❑ no
Microwave oven ❑ yes ❑ no
Is there an extractor hood?
If so, how frequently is it used? *(please specify)*:.....
Is there a window/balcony?
If so, how frequently is it used? *(please specify)*:.....

Common area

Furniture ❑ yes ❑ no
Sofas and armchairs ❑ yes ❑ no
Television, stereo, billiards, table tennis ❑ yes ❑ no
Is there a window/balcony?
If so, how frequently is it used? *(please specify)*:.....
Is there a CMV ventilation system?
If so, how frequently is it used? *(please specify)*:.....

Smoking area

Smoking areas/rooms compliant with the DPCM of 23/12/2003 ❑ yes ❑ no
If yes, for how many years?.....
area characteristics .....

Tobacco smoke and electronic cigarettes

Average total amount of tobacco consumed per day by all persons present in the area: .....
Type: ❑ cigarettes ❑ cigars ❑ pipes
Frequency: ❑ regular ❑ occasional

Total number of people in the area who use e-cigarettes on average per day: .....
Frequency: ❑ regular ❑ occasional

C - Other information

Employed staff

During normal office use: no. people .....
During sampling: no. people permanently in the office .....

Are there any devices or other equipment? ❑ yes ❑ no
(e.g. printers, photocopiers)

Shared areas

Employees and customers

During normal use of the area: no. people .....
During sampling: no. people .....

PLEASE NOTE

In Italy, **smoking is no longer permitted in public and private offices.**

This prohibition must be clearly indicated and accompanied by regular checks to ensure compliance.

Smoking should be avoided in the immediate vicinity of the building's entrance door, windows or balconies serving the offices to prevent smoke from entering when doors/windows are opened.

APPENDIX C
Questionnaire for information reports to be recorded during indoor air monitoring

Questionnaire on indoor air monitoring activities in offices (buildings, flats, spaces)

(fill in a form for each environment to be assessed)

A – Information on monitoring activities

A1 - Reasons that led to indoor air detection

Periodic Evaluation: ❑ yes ❑ no
Assessment during maintenance or renovation work: ❑ yes ❑ no
Assessment after completion of maintenance or renovation work: ❑ yes ❑ no

Complaint placed for attention: ❑ yes ❑ no
Complaint of odor: ❑ yes ❑ no

❑ occasionally
❑ *early morning* ❑ *afternoon* ❑ *evening* ❑ *other*.....

❑ continuous
❑ *early morning* ❑ *afternoon* ❑ *evening* ❑ *other*.....

Health problems: ❑ yes ❑ no
Symptoms occur: ❑ yes ❑ no ❑ occasionally ❑ continuous
Such as: .....
When did they start?
❑ *early morning* ❑ *afternoon* ❑ *evening* ❑ *other*.....

A2 – Building address

……

A3 – Pollutants monitored

VVOCs: ❑ yes ❑ no if yes, which ones: .....
VOCs: ❑ yes ❑ no if yes, which ones: .....
SVOCs: ❑ yes ❑ no if yes, which ones: .....
PM_{10}: ❑ yes ❑ no
$PM_{2.5}$: ❑ yes ❑ no
Metals: ❑ yes ❑ no if yes, which ones: .....
Biological: ❑ yes ❑ no if yes, which ones: .....

A4 – Type of collection

❑ in real time ❑ manual
❑ continuos ❑ discontinuos
❑ active ❑ passive (diffusional)

A5 – Number of samples

……

A6 - Location of sampling systems

Distance from wall: ……. m

Height from floor: …….. m

A7- State of natural or mechanical ventilation

Usual before collection

❑ Ventilation with mechanical system (HVAC) and/or conditioner

How long the HVAC remains active? min .....

❑ Natural exchange of air

If so, when is it carried out?

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

❑ Windows, doors, balconies in the room

opening ❑ occasionally ❑ continuous

Se sì, quando vengono aperti?

windows

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

doors

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

balconies

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

Closure ❑ occasionally ❑ continuous

windows

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

doors

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

balconies

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

During collection

Status of the controlled mechanical ventilation system (HVAC)

❑ in operation
❑ turned off

Has the system been regulated by staff? ❑ yes ❑ no

Status of air conditioning system/split system/heat pump

❑ in operation
❑ turned off

Has the system been regulated by staff? ❑ yes ❑ no

Status of doors, windows and balconies

❑ closed windows, balconies and doors

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

❑ opened windows, balconies and doors

❑ *early morning* ❑ *afternoon* ❑ *evening* min .....

B - Period, type, microclimatic and climate data

B1 – Period of collection

Start: date …… time ……
End: date …… time ……
Total hours sampled: ……..

B2 - Microclimatic parameters during collection

Temperature: …… °C
Air velocity: …… m/s
Relative humidity: …… %

B3 - CO_2 levels during collection

Start..... ppm time ……
During ..... ppm time ……
Day ..... ppm time ……

B4 - Weather conditions during collection

Average outdoor temperature: …… °C
Average wind speed: …… m/s
Average relative humidity: …… %
Rain ❑ yes ❑ no
Fog ❑ yes ❑no
Snow ❑ yes ❑ no

C – Other information

C1 - Staff present during monitoring activities

During sampling: no. people permanently in the office .....

Day 1: no. people permanently in the office …… time ……
Day 2: no. people permanently in the office …… time ……
Day 3: no. people permanently in the office …… time ……
Day x: no. people permanently in the office …… time ……

Are there visitors? ❑ yes ❑ no

On which day no. Visitors in the office……
At what times/times of day……

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