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FEASIBILITY STUDY

Development of Protocols for Equipment Maintenance and Application of New and Healthiest Technologies for IAQ improvement

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The present document is the Feasibility Study for Equipment Maintenance and Application of New and Healthiest Technologies for IAQ improvement in the national context of Italy. It has been prepared by SiTI – Istituto Superiore sui Sistemi Territoriali per l'Innovazione, project partner of InAirQ project.

A. Context of the study

Since the 1950s, the problem of air pollution (outdoor), considered to be a source of danger to human health and well-being, has been the subject of numerous international studies aimed at monitoring and reducing emissions of polluting substances and evaluate their effects on human health according to the exposure of people to certain pollutants in terms of both exposure duration and concentrations of pollutants in the air. Thus, with regard to outdoor air, the causes (car traffic, industrial plants, domestic heating systems, etc.), the potential effects and possible containment measures have been identified a long time ago.

The results obtained from these studies on outdoor air - in particular in relation to the high concentration of aggressive agents - have generated the mistaken belief that indoor environments constitute a shelter from any type of substance present in the outdoor air. In fact, indoor air quality in homes, offices, schools and, in general, buildings where people spend most of their lives, can represent a real threat to human health of the occupants, for several reasons.

In the first place, trivial actions such as opening windows to ensure air exchange mean that, thanks to mixing, the substances that pollute the outdoor air penetrate inside and are breathed by the occupants of the indoor environment. In addition, the concentration, the number and the dangerousness of the pollution sources inside may be greater than that outside: it is polluting sources of different types, which should not make us think to be safe only because we use them commonly.

We talk about detergents, perfumes, glues, building materials, furnishings, stationery, printers, etc.: sources that vary depending on the characteristics of the building and its facilities and the activities that take place within the confined environment. Obviously, the greater the outdoor pollution, the greater the risk for human health even within public and private buildings; but this does not mean that good indoor air quality also implies good air quality in confined spaces.

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. This is due directly to the increase in expenses related to emergencies, to shelters, to drug therapies and indirectly to the days of work and / or school lost when the indoor air quality is likely to cause some diseases of those who attend that environment. 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, loss of productivity and active social life.

Moreover, the scientific studies developed in the last decades have shown that some air pollutants are able to contribute to the increase in the incidence of malignant tumours; 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.

In particular, 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 than the general population.

Recent industry studies have also shown that an indoor environment uncomfortable or unhealthy also has a negative impact on learning ability.

Partly as a result of these studies, in recent years the focus of scientific and institutional world has turned to issues related to air quality in confined spaces, developing a greater sensitivity and awareness of the importance of the comfort of indoor environment.

This feasibility study, based on these considerations and on the results of the monitoring campaigns carried out in the 5 countries falling under the InAirQ project, aims to identify and describe the most innovative protocols for maintenance and technological solutions able to contribute to improving the indoor air quality in schools of Central Europe.

B. Vulnerability assessment at Italian level

B.1. Introduction and Reference legislation

Going into detail about primary (former elementary) and secondary (middle school) schools, according to the latest survey of ISTAT - National Statistics Institute – carried on in 2014, there are 16.995 primary schools, enrolling about 2.799.553 children and 8.045 secondary schools, enrolling 1.743.587 students. Total amount of this type of schools is 25.000.

In Piedmont Region, according to ISTAT and the school buildings registry of the Region (2014), there are about 1.364 primary schools attended by 191.399 children, and 561 secondary schools enrolling 117.997 children. In total, in Piedmont, regarding these two school levels, there are 1.925 schools. The city with more school buildings is Turin, which counts 223 complexes.

With such a significant consistency of school buildings and students who attend them, a lot of attention to health and medical aspects of indoor places must be taken into account and especially to the indoor air quality in general.

In Italy, unlike what happens about the atmospheric air, indoor air quality in public and private buildings is not regulated by actual legal regulations. The rules for the healthiness inside buildings shall be fixed for each municipality by the hygiene and health regulation.

However many provisions and directives deal with the indoor pollution problem, both at national and international level.

The Agreement of 27 September 2001 between the Minister of Health, Regions and Autonomous Provinces, about the document called "Guidelines for the protection and promotion of health in confined environments", provided an analysis of key indoor pollutants and their effects on health and environmental comfort and established some general guidelines for the creation of a national prevention program. In the framework of this agreement, the "indoor" commission of the Ministry of Health drafted a new "guidelines-schema defining technical protocols for predictive maintenance on air conditioning systems", since improper installation and maintenance can affect the quality of indoor air.

Regarding the limit values for indoor pollutants, there are no national standards; the only precautionary measure regarding formaldehyde is given in the Circular of the Ministry of Health of 22 June 1983 No. 57 "Use of formaldehyde - Risks related to the possible methods of use", which reports a maximum exposure limit of 0,1 ppm (124 mg/m^3) in indoor spaces. In addition, the Ministerial Decree 10 October 2008 establishes provisions relating to the manufacture, import and marketing of wood-based panels and products manufactured with the containing formaldehyde, in order to ensure the protection of human health in their use in indoor environments.

For other substances, reference is made to the limits stated in the document published in 2010 by the WHO, "WHO guidelines for indoor air quality: selected pollutants", in which indoor and risks are defined.

Table 1. Main indoor air pollutants and their value limits according to WHO guidelines

Pollutants	Value limit (WHO Guidelines)
Benzene	17 µg/m^3 (for 1/10.000 maximum risk of lives)
CO	100 mg/m^3 - 15 minutes 35 mg/m^3 - 1 hour 10 mg/m^3 - 8 hours
Formaldehyde	0,1 mg/m^3 - 30 minutes average
Naphthalene	0,01 mg/m^3 - yearly average
NO_2	200 µg/m^3 - hourly average 40 µg/m^3 - yearly average
IPA	1,2 µg/m^3 (for 1/10.000 maximum risk of cancer)
Radon	400 Bq/m^3

The technical rules for the detection of indoor pollutants are:

- UNI EN ISO 16000-1: 2006: Air in confined environments - Part 1: General aspects of sampling strategy.
- UNI EN ISO 16000-2: 2006: Air in confined environments - Part 2: Sampling strategy for formaldehyde.
- UNI EN ISO 16000-5: 2007: Air in confined environments - Part 5: Sampling strategy for volatile organic compounds (VOC).
- UNI EN ISO 16000-7: 2008: Air in confined spaces - Part 7: Sampling strategy for determination of concentrations of asbestos fibers suspended in the air.
- UNI EN ISO 16000-9: 2006: Air in confined environments - Part 9: Determination of volatile organic compound emissions from building products and finishing products - Method in emission test chamber.
- UNI EN ISO 16000-10: 2006: Air in confined environments - Part 10: Determination of volatile organic compound emissions by 25 building products and finishing products - Method in emission test cell.
- UNI EN ISO 16000-11: 2006: Air in confined environments - Part 11: Determination of volatile organic compound emissions from building products and finishing products - Sampling, storage of samples and preparation of test specimens.
- UNI EN ISO 16000-12: 2008: Air in confined environments - Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated benzo-p-dioxins

(PCDDs), polychlorinated benzofurans (PCDF) and polycyclic aromatic hydrocarbons (PAHs).

- UNI EN ISO 16017-2: 2004: Air in closed, air and ambient air at the workplace - Sampling and analysis of volatile organic compounds.
- UNI EN 13098: 2002 - Workplace atmospheres - Guidelines for measurement of airborne micro-organisms and endotoxins.
- UNI EN 15251: Criteria for the indoor environment for the design and assessment of energy performance of buildings, with regard to indoor air quality, thermal environment, lighting and acoustics.
- UNI EN 14412: Air quality in confined environments - Diffusive samplers for the determination of the concentration of gases and vapors - Guide for selection, use and maintenance.

In light of the premises, the main national and regional current regulations are reported below; they should guide the school buildings to reach environmental quality objectives.

National legislation

- Ministerial Decree 18 December 1975, Ministry of Public Works, "Norme tecniche aggiornate relative all'edilizia scolastica, ivi compresi gli indici minimi di funzionalità didattica, edilizia ed urbanistica da osservarsi nella esecuzione di opere" (Technical rules about school buildings, minimum indexes regarding construction and teaching functionality, to be applied in the works execution);
- Law 11 January 1996, n. 23 "Norme per l'edilizia scolastica" (School building rules).

Regional legislation (Piedmont)

- Regional Law n. 28 of 2007 "Norme sull'istruzione, il diritto allo studio e la libera scelta educativa" (Regulations about education, right to education and freedom of educational choice);
- Piano triennale di interventi in materia di istruzione, diritto allo studio e libera scelta educativa per gli anni 2012-2014 (Three-year action plan on education, right to education and freedom of educational choice, 2012-2014).

The first law on school buildings dates back to 1975. Its primary objective is the resolution of the serious situation of deterioration and inadequacy of schools structures, abandoned after Italy unification. The most significant credit about technical regulations, still in force today, was improving the standard of Italian schools to levels comparable to European ones, but still with many gaps.

In detail, the Ministerial Decree of 1975 takes into account sanitation criteria in the determination of the surface/child of classrooms, the individual air space requirements (CO_2 limit breathed relationship indoor/outdoor CO_2), the number of air changes, temperature and humidity limits. It concludes that, in order to meet sanitary criteria, the minimum area per child in primary schools and kindergartens is 1,80 square meters. A summary table (Table 2), taken from the text of the law, is reported.

Table 2. DM 1975 - Main indicators per type of school

Indicators	Primary	Secondary	High school
Classroom area (sqm)	153-167	201-275	166-301
Area per child (sqm)	6,11-6,68	8,06-11,02	6,65-12,28
Height (classroom, offices)	3	3	3
Height (gym)	5,4	7,5	7,5
Minimum area for school building construction (sqm)	2.295-12.550	4.050-12.600	6.620-33.900
Area per child in classroom (sqm)	1,8	1,8	1,96
Children number per class (DM 1975)	25	25	25
Persons number per class (fire prevention rules, maximum capacity)	26	26	26
Green areas (% of total area)	66,6%	66,6%	66,6%
Temperature /humidity	20°C + 2°C / 45-55%	20°C + 2°C / 45-55%	20°C + 2°C / 45-55%

The decree was repealed by the 1996 Law, but it was substantially included the new law, and present a number of significant shortcomings:

- Temperature and humidity fixed only for the winter season;
- Lack of air velocity and average radiant temperature of the surfaces;
- Effects of moisture on health;
- Natural air changes, enforced and monitored.

Essentially the sanitary aspects and the limit values such as temperature and humidity of 1975 are still in force.

National policies

In recent years, governments carried on interesting proposals about national policies, in parallel with the rules.

The *General Plan on School buildings* was confirmed as one of the priorities of the first period of government Renzi (2014). The great national plan called #scuolebelle is characterized by a program of small maintenance interventions to restore and maintain the functionality and decorum of school buildings, for an amount of 150 million euro (in 2014). These interventions affected 7.801 school buildings during 2014. Another 300 million euro were released in 2015 and covered 10.160 school complexes. The school building overall plan is made of two sectors: #scuolesicure, with interventions in the field of safety measures, asbestos and barriers removal (2.865 interventions) and #scuolenuove (404 school buildings to be constructed). The total investment, according to data issued by the government, is expected to exceed 1 billion euro.

The need to implement such a strategy is certainly dictated by the difficult situation for school buildings in the country: "About 60% of Italian school buildings, as reported by "Ecosistema scuola" dossier edited by Legambiente, was built before the adoption of seismic standards and consume about 1.3 billion Euros a year for energy supply, while the energy costs for public buildings is estimated in more than 5 billion euro per year (according to Consip, which is the head office of purchases of Italian public administration).

By 2016 a three-year period of big investments ended: around 7 billion euro were set aside for a total of 27.721 started projects. The redevelopment proceeds too slowly, however, especially regarding the works of seismic and energy adapting.

B.2. Types of school buildings (national level)

The picture emerging from the annual reports about the conditions of the school buildings (such as the already mentioned Legambiente and Cittadinanzattiva - "Ecosistema scuola") and the data resulting from the National School Buildings Registry (law n.23/1996) by the Ministry of Education, outlines a hygiene and safety related situation which is still far from the regulatory parameters relating to safety and health in the workplaces.

The school building stock is composed of about 45.000 schools, characterized by buildings with a very high average age, in several regions; furthermore, many buildings were made before the adoption of technical rules on school building (Ministerial Decree 18 February 1975) and measures for buildings with special requirements for seismic zones (Law n.64/1974). To this structural condition of the assets it must be also added the delay in the adoption of legal requirements relating to fire prevention and safety of operators and users and many issues related to resource consumption, to the wellbeing of the indoor environment, to the management of the interested bodies.

Depending on types of schools (primary, secondary, kindergartens) we usually have different types of buildings, both for construction mode and for size and inclusion in the urban context, different ways of building use, different levels of crowding of environments and different types of plants. Furthermore, it is evident that increasing the school grade generally also increases the size of the buildings, the number of users, the degree of crowding of classrooms, the amount of space dedicated to use accessories (offices, sports activities, canteen services etc.).

The different building types are generated by different and possible architectural configurations based on the ratio between the classroom and the spaces of the school structure, or from the main distribution models: the "corridor" and the "functional unit". The next section describes the main types of buildings that can be found within the Italian school building stock:

Block school

This type has been a model for a long time in school building: it derives from the development of the “corridor scheme”, through which a system of several adjacent classrooms is made using linear connections. In this conformation the building is directly in contact with the urban environment. Its dimensions don’t differ from the surrounding urban fabric and is distinguished by austere and formal look. Teaching rooms are generally distributed and positioned towards the main access road, while the connecting corridor is on the back. The size of the classrooms ranges between 55 to 80 square meters with a height between 4 and 4.50 m. Other configurations derive from this type: “spliced block”, aggregation of multiple blocks, generally with a “C” diagram, which generate a more complex articulation of volumes while maintaining a rigid and readable characterization; “internal empty block”, a locking configuration with an internal courtyard.

Griddle school

Type characterized by a main body from which a lot of branches connect the various spaces dedicated to educational activities of the school, distributed by both corridor type or functional unit type. The griddle school has a volumetric system similar to the block school, even if with lower heights, but with a plane extension similar to extended school structure. Generally they have one or two floors, so the planar development gives considerable size to the building. The lighting of most indoor environments occurs through windows placed on the cover/roof. Precisely because of lighting problems of the environments, the building type evolved into more complex type such as “plate with empty inside”.

Extended school

The extended school develops through a dilation of the spaces to the outside, in opposition to the block type, with a distribution linked to the “functional unit model”. This type is greatly different from the rationalist school model, introducing concepts such as repeatability of base nucleus and identifying new functional spaces, pointing to a progressive growth of the building over time, in relation to the changing in pedagogical or demographic needs.

Open plan

This configuration shows an extreme typological flexibility that was developed during the Sixties and Seventies. It is placed in an intermediate position between the block-diagram with a corridor distribution and the scheme for functional unit. It presents an open floor plan; there isn’t a hierarchical sequence of classrooms, but the space is organized according to different sizes and destined in different activities through the use of internal mobile partitions which allow to obtain articulable environments or large spaces.

Street school

The idea of the school as “street” was also born in the Sixties and Seventies: a body open to the surrounding environment, which favors social relations; main accesses and hierarchies between spaces disappear, so that school, now projected outside of its traditional isolation, reproduces the characteristics of the city and becomes itself an urban fact.

B.3. State of conservation of school buildings (national level)

B.3.1. School buildings age

- 6,50% was built before 1900;
- 14,79% was built between 1900 and 1940;
- 43,74% was built between 1941 and 1974;
- 27,85% was built between 1975 and 1990;
- 7,12% was built between 1991 and 2012.

B.3.2. School buildings previous use

Besides knowing the year of building construction, it’s relevant to investigate whether it was subject of recent maintenance work: any regulation may have led to adaptations of buildings; for example, interventions made by the fact that the building was born with other purposes and then used as a school. In Italy the buildings currently hosting schools were originally:

- 87,44% schools;
- 6,60% historic buildings;
- 4,78% housing;
- 0,11% barracks;
- 1,08% other use.

In addition, the year of construction of the buildings is associated with the structural deficit of them: in fact, many of the existing schools are built without the static suitability and with a seismic safety level not aligned to current standards, set out today in the technical standards for construction issued by the Ministry of Infrastructure with Ministerial Decree 14 January 2008. Assessing the construction periods, it’s possible to find almost all the construction techniques: traditional construction, mixed structures with bearing walls and floors of reinforced concrete, reinforced concrete structures on site or prefabricated, steel structures. The safety of the facilities, a good livability of the school environment, the suitability of the equipment and furniture are essential to ensure the smooth running of teaching and administrative activities.

B.3.3. State of the facilities and other features

- 10,14% is built according to seismic criteria;

- 56,05% has the static suitability certificate;
- 57,74% has a certificate of viability;
- 69,79% owns the sanitation certificate;
- 35,41% has the fire prevention certificate;
- 51,82% has fire escapes;
- 90,07% has panic doors;
- 95,07% carried out evacuation drills;
- 14,37% addressed interventions for eliminating architectural barriers;
- 74,27% has green areas and gardens;
- 55,11% has gyms;
- 23,07% has a kitchen inside.

From a survey carried out by the Ministry of Education on the implementation of Legislative Decree no. 626/1994, on a sample of 9.590 schools, it is clear that the situation of schools is still far from the regulatory parameters relating to safety and health in the workplace. But thanks to a careful verification, there was an increase of static usability certifications of buildings and sanitary-usability certifications, as well as an enhancement of the culture of exercises for safety (evacuation tests). Many schools, however, still need urgent maintenance.

The existing school stock is a much larger share than new construction school and, as noted, is responsible for the majority of energy consumption. The data shows that the newly built schools meet, for the most part, all the sustainability and resource-saving requirements, but the same cannot be said about the existing buildings. Italians school buildings dating back to years 1950-1980 have been built without any rule on savings; those built in the period from the eighties to the present day have been made according to the criteria defined by the law n.373/1976, which nowadays are completely unsatisfactory. With the enactment of Law n.10/1991 schools, like all new public buildings or building renovations, would have to integrate energy saving measures and renewable systems for public interest, but the application of the rule in the whole national territory has led to a school building stock with a lower standard of quality than the European average. Some studies, conducted in buildings taken as a sample, also state that the total energy consumption of the Italian schools has a share of 77% for heating and 23% for electricity. The average consumption of primary energy relative to the winter heating of a school building is about 290 kWh/sqm per year, while the average electricity demand for lighting is about 70 kWh/sqm per year. The confirmation of these values stays in the building structure: the low average transmittance of the building structure is about 1,25 W/(m^2 K) and the types of equipment installed shows a poor performance.

Innovative policies in energy sector:

- 63,9% of the buildings use energy-efficient sources for lighting;

- 24,4% use other forms of energy saving, such as the use of thermostatic valves, compensated control instruments, photoelectric cells etc;
- 8,2% use renewable energy sources (photovoltaic systems and solar thermal panels etc.).

B.3.4. School building management

- 36,1% of the buildings need urgent maintenance interventions;
- 56,0% of the buildings suffered in the last five years of extraordinary maintenance.
- The average investment for maintenance is € 40.961 for extraordinary maintenance (average cost for each building).

B.4. Air quality data (city/region)

Environmental data, collected in the last decade by measuring stations operating in the Piedmont Region and managed by ARPA Piemonte (Regional Agency for the Protection of Environment, which is responsible for the official environmental monitoring in the whole regional territory), show an overall trend towards improvements in air quality, net of annual weather variability, but still underline the critical difficulty of the territory, in particular the urban area of Turin (the city is located in a valley protected from winds due to the presence of the Alps) in respecting limits and target values for the protection of human health.

In 2015, only 5 of 12 pollutants measured by ARPA exceeded the respective limit values throughout the regional territory. PM_{10} exceeds the annual limit value in 17% of the measuring points, particularly those characterized by intense traffic; the daily limit is exceeded in 67% of the stations. Compliance with the annual limit value is observed only in rural areas and in valleys contexts. $PM_{2.5}$ exceeds the limit value in 65% of monitoring stations, mainly located in lowland areas with discrete levels of human activity. The situation has worsened compared to 2014, the annual limit value of 25 $\mu g/m^3$ exceeded in 5 monitoring stations on 8, while in 2014 had been exceeded in one station.

Nitrogen dioxide (NO_2) exceeds the annual limit value in 32% of the stations measuring it, in particular those operating in the urban area of Turin; the hourly limit is respected everywhere except in the traffic station of Turin-Rebaudengo. Benzene has exceeded the target value in 27% of measuring sites. The highest values are found in sites from the Turin urban area. There has been a general increase compared to previous years. Ozone (O_3) confirms its criticality in the summer months throughout the study area. The target value for the protection of health was exceeded in 92% of the measurement points. Overall, the higher values of the pollutants (PM_{10} concentration, $PM_{2.5}$ and NO_2) are found in the urban area of Turin, although O_3 has higher concentrations in rural and mountain areas.

The year 2015 shows a worsening trend compared to 2014, which is believed to be primarily due to particularly unfavorable dispersion conditions in winter months.

Table 3 shows the data collected by ARPA Piemonte, referring to annual averages of the main pollutants recorded by all regional station for the last five years available.

Table 3. Annual averages of the main pollutants recorded by ARPA Piemonte monitoring stations, 2011-2015.

Year	PM_{10} [µg/m^3]	$PM_{2,5}$ [µg/m^3]	NO_2 [µg/m^3]	O_3 [days per year]	Benzene [µg/m^3]
2015	30,5	21	22	56	1,5
2014	28,5	16	29	21	1,3
2013	31,5	19,6	32	48	1,3
2012	35	21,6	35	63	1,5
2011	36,5	21	38	71	2,1

Insight: City of Turin

Turin is located in the most industrialized area of Italy and among the most industrialized in Europe. The pollutant emissions are therefore particularly high. Furthermore, the river Po valley is characterized by a morphological conformation that makes difficult the dispersion of pollutants. Nevertheless, the air quality in Turin has improved significantly over the past 30 years.

Since the 70's, policies for the reduction of chemical agents dispersed in the air have been adopted. These policies have yielded good results, allowing significant reductions in the concentration of sulfur dioxide (SO_2), benzene (C_6H_6) and carbon monoxide (CO). However, the objective and significant improvement in air quality is still not enough to meet the new limits introduced by European legislation to protect human health and the environment. Strong criticalities remain for: nitrogen dioxide (NO_2), ozone (O_3) and suspended fine particles (PM_{10}).

Regarding in particular PM_{10} and NO_2 should be noted that, despite a sharp decrease of these pollutants has been registered in the last 30 years, the European Union sets strict rules of the limits: for PM_{10} annual average must not exceed 40 µg/m^3 and 35 is the maximum number of exceedances of the daily average of 50 µg/m^3 allowed; for NO_2 annual average should not exceed 40 µg/m^3 and 18 is the maximum number of exceedances of the hourly limit value of 200 µg/m^3 allowed. The pollution from PM_{10} and NO_2 represents the most heartfelt urgency, and the measures undertaken by Turin and other Italian cities are mainly concentrated on reducing them. In this regard, the traffic restriction measures adopted by the City of Turin contributed, in recent years, to a gradual reduction of pollutant concentrations in the air; nevertheless, as mentioned, such results remain insufficient. With regard to PM_{10}, for example, in 2015 the average values registered were lower by about 40% compared to 2006, and the number of exceedances of the limit value was also significantly decreased (-54% in 2015 compared to 2006). For nitrogen dioxide improvements have been registered in 2015 compared to 2006 (-31% of the average value).

Table 4 reports the data collected by Arpa Piemonte, referring to monthly averages of the main pollutants recorded by all regional station for the last year available (2016).

Table 4. Monthly averages of the main pollutants recorded by ARPA Piemonte monitoring stations, 2016

Date/Month	PM_{10} [µg/m^3]	NO_2 [µg/m^3]	CO [µg/m^3]	O_3 [µg/m^3]	SO_2 [µg/m^3]	Benzene [µg/m^3]
01/2016	57,8	98,9	2,7	31,3	5,9	5,3
02/2016	40,8	83,9	2,2	44,2	8,8	3,7
03/2016	32,6	87	2	64,4	7,7	2,9
04/2016	27	62,1	1,6	82,1	6,5	1,7
05/2016	17,8	64	1,4	67,2	5,9	1,5
06/2016	18	54,8	1,5	112,8	9	1,3
07/2016	21,4	61,6	1,4	150,3	9	1,2
08/2016	18,4	47,4	1,2	123,7	7,3	1,1
09/2016	26,6	82	1,3	118	8	1,5
10/2016	37	85,3	1,3	48	10,5	2,6
11/2016	49,2	88,4	1,6	30,3	13,3	3,7
12/2016	75	134,5	2,8	9,9	14,9	8
Average 2016	35,1	79,2	1,8	73,5	8,9	2,9

B.5. Indoor air quality data in school buildings

Poor indoor air quality (IAQ) has respiratory effects and other effects related to the health of the occupants. The IAQ affect the general well-being due to the possible presence of numerous specific pollutants with a wide variety of causes and sources. The problem has been reported on many occasions in the scientific literature and was mentioned in recent policy statements, guidelines on air quality and overall strategies of the IAQ management, as well as by political and organizational bodies that deal with health public and related environmental issues. Although there are no rules and regulations in Italy, many organizations, institutions and local health agencies (ASL) have conducted experiments and pilot projects on monitoring air quality in indoor environments (schools, offices, housing) in the last 10-12 years. The data reported in the tables relating to the “Data Collection”, carried out in the framework of InAirQ project in WP_T2, refer to all of these experiences, mainly in European projects: SEARCH, INDOOR, SINPHONIE, HESE, INDEX and EXPAH. In them, many schools from different Italian regions were monitored, from north to south; these cases bring reliable and consistent results which effectively represent the indoor air quality of Italian schools.

Table 5 provides the annual average of pollutants monitored in 44 schools in six different regions.

Table 5. Annual average of pollutants monitored in 44 schools in six different regions

Year	PM_{10} [µg/m^3]	NO_2 [µg/m^3]	Formaldehyde [µg/m^3]	Toluene [µg/m^3]	Ethylbenzene [µg/m^3]	Benzene [µg/m^3]	Xylene [µg/m^3]
2008	82	19	33,07	5,01	1,82	1,95	7,1

In order to investigate cases carried out in Piedmont Region, in particular near Turin, a case study of the SEARCH project, carried on in Venaria Reale is reported. Experts from Arpa Piemonte and ISPRA (Higher Institute for Environmental Protection and Research) have monitored the air quality in a secondary school, "Scuola media Don Milani", by measuring the following pollutants: PM_{10}, NO_2, Formaldehyde, Toluene, Ethylbenzene, Benzene, Xylene.

The results of the project show that this school has the worst performances of all schools involved in the project regarding the recorded PM_{10} levels (very high), indoor and outdoor. In general, Italy was in line with the other European countries of the project, except regard formaldehyde, which is very high compared to other foreign cases.

Table 6 shows the data relating to the monitoring phase in Don Milani school. Please refer to the prepared Excel file, compiled in the phase of Data Collection, as part of WP_T2 of InAirQ project.

Table 6. Results of the monitoring phase performed in school "Don Milani" in Venaria Reale, February 2008. Type of data: 5 days average

Classroom	PM_{10} [µg/m^3]	NO_2 [µg/m^3]	Formaldehyde [µg/m^3]	Toluene [µg/m^3]	Ethylbenzene [µg/m^3]	Benzene [µg/m^3]	Xylene [µg/m^3]
Artistic Lab	233	43,26	24,4	5,9	1,32	0,43	6,3
1D	136	38,01	6,0	4,4	0,82	1,82	3,2
1G	149	52,08	7,3	3,1	0,79	1,58	2,6
1A	-	31,92	7,5	4,4	0,82	1,82	3,1
1F	-	40,32	8,2	5,0	0,91	2,02	3,6
1B	-	36,12	9,1	5,5	1	2,24	3,9
1H	-	38,22	10,2	5,7	1	2,34	4,1
weighted average	142,5	41,67	8,07	4,71	0,95	1,98	3,4

B.6. Conclusions

In Italy the situation of school facilities shows all the difficulties and shortcomings of the lack of planning in the sector, although there are some excellent examples of school architectures. In addition to the resources, it remains one of the main problems to deal with in this country.

The regions that have historically big cities in the top positions of the rankings for the quality of services and school construction, like Piedmont, Tuscany and Emilia Romagna, are also those that have doubled and tripled funding than the national average of investments in the maintenance of school buildings. In fact, the difference between North and South is substantial in medium-routine maintenance investment, denoting a different political-administrative approach in the overall management of the school structures. Also in the north regions, there is a greater focus on routine maintenance, with an average investment of Municipalities double than in the south: about 12.000 euro for building in the north against the 4.900-5.000 € in the south. However, the positive trend that we find over the years regarding the adoption of practices related to energy saving is rather interesting, although it’s still quite shy compared to the opportunities in the field: in four years, in fact, the schools using sources of energy efficient lighting have increased from 46,50% to more than 63% and the structures using energy from renewable sources has doubled from 4% up to over 8%.

About the specific case of the monitoring indoor air quality in schools, except some experience related to European projects and some research studies related to ASL (Local health companies), important addresses and constraints that must improve the current situation are not found in regulation/laws. In fact, there are no enforcement authorities at national level responsible of monitoring air quality in schools, there are no standards to be met at regulatory level, there is no obligation to conduct monitoring campaigns. The only imposed ones are the safeguard levels for temperature and humidity in schools (Ministerial Decree 1975).

C. SWOT Analysis

Improvement of the Indoor Air Quality in the school environment

Identify Strengths, Weaknesses, Opportunities and Threats but limit the points to a maximum of ten under each heading (Zaletel-Kragelj L. and Boţikov J., 2010).

	Internal analysis	
SWOT analysis tool	**STRENGTHS** What has a positive impact on the school environment regarding IAQ? 1. The location inside the city guarantees a good accessibility through public transport or other means. 2. Classrooms are always structurally separated from the refectory, play rooms and gyms. 3. Good availability of many information about IAQ for school staff, interested in good IAQ. 4. Great involvement of Turin city on the IAQ theme.	**WEAKNESSES** What has a negative impact on the school environment regarding IAQ? 1. Lack of finance 2. Lack of staff in cleaning service (number of employees is decreasing) 3. Lack of interest and efforts to improve IAQ. 4. Insufficient awareness of the risks and possible improvements in IAQ by staff and also by children parents. 5. Difficult air conditions inside school buildings - caused by insufficient air exchange especially during winter season, and by insufficient air volume

		5. Big spaces and big windows in schools and classroom guarantees a lot of opportunities to adjust the climate inside. 6. The manager-owner is always the same: the municipality. 7. At least half of the school buildings were renovated during last 10 years (windows, insulation etc)	per pupil in the classrooms. 6. Classrooms sometimes overcrowded. 7. Too much movement by children in the classroom (during breaks) that cause an air quality decay without a correct management of windows.
External analysis	**OPPORTUNITIES** What are the opportunities to improve the IAQ in the school environment? 1. Introduction of new legislative limits, follow-up supervision of Public Health Authorities, and continuous research on the subject. 2. Awareness-raising activities at staff-school level. 3. Introduction of new technologies and materials (cleaning agents, low emission materials) for schools following EU directives. 4. Possibility of IAQ control in schools (microclimate sensors, pollutants monitoring).	**Opportunity-Strength (OS) Strategies** How can we use Strengths to take advantage of Opportunities? 1. Introduction of legislative updates about IAQ in schools, including requirements for materials of school facilities. 2. Educate children, school staff and ownership in schools about IAQ and its influence on the health and attentions of children and teachers. 3. Promote the use of modern technologies to continually monitor and analyze IAQ status in schools. 4. Introduction of proper cleaning technology: non-irritating cleaning	**Opportunity-Weakness (OW) Strategies** How can we overcome Weaknesses by taking advantage of Opportunities? 1. Introduction of legislative updates about IAQ in schools, including requirements for materials of school facilities. 2. Introduction of proper cleaning technology: non-irritating cleaning chemicals, proper timing and frequency of cleaning. 3. Organizing educational seminars in schools for children and parents. 4. Educate children, school staff and ownership in schools about IAQ and its influence on the health.

	5. Collaboration with local foundation and the municipality to improve the situation and carry more pilot projects on IAQ in schools. 6. Improvement of city planning by the municipality: placement of new school buildings. 7. Guidance and recommendations developed in the frame of projects aimed at improving the indoor air quality in schools.	chemicals, proper timing and frequency of cleaning. 5. Better selection of materials and technological processes to renovate school buildings.	5. Supporting school staff in use of new methods and forms of education and training. 6. Foster new form of collaboration between schools and foundations/public entities aim to find funds or direct solutions.
	THREATS What are the threats that can negatively influence the IAQ in the school environment? 1. Outdated legislation: old limits and need of new paradigms about IAQ. 2. Slow response of legislation and public health authorities to actual issues. 3. Different kind of restructuring, insufficient staffing capacity in schools. 4. Insufficient information on how to improve IAQ. 5. Disinterest of owners and school managers to improve IAQ beyond the legislative requirements. 6. Urban planning regardless of the proximity	**Threat-Strength (TS) Strategies** How can we use Strengths to avoid Threats? 1. Update legislation in cooperation with experts and school representatives. 2. Urban planning: define requirements for the placement of schools. 3. School construction: prohibition of using unverified technologies and inappropriate materials in schools. 4. Ensuring capacities, technical assistance and resources for the necessary measures. 5. Foster the exchange of air inside classroom (open windows) and frequent cleaning and exact removal	**Threat-Weakness (TW) Strategies** How can we minimize weaknesses and avoid Threats? 1. Use all available options to improve IAQ (collaboration between schools and foundations/public entities). 2. Improve the level of awareness of staff and school owners on the indoor air quality. 3. Consistent application of the precautionary principle when introducing new technologies and products. 4. Promote new form of funding for ongoing status monitoring/air quality monitoring in schools.

	of schools (transport, industry, etc.) that cause negative impact of changes. 7. Heavy traffic and infiltration of large amounts of pollution inside school environment from the outside.	of dust.	5. Construction parameters: implement solutions aim to optimize the exchange of air for individual parts of the building.

D. Aim of the study

It has been proven that the levels of carbon dioxide in the classrooms are directly related to the concentration of students: the higher the levels of carbon dioxide, the lower the ability of the students to stay focused. High levels of carbon dioxide arise from a lack of fresh air intake and have a negative influence on students' health and learning ability.

D.1. Characterisation of indoor air quality

As we have seen from the results of the monitoring campaign, indoor air quality in the Turin area is typically affected by three major groups of pollutants:

i. outdoor air pollutants, such as e.g. carbon monoxide (CO), benzene (C_6H_6), ozone (O_3), oxides of nitrogen (NO, NO_2), and particles, which penetrate the building envelope, or enter the building through windows or air handling units;
ii. pollutants mainly generated in households, i.e. occupant-related pollutants like CO_2, bio-effluents and particulate matter (PM) in different size ranges;
iii. building-related pollutants, typically volatile organics (VVOCs, VOCs, SVOCs) originating from e.g. construction material, furnishings and office equipment as well as microbial contaminants such as viruses, fungi and bacteria.

The affection of IAQ by the infiltration of outdoor air to indoor environment depends also on the type and operation of the ventilation system of a building, which could be natural or mechanically ventilated.

The spatial distribution of ambient air pollutants might be diverse as shown in Figure 1 for PM10, PM2.5, NO_2 (annual mean) and ozone (number of days exceeding 120 µg/m^3 calculated as 8 h averages) in the year 2015 in Italy. The dashes represent urban areas with a high density of population.

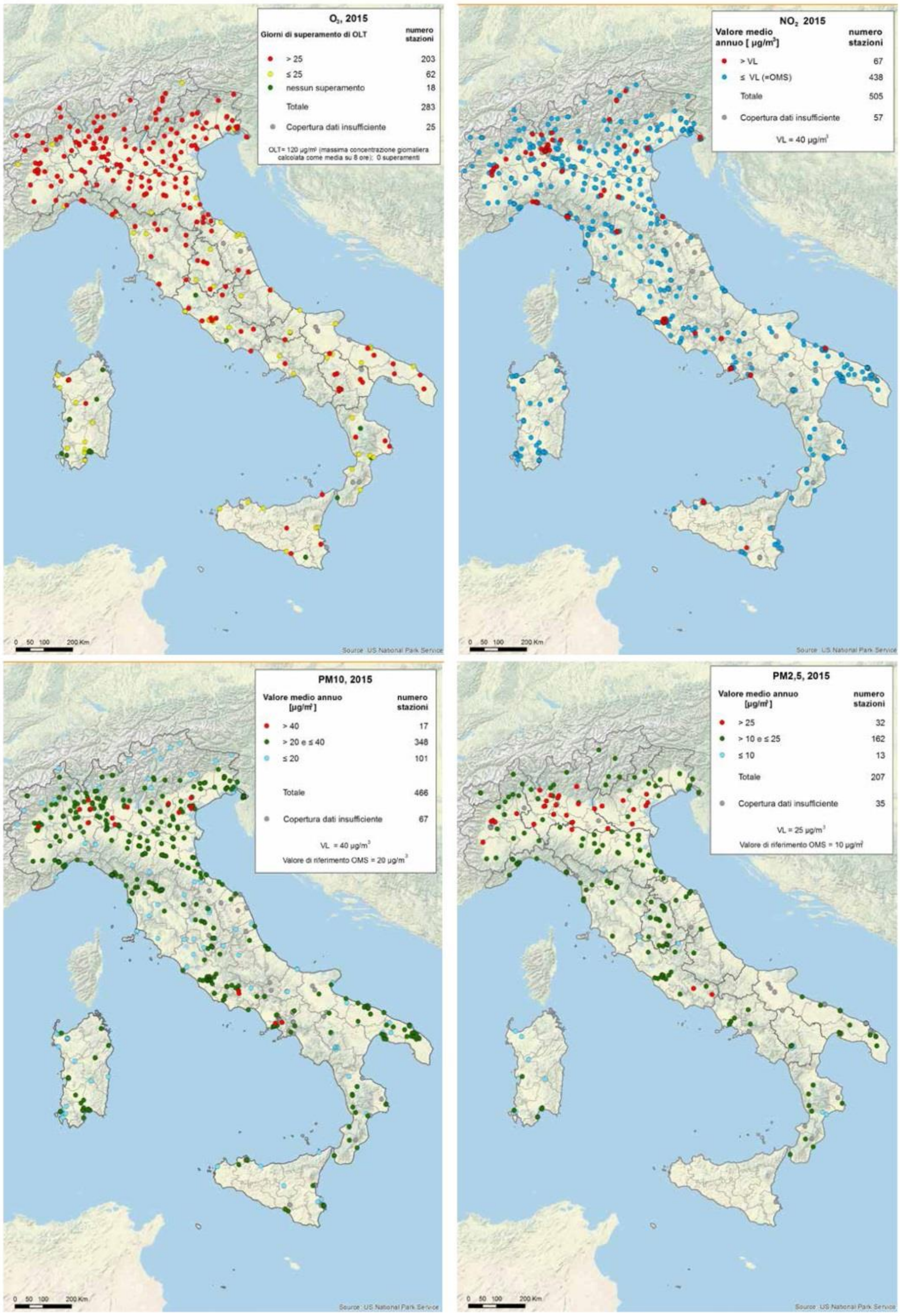

Figure 1. Spatial distribution of ambient air pollutants in Italy for the year 2016. NO_2, PM10 and PM2.5 are provided as annual means, for ozone the number of days exceeding 120 µg/m^3 (8 h averages) are presented. The dashed lines indicate urban areas with high population densities. The figures were taken from the Report on the State of Environment, year 2017, edited by ISPRA – Istituto Superiore per la Protezione e Ricerca Ambientale (Higher Institute on Environmental Protection and Research)

As expected, NO_2 is clearly related to city centres and traffic with annual concentrations sometimes exceeding the WHO guideline value of 40 µg/m^3. Almost everywhere it was recorded an higher number of days exceeding 120 µg/m^3 ozone limit, probably due to the warm and sunny climate all over Italy, which supports photochemical reactions. Stowell et al. consider climate change induced tropospheric ozone as one of major threats to human health. Figure 1 also makes clear that different geographic regions are affected by different types of air pollutants. This needs be taken into account in the building design of ventilation systems in modern housings.

Ozone levels indoors are mostly low due to chemical reactions on indoor surfaces. However, nitrogen dioxide (NO_2) concentrations can be increased during warm periods (spring, summer) because of the frequent opening of windows, especially near busy roads. Indoor combustion processes (e.g. gas cooking, decorative fireplaces) result in elevated indoor/outdoor (I/O)-ratios for NO_2. For this reason, increased NO_2 concentrations can also occur during the cold seasons even when air exchange rates are low.

Table 7 sums up the relationship between pollutants, their sources, comfort and health effects, and gives possible solutions about control measures.

Table 7. Relationship between pollutants, their sources, comfort and health effects and possible control measures

Pollutant	Sources	Comfort and Health Effects	Control Measures
Airborne Biological Pollutants Biological materials, bacteria, viruses, fungi (moulds and yeasts), pollen, dander, and insect (cockroaches and dust mites) parts are present nearly everywhere in indoor environments. These particulates range from less than one to several microns in size. When airborne, they are usually attached to dust particles of various sizes so that all sizes of airborne particles may include them.	People, plants, pets, and insects may serve as sources or carry biological agents into a building. Drapery, bedding, carpeting, and other places where dust collects can harbour them. Cooling towers, dirty air conditioning equipment, humidifiers, condensate drains, and ductwork can incubate bacteria and moulds. Other sources include wet or damp building materials and furnishings including insulation, carpet, ceiling tiles, wall coverings, and furniture.	Tuberculosis, measles, staphylococcus infections, influenza and Legionnaires disease are some of the diseases caused by exposure to biological material in indoor air. Pollens and moulds can cause allergic reactions for a significant portion of the population. Common symptoms include sneezing, watery eyes, coughing, and shortness of breath, dizziness, lethargy, and fever.	Good housekeeping and maintenance of HVAC equipment are very important. Adequate ventilation and good air distribution also help. Higher efficiency air filters remove viable particles along with other particles. Any water-damaged building materials or furnishings should be promptly cleaned, dried, or replaced. Maintain relative humidity between 40 to 60 percent. Cooling tower water treatment procedures exist to reduce levels of Legionella and other organisms.
Asbestos is composed of small, natural mineral fibres. Chrysotile is the most commonly used asbestos and represents about 95 percent of the asbestos used in buildings in the United States.	Widely used in insulation and other building materials manufactured before 1977. Examples include pipe and furnace insulation, vinyl floor tiles and sheet flooring, patching compounds, textured paints, roofing	No immediate acute health effects are known. Fibres deposited in the lung are the only known cause of mesothelioma, a cancer of the chest and abdominal lining. Asbestos is also associated with cancer of	The recognized methods of responding to friable or hazardous asbestos containing materials include repair, removal, enclosure, and encapsulation. Removal has often been the abatement method of

	materials, wall and ceiling insulation, and brake and clutch pads.	the oesophagus, stomach, colon, and other organs. It can also cause asbestosis, a non-cancerous chronic and debilitating lung disease found in high-level industrial exposures.	choice, although removal is not necessarily the most cost-effective method to protect human health and the environment.
Carbon dioxide (CO_2) is a colourless, odourless, and tasteless gas. It is a product of completed carbon combustion.	All combustion processes and human metabolic processes are CO_2 sources. Concentrations of CO_2 from people are always present in occupied buildings.	Carbon dioxide is a simple asphyxiant. At concentrations over 1.5 percent, breathing becomes more difficult. Above 3 percent, CO_2 causes nausea, headaches, and dizziness, and above 6 to 8 percent stupor and death can result. At lower concentrations (0.1 percent), building occupants may experience headaches, fatigue, or eye and respiratory tract irritation. At low concentrations, the build-up of CO_2 indicates inadequate ventilation.	Ventilate with fresh air to control carbon dioxide levels. Ventilation rates should meet WAC 51-13. Which requires 15 CFM/person in atypical classroom.
Carbon Monoxide (CO) is a colourless, odourless, and tasteless gas. It results from incomplete oxidation of carbon in combustion.	Incomplete oxidation during combustion in gas ranges, unvented heaters, leaky wood and coal stoves, and tobacco smoke may cause high concentrations of CO in indoor air. Worn or poorly adjusted and maintained combustion devices can be significant sources. Automobile, bus, or truck exhaust entering buildings from attached garages, nearby roadways or parking areas can also be a source of CO.	Acute or short-term effects of carbon monoxide (CO) exposure are due to the formation of carboxyhemoglobin in the blood, which inhibits oxygen intake. At moderate concentrations, symptoms may mimic influenza and include fatigue, headache, dizziness, nausea, and vomiting. Other symptoms include impaired judgment and impaired vision. At higher concentrations, CO exposure is fatal.	Maintaining and properly venting combustion equipment is most important. Manage vehicular use adjacent to buildings and in vocational programs to avoid entry of exhaust into buildings. Additional ventilation can be used as a temporary measure when high levels of CO are expected for short periods of time.
Formaldehyde is a colourless, water-soluble gas. Due to its wide use, it is frequently considered separately from other volatile organic compounds	Materials containing formaldehyde are widely used in buildings, furnishings, and consumer products. Urea-formaldehyde resins are used in the manufacture	Formaldehyde has a pungent odour and is detected by many people at levels of about 0.1 parts per million (ppm). Besides the annoyance, at higher concentrations	For problem UFFI cases, removal is indicated although the cost can be high. Even then, residual materials may remain in the structure and continue to off-gas.

(VOCs).	of plywood, particleboard, fibreboard, and textiles. Other potential sources include furniture, shelving partitions, ceiling tiles, wall coverings, and carpet backing. The walls of some buildings have been insulated with urea-formaldehyde foam insulation (UFFI). Tobacco smoke and incomplete combustion of cooking and heating fuels are secondary sources.	it can also cause eye, nose, and throat irritation; coughing; wheezing; fatigue, skin rashes; and in rare cases, serious allergic reactions. Formaldehyde has caused nasal cancer in laboratory animals, but chronic effects have not been established for human beings. Some people exhibit a high sensitivity to very low concentrations.	Increased temperature, humidity, and ventilation will accelerate off gassing of formaldehyde. Therefore, ventilation may not be an effective means of control. Some manufacturers are producing products with lower off-gassing rates. Some surface treatments (such as nitrocellulose or water based polyurethane finishes) are being used to reduce off gassing.
Nitrogen Oxides The two most prevalent oxides of nitrogen are nitrogen dioxide (NO_2) and nitric oxide (NO). Both are toxic gases with NO_2 being a highly reactive oxidant, and corrosive. NO gradually reacts with the oxygen in the air to form NO_2.	The primary indoor sources are combustion processes, such as unvented combustion appliances, defective installation of vented appliances, welding, vehicle exhaust, and tobacco smoke. Combustion appliances include wood, gas, and coal stoves, as well as unvented kerosene heaters and fireplaces under some circumstances.	Oxides of nitrogen have no sensory effects in concentrations normally found in schools. Acute effects of lung dysfunction have been reported at higher concentrations. Oxides of nitrogen produce delayed short-term effects on airway activity. Persons at special risk are those with chronic bronchitis, emphysema, asthma, and children under two years old. Long-term or chronic effects are not well established.	Venting the sources of nitrogen dioxide to the outdoors is the most practical measure for existing conditions. This includes proper installation, operation, and maintenance of all combustion appliances and prevention of vehicle exhaust entry into buildings.
Other Volatile Organic Compounds (VOCs) are compounds that vaporize (become a gas) at room temperature. There are hundreds of VOCs found in the indoor air, sometimes in concentrations suspected of being harmful.	VOCs are released from many housekeeping and maintenance products, building materials, furnishings and equipment, and from human metabolism. Examples include: acetone and alcohols that are by products of human metabolism and can be released from cleaners and personal care products; ammonia from cleaners and diazo copiers; aromatic hydrocarbons from combustion processes, pesticides, paints, and	Several of these compounds have been identified individually as causing acute and chronic effects at high concentrations. At higher concentrations than are typically expected in school buildings, some VOCs have been linked to cancer in humans, and others are suspected of causing cancer. Anecdotal reports suggest that combinations of these compounds in low concentrations may be associated with sick building incidents.	Selective purchasing and use of construction materials, furnishings, operational and maintenance materials can help reduce VOC emissions. Products should be stored in well-ventilated areas apart from occupied zones. Increased ventilation or direct exhaust can be used for activities that have high VOC emissions, such as painting. Scheduling the use of products to avoid occupant exposure to high levels of VOCs can

	solvents; benzene from combustion processes, gasoline, and solvents; chlorinated hydrocarbons, from wood preservatives and solvents; styrene from carpet systems; phenols from equipment and furnishings; toluene from adhesives, gasoline, paints, and solvents; and 4-phenyl cyclohexane (4-PC) released from carpet systems.	However, this has not been confirmed through rigorous experimental or observational studies. Symptoms attributed to VOCs include respiratory distress, sore throat, eye irritation, nausea, drowsiness, fatigue, headaches, and general malaise.	also be useful.

E. Technical solutions to improve the IAQ in schools and their feasibility

E.1. Technical solutions

The selection of a solution is based on the data gathered during diagnostics, i.e. after the analysis of the monitoring campaign results and of the classroom questionnaires. The diagnostics may have determined that the problem was either a real or a perceived IAQ problem, or a combination of multiple problems. For each problem, a solution has been proposed using the basic control strategies described below.

There are a few basic control methods that can lower concentrations of indoor air pollutants. Often, only a slight shift in emphasis or action using these control methods is needed to control IAQ more effectively. Specific applications of these basic control strategies are listed below.

E.1.1. Source removal

Actions aimed at source removal may imply changing the ordinary materials used both during classrooms and labs both in cleaning operations, but also changing school furniture (tables, chairs, closets, paintings etc.), in order to eliminate a specific source of pollution in the indoor environment.

E.1.2. Source reduction/substitution

Source reduction and/or substitution may imply changing some of the ordinary materials used both during classrooms and labs both in cleaning operations, but also changing school furniture. This action is not about eliminating a source of pollution but about reducing the concentration of a pollutant in the indoor air by acting on its source, or changing a pollutant with another one (typically less harmful) by changing the source of pollution.

E.1.3. Ventilation

Lowering the concentration of pollutants by diluting the polluted air with clean air can be done by manual systems (i.e., simply open the windows and ventilate the premises at regular intervals) where the school does not have automatic air exchange systems. This result can also be accomplished through automatic systems that, at regular time intervals or (with more sophisticated systems) automatically operating after detecting that the concentration of some pollutants in the indoor air is too much high, makes a change of air between inside and outside can be the ideal solution where the school has no automatic air exchange systems. In Italy, this happens in more than 90% of schools.

E.1.4. Exposure control

Adjusting the time and location of pollutant exposure, including moving the pollutant source away from occupants or even relocating susceptible occupants is a more complex solution as it requires a detailed study of both the exposure times of the school occupants to the single pollutants and of the diffusion models of the individual pollutants in the air.

E.1.5. Air cleaning

This solution consists in applying filters to automatic ventilation systems. The filters ensure that the air which is forcibly fed from the outside in the interior is subjected to a "cleaning" process that mainly eliminates dust and suspended particulate matter. Obviously this system can only be applied to an existing forced ventilation system, or installed simultaneously with the installation of a new system for forced ventilation.

E.1.6. Regular monitoring campaigns of air quality

The implementation of further air quality monitoring campaigns must be carried out in ways that allow more detailed and detailed information to be obtained compared to those obtained by the InAirQ project monitoring body. In particular, it will be necessary to provide adequate monitoring periods (at least 30 days in the cold season and 30 days in the hot season) and to carry out monitoring campaigns with protocols and tools provided for by current European regulations. This action allows to have a more detailed knowledge of the phenomenon of indoor and outdoor pollution and their interaction and, therefore, to be able to formulate measures to contain and reduce indoor pollution specifically designed for the individual case study.

E.1.7. Education and awareness raising

This solution involves a major effort of communication and involvement to be carried out on the main actors of school day-to-day life: school managers, teachers and school staff, pupils and their families. The awareness-raising action should be carried out by specialized personnel (such as, for example, the Italian partners of the InAirQ project) and should benefit from all the knowledge shared and developed within the InAIrQ project. Communicating this type of information and the importance of pursuing good indoor air quality with the goal of protecting health is the first step towards a positive change in individual behaviours that could make sure that not only at school but also in the homes of all the people involved, the habits are changed and the air pollutants concentration is reduced.

Some solutions, such as major ventilation changes, may not be practical to implement due to lack of resources or the need for long periods of non-occupancy to ensure the safety of the students and staff. Use temporary measures to ensure good IAQ in the meantime.

Other solutions, such as anti-idling programs, offer low-cost options that can be easily and quickly implemented.

E.2. Feasibility assessment

In the following table, the listed measures for the improvement of indoor air quality in the schools of Turin area are assessed with regard to their feasibility at local level and stakeholders which need to be involved to ensure the success of the initiative.

Table 8. Feasibility of measures to improve IAQ in Italian schools

Measure	Stakeholders to involve	Feasibility
Source removal	School managers School staff and teachers Children and their families Local school office Municipality	**Low** ☹ The local context (bureaucracy, public budget, current laws) makes it difficult to plan a total substitution of pollution sources, as pollution sources may be found in different tools and equipment from daily school life.
Source reduction/substitution	School managers School staff and teachers Children and their families Local school office Municipality	**Medium** 😐 The source reduction may be easy to operate depending on the pollution source we want to reduce. It's much more easier to reduce pollution sources originating from personal behaviours (such as tetrachloroethylene sources, coming from cleaning process of personal dresses) than sources which need investments and/or stakeholders' cooperation to be accomplished (such as substitution of school furniture, or cleaning products)

Measure	Stakeholders to involve	Feasibility
Ventilation (manual)	School managers School staff and teachers Children	**High** ☺ A simple solution like agreeing, at level of single school, a good practice such as periodically ventilating the classrooms to reduce the concentrations of pollutants (to a greater extent CO2) is extremely feasible, both because the stakeholders to be involved are very few (yes it deals with the school manager, the teachers and the school staff and the pupils) and because it is a solution at no cost.
Ventilation (automatic)	Local school office Municipality School managers	**Medium** 😐 This solution, although it foresees the involvement of institutional stakeholders and an investment in terms of plants, can be on average feasible because, in some cases, the installation of new plants may be done thanks to the attraction of private investments (for example, in Turin, by no-profit institutions bodies whose institutional mission is to improve public environments) or awarding European funds.
Exposure control	School managers School staff and teachers Local school office Municipality Research institutes / bodies specialised in studying air quality, pollutant sources and diffusion etc.	**Low** ☹ This solution has a low feasibility mainly because the need to carry out in-depth studies relating to the precise concentrations of pollutants in individual school environments, to the models of diffusion of pollutants, to sources of pollution and to methods of reducing concentrations is an element that times of identification and application of the solutions and involves a plurality of different subjects, which could be curbed by the difficulties implicit in the national context (typically the bureaucracy).

Measure	Stakeholders to involve	Feasibility
Air cleaning	Local school office Municipality School managers	**Low** ☹ This solution has low feasibility because in Italy only very few schools have forced ventilation systems - before applying this solution it is necessary to install a forced ventilation system.
Regular monitoring campaigns of air quality	Local school office Municipality Local Agencies operating in the field of environmental monitoring	**High** ☺ This solution is highly feasible because, despite increasing the number of stakeholders involved, it provides for the participation of ARPA - Regional Environmental Protection Agencies which, in their institutional missions, have to provide for environmental monitoring in consultation with local authorities. Local authorities, in turn, are normally interested in acquiring additional information on the state of the environment, especially when they are aimed at protecting children's health.
Education and awareness raising	School managers School staff and teachers Children	**High** ☺

F. Conclusions

The feasibility study on the application of measures aimed at reducing indoor air pollution in schools in Turin and Italy in general has led to interesting results, linked both to the specific need to protect the health of children and to the national context in relation to the theme of indoor air quality and school management.

First of all, it must be underlined that, as in the other Central European countries, even in Italy there is no specific legislation concerning both monitoring and management of indoor air quality, both in public and private buildings. In recent years, some progress has been made with the approval of CAM (Environmental Minimum Criteria), protocols that collect a series of regulations aimed at governing the use of materials and substances in the public procurement field.

These protocols are based on the idea of using safer and healthier materials from the point of view of emissions and do not provide any ex-post control of the actual air quality as a result of their use. Although, therefore, they are not yet sufficient to guarantee an acceptable indoor air quality, they constitute a very important first step towards awareness of the IAQ theme.

The measures identified as a result of the studies done in the context of InAirQ project in order to improve the indoor air quality in schools have a variable feasibility in relation to the reference context and to the stakeholders to be involved. In general, actions of an intangible nature, such as campaigns to increase awareness, are more feasible than others because they cost far less than what could be hypothesized for material measures, and because they involve a number minority of stakeholders, generally limited to the scholastic reality in which the campaign is to be carried out.

In this context the actions aimed at teaching virtuous behaviours are included, such as the agreement of periodic window openings in the confined rooms of the schools in order to allow a change of air between inside and outside and the consequent reduction of the concentrations of some pollutants (such as CO_2). These interventions also have a high degree of feasibility because they are not very costly, involve few stakeholders and leverage the awareness of a problem that, at least in schools participating in the InAirQ project, has already been raised and addressed.

Finally, also the deepening of air quality monitoring campaigns has a high feasibility, since in general institutions are always interested in environmental monitoring, which prepares them for the identification of solutions for the improvement of environmental quality and the life of people, especially of minors.

Other measures to reduce the concentration of pollutants in indoor air schools have a medium feasibility. Specifically, it is the substitution / reduction of polluting sources, because some polluting sources can be easily reduced: they are those that depend on individual behaviours (for example the use of perfumes, the use of particular types of elements of stationery, etc.): even in this case, awareness raising campaigns may be able to bring about positive changes in people's behaviour, which could thus improve the air quality of environments confined not only in school environments but also in inside their homes.

Also the installation of automatic ventilation systems has a medium feasibility level. In this case, we talk about material interventions on the plant engineering part of the school, which would require a certain level of investment. The national context makes it difficult to find funds to develop these activities, but in some specific cases this difficulty may not be insurmountable: for example, non-profit organizations could be identified that for institutional mission invest money in improving public buildings, or it would be possible to find funds from European funding sources.

Finally, other interventions have a very low level of feasibility in relation to the reference context. In general, these are interventions that require the involvement of many institutional actors (the more numerous and less local institutions are, the lower the level of feasibility), and / or measures that require investment, material changes in buildings and generally they imply that there are pocket costs to deal with. These little feasible measures include the elimination of polluting sources and the control of the exposure of building occupants to a certain type of pollutants (because the replacement of products to be used or furniture inside schools would require a large number of bureaucratic procedures to which a plurality of public bodies should share) and the installation of systems for cleaning the air when it is forcefully introduced from the outside (because, simply, to use this measure, forced ventilation systems should be installed, of which more than 90% of the Italian schools are lacking.

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