An European project for the assessment of indoor air quality in school buildings

Elisabetta Cimnaghi, Andrea Di Maggio**, Maria Giovanna Dongiovanni****

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Abstract[1]

According to the definition of the Ministry of Environment and Protection of the Territory and the Sea, the indoor pollution is "the presence in the air of confined environments of physical, chemical contaminants and naturally not occurring in the outside air of high-level ecological systems quality" (1991).

If we consider that most of the European population spend up to 90% of their day in confined spaces breathing an air volume of about 15 m3 every 24 hours, it emerges that it is of fundamental importance to consider the indoor air quality as principle for health (Lee and Chang, 2000; ISPRA 2010).

In most cases, in fact – in the daily average – the indoor environment is more polluted than the outside, because the air is taken, often already contaminated, by outside and additional elements are added to it.

Indoor pollution originates from the occupants' personal activities, from the professional activities of the workers, from inadequate ventilation methods, from construction materials, from furnishings, from particular methods of cleaning and from the products used.

The subjects most sensitive to health effects due to the exposure of indoor pollutants, therefore exposed to a greater risk, are the elderly, children, asthmatics and people suffering from heart and lung diseases. Starting from these assumptions and turning the attention to the younger segment of the population, it is particularly urgent to understand what the students breathe during the hours spent at school.

This question is answered by a European project which lasts three years: InAirQ - Indoor Air Quality. The project aims to identify adaptation actions oriented to an integrated management of indoor air quality at a transnational level.

The project stems from the finding that most of the population spends most of the day indoors: hence the need of pollution assessments with regard to closed environments.

The InAirQ project, in particular, aims to describe the impact of indoor air quality on the health of children and young people aged between 6 and 15 years, with the ultimate goal of proposing actions to improve the healthiness of the environments school.

The project, funded by the Interreg Central Europe Program, involves 9 partners - 6 public institutions, 1 school, 1 research center, 1 interest group - in 5 countries: Italy, Slovenia, Czech Republic, Poland and Hungary. In Italy, SiTI (Istituto Superiore sui Sistemi Territori per l'Innovazione - Higher Institute on Territorial Systems for Innovation) and Fondazione per la Scuola (School Fundation) of the Compagnia di San Paolo, both based in Turin, are involved.

[1] The contribution is the result of the joint work of the three authors. Although the scientific responsibility is attributable to all three authors, the abstract and paragraphs 1, 2, 3 and 7 have been edited by Ing. Elisabetta Cimnaghi, while paragraphs 4, 5 and 6 by Ing. Mariagiovanna Dongiovanni and dall'ing. Andrea di Maggio jointly. The translation is edited by Elisabetta Cimnaghi.

The aim of this work is to retrace the main phases of the project, with particular attention to the social component, in terms of stakeholder engagement and comparison between the parties, to the proposed monitoring model, key element of the project to define improvement solutions and the drafting of the Action Plan, the operational outcome of the project.

To this end, the intent of the authors is to analyze the Italian case studies in terms of results achieved and to define guide lines of intervention.

1. INTRODUCTION TO THE CONCEPT OF INDOOR POLLUTION

Since the 1950s, the problem of outdoor air pollution, considered to be a source of danger for human wellbeing and health, has been the subject of numerous international studies in order to monitor and reduce emissions.

In this regard, the causes (car traffic, industrial plants, domestic heating systems, etc.) and the effects were identified and possible containment measures were proposed.

On the basis of the results obtained it was thought that the internal environment was a shelter from any type of substance present on the outside.

In reality, the quality of the air inside homes, offices, schools and, in general, buildings in which people spend most of their lives, represents a real threat to human health because the concentration of pollutants are often greater than the outside (Willard et al, 1975).

Obviously, the greater the outdoor pollution, the greater the risk for human health even within public and private buildings[2].

In general, indoor air quality is an important problem for public health, not only in terms of the risk of contracting more or less serious pathologies, but also of economic costs and decreasing productivity and general wellbeing of the population (Becchio *et al.,* 2018).

This is directly due to the increase in expenses related to emergencies, hospitalizations, drug therapies and indirectly to the lost of work or school days. These costs are also added to the non-quantifiable moral damages that fall on the patients and their families, causing a deterioration in the quality of life and loss of productivity.

Moreover, the scientific studies of recent decades have shown that some air pollutants are able to contribute to the increase in the incidence of malignant tumors; many chemical compounds present in the indoor air are potentially irritating or stimulating of the sensory apparatus and therefore the origin of feelings of discomfort.

The school is an environment in which indoor air quality is of decisive importance for occupant health as children are weaker and potentially more at risk. Recent sector studies have shown that a poorly comfortable or unhealthy indoor environment has negative repercussions on learning ability (EPA, 2018).

In recent years the attention of the scientific and institutional world has turned to the problems related to the air quality of the confined environments, maturing an ever greater sensitivity and awareness on the importance of comfort of confined environments (Comba *et al.*, 2007; Commission of the European Community, 2004; ISPRA 2010).

At the national level, the Ministry of Health, has promoted important initiatives to ensure healthy living environments and protect the health of the population, including the "National Plan of prevention for the protection and promotion of the health of confined environments" (Ministry of Health, 2000).

Unfortunately, in Italy, unlike what happens for the atmospheric air, the air quality in public and private buildings is not regulated by true normative references[3].

The rules for the healthiness of buildings are set, for each municipality, by the health and hygiene regulation. However, there are numerous provisions, directives and studies that deal with the problem of indoor pollution, both nationally and internationally (European Parliament, 2008, World Health Organization, 2009 and 2010).

2. INDOOR POLLUTION SOURCES

The quality of the air inside the buildings is influenced not only by external pollutants, which usually penetrate through the opening of doors and windows, through joints, cracks in the walls or interstices around the fixtures and through the mechanical ventilation systems or thermoventilation, but

[2] The term "indoor environment" refers to the confined spaces used for life and work. The term indoor therefore includes: public and private offices, community structures, schools, etc., premises for promotion and social activities (cinemas, bars, restaurants, shops, etc.) and finally the means public or private transport (car, train, plane, etc.).

Industrial environments do not fall within this definition because the quality is internal, correlated with the type of production activity carried out and subject to specific controls and laws.

[3] The evaluation of indoor air quality is particularly difficult because it depends on an interrelated series of factors: from the site chosen for the construction of the building, the design methods, the materials and application technologies, in addition to the behavior of the inhabitants. On some of these elements the action carried out over the years by the Building Hygiene regulations is fundamental. It is also complex to establish the limit threshold beyond which problems are created for the health of individuals, both for lack of information on the dose-response relationship, and for the variety of subjects involved.

also from the pollutants present inside the building itself.

The substances that constitute the primary cause of indoor air quality, derive from numerous sources such as:

- building materials and plants (heating, air conditioning, ventilation);
- fixed and mobile furnishings;
- coverings (floors, walls, ceilings);
- chemical products for the maintenance and cleaning of environments (solvents, glues);
- methods of using interior spaces (life styles, work tools, etc.);
- occupants' habits (tobacco smoke, use of clothes washed in dry cleaners, etc.);
- quality of the ground below the structure.

The main contaminants of indoor air are divided into three categories:

- chemical pollutants: volatile organic compounds and inorganic compounds, including dioxide and carbon monoxide, sulfur dioxide and nitrogen dioxide, ozone, etc.
- biological pollutants: viruses and bacteria, fungi and molds, pollens and mites;
- pollutants of a physical nature: radon (World Health Organization, 2010).

Chemical pollutants can be natural or artificial and present in indoor air in liquid, solid or gaseous form; some originate within, others come from the outside air. Among the main chemical pollutants coming from the outside there are combustion products (nitrogen oxides), ozone, particulate matter, benzene; while among those deriving from the internal environment are the volatile organic compounds, asbestos and synthetic mineral fibers.

As for biological agents, the degree of exposure depends on the type of environment. In general, in the indoor air the concentrations of microorganisms are greater than the external ones, a cause of the recirculation of the powders, of the limited or no direct solar irradiation and of the presence of people.

The biological contaminants detected in indoor environments can be categorized into five main groups.

1. Bacteria and viruses: they are mainly transmitted by people and animals; they lurk in conditioning systems and can release water-soluble endotoxins that are dispersed inside the building and whose inhalation can cause fever, muscle aches, headaches, perspiration.
2. Molds: micro-organisms belonging to the mushroom species, the formation of which is caused by high humidity; they are deposited inside air conditioners and humidifiers, on damp walls and floors. Mycotoxins produced by molds can cause respiratory rhinitis and allergies that, in severe cases, can develop into asthma.
3. Pollen: granules diffused by plants and transported by insects, animals and by the wind, are deposited on clothes, shoes and pets; they can produce annoying states of discomfort especially in allergic subjects.
4. Mites: the dust mite is considered one of the most common indoor allergens and the main cause of allergic asthma. It lives mostly in the bedrooms, nesting in mattresses, sheets, rugs, carpets, etc.
5. The main sources of internal microbiological pollution are represented by the constructive elements, the furnishing, the services of the buildings, the occupants (man, animals and plants). Other sources of micro-organisms are humidifiers and air-conditioners, where the presence of high humidity and inadequate maintenance cause the establishment and multiplication of micro-organisms which are then diffused in environments by the air distribution system.

The most common indoor air pollutant is radon.

It is a natural radioactive natural gas, present everywhere on Earth, in variable concentrations, and it is the main radioactive source in buildings. It originates from uranium, a radioactive element that is widespread in all the rocks of the earth's crust, particularly in granite and tuff. Also the building materials are therefore a source of radon. The soil is responsible for 80% of the radon diffused in the atmosphere, the water of 19% and the other sources only 1%.

From the ground, radon penetrates into the buildings, therefore the rooms directly in contact with the source are the cellars and the basements. The continuous production of radon inside rocks and soils containing uranium can make it reach, in some closed places (mines, tunnels, basements or simple dwellings), concentrations potentially harmful to human health, if you breathe for a long time .

The International Agency for Research on Cancer (IARC) has in fact classified the radon and its decay products among the group 1[4] carcinogens and the exposure to radon is now recognized, on a scientific level, as one of the main causes of lung cancer after cigarette smoking.

According to some preliminary analyzes carried out within the Radon National Plan, drawn up by the Istituto Superiore di Sanità (ISS), a risk due to radon for lung cancer over the entire life of the order is estimated from the average values obtained in Italy. 0.5%, corresponding to 5-15% of the total lung cancers that occur every year in Italy.

3. INDOOR AIR QUALITY IN SCHOOL BUILDINGS AND HEALTH EFFECTS

In European countries children spend about a third of their day at school. The increase in allergic diseases found in

[4] The classification of the International Agency for Research on Cancer (IARC) provides five categories of carcinogens according to a decreasing level of harmfulness. group 1 concerns "Human carcinogens: category reserved for substances with sufficient evidence of carcinogenicity for humans".

children, which are related to the concentration of pollutants in the air, highlights the urgency of working to improve indoor air quality in schools.

A healthy and safe school environment is a fundamental prerequisite for ensuring children's growth, learning and productivity, as well as cultural and social development, whereas, on the other hand, poor indoor air quality negatively affects well-being and produces effects. significant health issues, ranging from mucosal irritations to cardiovascular diseases.

Children are more sensitive to the effect of pollutants than adults, so air quality in schools plays a role of primary importance for public health.

The study SIDRIA – Italian Studies on Respiratory Disorders in Children and the Environment (2012) – in fact highlights that 20% of children under 15 years have suffered or suffer from allergic rhinitis, 10% of children and adolescents suffer from asthmatic symptoms, 10% of children between 6-14 years suffer from atopic dermatitis, 4% of children suffer from food allergies.

The main indoor sources of pollution in schools are the building and plant elements that directly influence the microclimate, the materials used for educational activities, the furnishings, the environmental hygiene of the building, the cleaning products, the occupants. The healthiness of the school building also depends on the interaction with the outside, therefore on its location, by the proximity of green areas or industrial centres, etc. (EPA, 2018).

Among the biological pollutants, those present in greater concentration are mites, as in the school environments there are many areas of difficult cleaning, such as shelves, books, drawers, in which these species nest. They are susceptible to environmental parameters such as temperature and humidity, in fact generally the symptoms of mite allergy occur in winter, when the air changes in schools are drastically reduced and the internal microclimate is characterized by high temperatures and a favorable moisture content to the proliferation of these allergens. The environmental humidity also favors the growth of fungi and mold on the walls, in organic waste, on plants and on everyday objects.

Among the potentially present chemical substances, in addition to formaldehyde, sulfur oxides, carbon monoxide and ozone, there are Volatile Organic Compounds (VOC), particulate, Polycyclic Aromatic Hydrocarbons (PAH) and mineral fibers. Finally, as regards the physical pollutants, radon is no exception in school buildings.

The size of the classrooms are often insufficient and inadequate to the average number of students, so there are problems of overcrowding that imply high concentrations of CO2 (commonly perceived as "stale air") which are at the origin of headaches, disturbances in concentration and drowsiness.

According to the Ministry of Health, the diseases associated with buildings, the so-called Building Related Illness (BIS) derive from specific chemical, physical or biological substances whose effects affect the respiratory system, the cardiovascular system, the exposed skin and mucous membranes, the nervous system and the immunological system.

4. THE INAIRQ PROJECT AND THE ITALIAN CASE STUDIES

The InAirQ Project is part of the activities supported by the Interreg Central Europe program of the European Union – European Regional Development Fund – and involves 5 states: Hungary, Italy, Poland, the Czech Republic and Slovenia.

The partners who collaborate to improve indoor air quality in schools are 9 - 6 public institutions, 1 school, 1 research center, 1 interest group; In Italy, the SiTI research institute (Advanced Institute for Territorial Systems for Innovation) and the Foundation for the School of the Compagnia di San Paolo, both based in Turin, make their contribution.

The duration of the project is 36 months: started in the summer of 2016, InAirQ will end in June 2019.

The activities, which are currently around two thirds of their development, provides for a number of complementary actions:

- awareness-raising, communication and training activities, which took place through meetings organized with the students and the families of the schools chosen as pilot cases. Furthermore, events and training meetings were organized for school staff, teachers and school managers. The purpose of these activities is to inform about the impacts of indoor air quality on health and to describe intervention measures.

  A further training phase concerns the public actors in charge of planning, control and management of the institutes, with the aim of improving their skills and increasing their awareness.

  In this regard, the authors mention the seminar entitled "Air quality in school buildings. Projects, perspectives, questions", organized in Turin on 18 May 2018 in collaboration with the Order of Engineers of the Province of Turin.
- Organization of the Environment Quality Forum, that are moments of discussion with the institutions and all the subjects interested in the topic, dedicated to the diffusion of information on air quality and to the sharing of the results obtained within the InAirQ project. To the events, characterized by high scientific content but also popular, are invited institutional bodies, school representatives, teachers, research institutes, environmental agencies.
- Discussion and dialogue with schools through the administration of questionnaires to assess the health and well-being of the students.
- Monitoring of the concentration of air pollutants in

school buildings. This is a fundamental activity of the project, as it allows to highlight any problems and propose solutions. In particular, 12 school buildings were chosen for each State involved, representative of the building heritage in terms of typology, construction technology and construction time. So, for each school, a class was chosen in which, between October 2017 and April 2018, field measurements were organized. Furthermore, through a questionnaire sent to parents, the health of children and young people and the presence of symptoms related to indoor air quality (activity linked to the previous point) was investigated.

- Definition of a shared transnational strategy aimed at planning actions to improve indoor air quality in schools, following the monitoring campaign. Starting from this strategy, each partner country is working to outline its own operational Action Plan. These plans contain an analysis of local and regional problems related to indoor air pollutants, a series of proposals to improve air quality for local authorities, stakeholder involvement in the implementation of the plans themselves, guidance on methods of environmental monitoring and necessary tools, proposals for mitigation and training and information actions.

In Italy, the schools involved in the project are 12, located in the Municipalities of Turin and Chieri, between primary and secondary schools. The choose is made in order to intercept children and young people between 6 and 14 years of age.

Below is a list of the schools involved.

The choice of case studies is made by referring to two different elements: the representativeness of the school in terms of building characteristics, location, etc. and the availability of school leaders to participate in the project.

The authors are involved in all the activities listed, with the exception of the analysis of the samples collected during the monitoring. This activity is in charge of a specialized laboratory.

With regard to the activities carried out in Piedmont (questionnaires, monitoring campaign, organization of events, etc.) the authors work autonomously with a constant comparison with the other foreign partners. While regarding activities transversal to the project (definition of a transnational strategy, drafting of an Action Plan etc.) the authors work in constant collaboration with the other partners.

Table 1 - *List of the schools involved in the projects*

Name of Schools	Address
Gateano Salvemini Primary School G. Salvemini	Negarville Street 30/6, Torino
Gateano Salvemini Secondary School Castello	D. Coggiola Street 20, Torino
Carlo Collodi Primary School Rodari	Piacenza Street 16, Torino
Mazzini Primary School Mazzini	Orbassano Street 155/A, Torino
Sandro Pertini Primary School Duca degli Abruzzi	Montevideo Street 11, Torino
Sandro Pertini Secondary School G.B. Vico	Tunisi Street 102, Torino
Secondary School Viotti Secondary School G B. Viotti	Vercelli Street 141/6, Torino
Gabelli Primary School Gabelli	Santhià Street 25, Torino
Marconi Antonelli Primary School A. Antonelli	Vezzolano Street 20, Torino
Regio Parco Primary School Lessona	Regio Parco Street 19, Torino
Chieri 1 Primary School S. Pellico	Pellico Square 2, Chieri
Chieri 4 Secondary School Chieri 4	Bersezio Street 2, Chieri

5. ACTIONS FOR STAKEHOLDER ENGAGEMENT

One of the fundamental objectives of the InAirQ project is to increase the awareness and knowledge of the stakeholders involved about the potential health risks deriving from indoor pollution, also in order to reduce its effects through more appropriate behaviors.

The intent is to make active, participatory and aware the role of teachers, students and parents and gather useful information to set up the monitoring campaign and transfer good behavioral practices.

The theoretical reference is the "stakeholder-oriented approach", according to which it is important to create a systematic process of dialogue and involvement of the main interlocutors in order to define shared strategies and solutions (Freeman, 1984).

Technically, the involvement of the population can take place in different ways: through collective and thematic meetings where participants are provided with informational material on specific topics, or through face-to-face meetings, or short individual interviews in which groups will be provided (for example the individual classes).

In this case, it was decided to use the interview, through three different types of questionnaires, with three different purpose.

The collaboration with teachers, students and school managers is very good. In September 2018, all the questionnaires (over 200) have been completed and returned.

The three different types of questionnaire refer to the following characteristics:

1. Checklist and questionnaire for the school as a work environment, to be completed by the school administration and project team.

   The perspective is to have a picture about the characteristics of the building, the presence of pollutants, the habits of teachers, comfort in terms of lighting, healthiness of the air, etc. for a total of 45 questions.

   The following is an example of a question:

   Are windows open during class hours?

2. Checklist and questionnaire related to a specific classroom chosen as a place for experimentation and measurement of pollution data, to be completed by the teachers involved and the project team.

   The purpose is to have a detailed picture about the characteristics of the classroom, its location, the presence of pollutants (for example mold), the habits of the teachers working in it, the perception of comfort in terms of lighting, air health etc. by students and teachers for a total of 47 questions.

   Below is an example of a question:

   How is the cleaning of the classroom perceived?

3. Questionnaire on respiratory health and on the home environment of pupils, to be completed by the parents of the pupils involved.

   The purpose of this questionnaire is to collect information about the health of children and young people involved, in terms of respiratory problems, the presence of asthma, the presence of allergies, etc., define the characteristics of the environments they attend – mainly school and home – in terms of healthiness and comfort and understand habits and lifestyles.

   Below is an example of a question:

   How often does your child feel unwell after hours spent at school?

Data processing has shown that, in general, the issue of indoor pollution is interpreted as urgent but at the same time the set of causes and possible solutions is not clear.

6. THE MONITORING MODEL

One of the fundamental phases of the InAirQ project, both in terms of knowledge of the state and of setting up actions for the future, is the monitoring of the pollutants present in the classroom.

To do this, a specific room has been chosen for each educational institution involved; the monitoring actions took place in the winter season 2017-2018, beginning in January 2018 and ending in April 2018, in correspondence with the heating season.

In the heating season 2018-2019 a second data collection campaign will be carried out, in order to deepen and validate what emerged in the first year.

The monitoring lasts one week (from Monday to Friday) for each school, and is carried out indoors (1 class per school) and outdoors. It is carried out during the lessons, beginning in the morning and ending at the end of the lessons, according to the following program:

- weeks prior to monitoring: indoor and outdoor inspection by the InAirQ project team;
- monitoring week, Monday:

  short meeting with school staff and daily diary delivery;

  Installation of indoor and outdoor instruments before classes start;

  start and end day operations.
- monitoring week, from Tuesday to Friday:

  start and end day operations;
- monitoring week, Friday afternoon:

  recovery of daily diary and disassembly of instruments.

The so-called "start and end day operations" are the responsibility of the school staff.

At a technical level, the monitoring for each pollutant is carried out according to two methods of different complexity and significance.

The first consists of a passive type of monitoring, whose strengths are the low costs and the extreme compactness of the instrumentation while the critical points refer to the reduced sensitivity.

For this monitoring method, absorbent pods placed in the classroom are used during the stay of the students. The pods thus "polluted" are then analyzed in order to return a picture of the indoor pollutants and of the quantity of such pollutants absorbed by the occupants of the room during the period of exposure of the pods.

This monitoring, in order to obtain more precise results, is accompanied by a continuous and instantaneous monitoring, much more significant. This method, by returning a graph that over time illustrates the trend of the different pollutants present, allows to make correlations in terms of cause and effect. In other words, through this type of monitoring, it is possible to try to associate the concrete actions that have generated or mitigated them to the pollutant trend: the use of chalk on blackboard, cleaning products, opening of windows.

For this monitoring mode, an electronic control unit is used.

Below is a list of the pollutants for which monitoring is expected, with an indication of the instruments used for the measurement.

Table 2 - *List of the monitorated pollutants*

Pollutants	Type of instrument used
VOCs	Radiello ®
Aldehydes	Radiello ®
$PM_{2.5}$	Sampler (low noise level pump + sampling head) continuous monitoring with data logger (control unit)
Radon	Passive sampler only indoor measurements
Temperature, humidity, carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3) Fine powders ($PM_{2.5}$)	monitoraggio continuo con data logger (centralina)

For the analysis of the samples, the Italian project team is supported by a specialized laboratory.

7. RESULTS AND FUTURE ACTIVITIES

The InAirQ project addresses an important and at the same time sensitive issue: the wholesomeness of the places of study, in which children and young people spend most of the day.

There are numerous pollutants that can be found in school buildings: hence the need to know them and measure them as a first step for improving the comfort and health conditions of the occupants.

The results achieved by the project are the following:

- in the classrooms involved there are the "typical" indoor pollutants, to keep under control but that anyway, in relation to the threshold values recommended by the WHO and other recognized organizations that deal with human health, they are not worrying;
- there is a high level of interest in teachers, pupils and families, but at the same time the theoretical references and possible solutions are not clear;
- it is useful to provide a second monitoring campaign with approved instruments in order to validate the collected data and understand the usefulness of any corrective measures taken.

The operative results of InAirQ consists in the drafting of the Action Plans in which are reported the results emerged at the conclusion of these 36 months of activity.

Within these documents are provided design and management indications that can support in the identification of measures aimed at improving air quality in school buildings.

Moreover, when will be presented the results, great importance must be given not only to the technical and management components of school buildings, but also to the social component of the project, in the belief that awareness and knowledge are fundamental tools for stimulate the active participation of citizens and stakeholders in operations aimed at improving indoor air quality.

The next months of work will be dedicated to the drafting and presentation of the Action Plans, with the goal of raising public awareness of the urgency of taking action to contain indoor pollution in schools.

* **Elisabetta Cimnaghi,** *SiTI, Istituto Superiore sui Sistemi Territoriali per l'Innovazione.*
e-mail: *elisabetta.cimnaghi@siti.polito.it*
** **Andrea Di Maggio,** *SiTI, Istituto Superiore sui Sistemi Territoriali per l'Innovazione.*
e-mail: *andrea.dimaggio@siti.polito.it*
*** **Maria Giovanna Dongiovanni,** *SiTI, Istituto Superiore sui Sistemi Territoriali per l'Innovazione.*
e-mail: *mariagiovanna.dongiovanni@siti.polito.it*

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