INDOOR AIR QUALITY ACION PLAN

School environment

POLAND

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1. Indoor Air Quality in school environment in Poland

Recognition of the actual state of schools environment in Poland that has been performed as part of the InAirQ project indicates that the Indoor Air Quality is rather low. A detailed analysis of the data gathered in the field campaign conducted in twelve schools selected for this purpose in the city of Lodz has indicated and determined major problems. In the analysis all data obtained from the questionnaire studies and interviews with schools directors, technical headmasters and teachers in conjunction with the results of the indoor air and the air exchange rate measurements were taken into account. Conclusions from this analysis allowed for an identification of major problems in the schools environment in Poland:

- a very high level of the outdoor air pollution in the surroundings of the schools,
- a low level of air exchange rate in the classrooms,
- insufficient funds with respect to renovation purposes,
- very low awareness of the IAQ among the schools staff.

According to the Vulnerability Assessment, prepared under WP T2 in the InAirQ project the technical state of primary school buildings in Lodz is rather bad. More than half of the buildings require a thorough renovation including thermo-insulation of walls, replacement of windows, fixing roofs and facades, replacement of sanitary, electric installations, replacement of lighting, renovation of interiors and replacement of furniture. The need for cleaning or repairing ventilation systems that has been reported by 50% of schools included in the reportis particularly alarming. Improperly working ventilation results in the increase of the concentration of harmful agents present in the indoor air, mainly including CO_2 exhaled by the pupils. Exposure to a high concentration of CO_2 in humans affects well-being in a negative way. It has also negative health effects (among others: headache or mucosal irritation). The need for windows replacement is equally alarming. Old, damaged windows are often impossible to open, thus, proper airing of the classrooms is sometimes difficult. As a consequence in the classrooms children are exposed to very high levels of CO2 as well as other various pollutants.

Majority of the schools have reported the need for interiors renovation and furniture replacement. Selection of new flooring materials and furniture has to be performed with care. Several consumer/building products emit volatile organic compounds, which might cause the same symptoms as the ones caused by exposure to a high level of CO_2, i.e. sensory irritation of the eyes and airways as well as performance deterioration. Replacing old windows with the airtight ones in the primary schools could lead to the reduction of energy used for heating; however, concentration of the indoor air pollutants (e.g., volatile organic compounds, carbon dioxide) might be higher due to the lower air exchange rates. The problem can be solved by mechanical ventilation installation but in Polish circumstances, in the case of classrooms it is natural ventilation that usually takes place. In the vast majority of the schools mechanical ventilation is operating only in a canteen and kitchen part.

In the last decade, the school buildings were gradually subjected to renovations, which most frequently included thermo-modernization process. This process is associated with legal regulations that apply in the European Union (reduction of CO2 emission) as well as actual renovation needs (among others a poor state of window joinery and elevations of the school buildings). Such work should be conducted taking into account the best knowledge to preserve good indoor air quality, proper thermal comfort as well as productivity of pupils and school staff, including teachers. It is very important to avoid negative agents inducing negative health effects. In many school buildings thermo-modernization works had been performed few years ago using a very low budget. The low cost processes (including low cost materials) as well limited knowledge of schools management result in a decrease of the indoor air quality. In order to make the school environment better and healthier for pupils, actions aiming at improvement of the indoor air quality should be undertaken.

2. Characterization of the current state of the school environment

2.1. Description of the environment and populations affected by the problem

Currently, in Poland an educational reform that covers primary schools is taking place. Till the year 2015/2016 primary school lasted 6 years, and from the year 2016/2017 it has been extended by 2 years and now it lasts 8 years. Similar changes concern children who just start school. Over the years 2014/2015 and 2015/2016 children aged 6 years old started school; but now, after the reform has been introduced, beginning from the current school year, the age of 7 as the age of starting school has been brought back. Primary school pupils, in accordance with the new system (starting from the school year 2016/2017), are children aged 7-15. Generally, in Poland public school sector dominates over the private one.

In the school year 2015/2016, approximately 2 480 800 pupils attended primary public and non-public schools with a public status (schools that are run by institutions other than municipalities but receive a subsidy from the municipal budget to conduct educational activities). Of this number, 2 388 890 pupils attended public schools, and about 91 900 non-public schools with a public status (Table 1).

Table 1. Primary schools, teachers and students in 2015/2016 school year in Poland.

Specification	The number of:		
	schools	teachers	pupils
Grand total Poland	13 563	190 510	2 480 793
Primary public schools Poland	12 365	180 426	2 388 890
Primary non-public schools with public status Poland	1 198	10085	91903
region of Lodz (incl. Lodz city)	845	11 617	151 776

Source: Oświata i wychowanie w roku szkolnym 2015/2016, Główny Urząd Statystyczny, 2016; [Education and upbringing in the school year 2015/2016, Central Statistical Office of Poland, 2016]

Table 2. Pupils in primary schools by place of residence in 2015/2016 school year.

Specification	Urban areas		Rural areas
	less than 5 thous. inhabitants	more than 5 thous. inhabitants	
Grand total Poland	77 610	1 319 703	1 083 482
region of Lodz (incl. Lodz city)	3 910	84 504	63 362

Source: Oświata i wychowanie w roku szkolnym 2015/2016, Główny Urząd Statystyczny, 2016 [Education and upbringing in the school year 2015/2016, Central Statistical Office of Poland, 2016]

2.2 General overview of the types of school buildings in the country

Primary schools in Poland are run mainly by district authorities. However, an increasing part of schools run by other organs is being observed. In the school year 2007/08 district authorities ran 94.1% of primary schools, and in the year 2012/13 – already only 89.8%. Those changes stem from closing primary schools down by district authorities and passing them to other organs (mainly societies). The mean size of a school depends significantly on the type of an organ which is responsible for it. The mean size of a school run by district authorities is about 180 pupils.

In the last decade in the whole country, school buildings were gradually subjected to renovations, which most frequently included a process of thermo-modernization. This process is associated with legal regulations that apply in the European Union (reduction of CO_2 emission) as well as actual renovation needs (among others a poor state of window joinery). In general, non-public school buildings are in a better condition that those of the public schools. To the best of our knowledge, in Poland there is no actual data on the state of school buildings.

2.3 State of the school buildings in the region.

The state has provided financial support allotted mainly for the improvement of educational tools (e.g., new computers and boards), less financial support remained for the renovation works. Nevertheless, thanks to the courtesy of the Unit of Projects and Investments, Department of Education, The City of Lodz Office, the employees of which contacted all the schools via phone and gathered very detailed information, it became possible to prepare a report on the state of public school buildings in Lodz. As there is no basis to conclude that the schools in Lodz differ considerably from the schools in the rest of the country, this report may be considered as representative for the whole Poland. Table 3 and Figure 1 present institutions that run primary schools in Lodz.

Table 3. Primary schools in Lodz by funding institution in the school year 2016/2017.

Schools	Funding institution	Number of schools
Public (n=86)	City of Lodz Office	83
	Society	3
Non-public (n=22)	Foundation	3
	Church/ religious organizations and societies	2
	Private schools (companies)	9
	Other (societies)	8

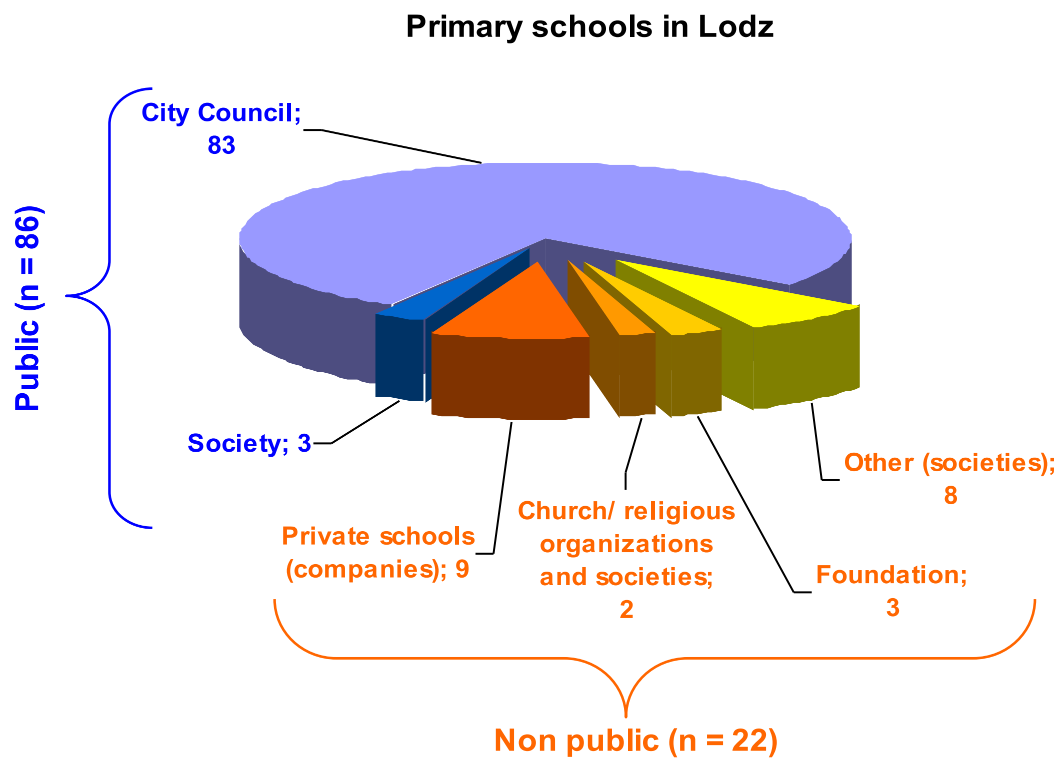

Figure 1. Percentage of primary schools in Lodz by funding institution in the school year 2016/2017.

A detailed list of selected features of the buildings of public schools in Lodz is presented in Table 4. The list includes buildings according to the state as of January 2017, i.e. before the educational reform that has closed down junior high schools, the part of which will be transformed into primary schools in the coming years. However, buildings of junior high schools in Lodz do not differ from the buildings of primary schools because of the fact that in the period during which they were created, in vast majority, they were created from the buildings of the closed down primary schools.

Table 4. The state of public primary school buildings in Lodz in the school year 2016/2017.

Specification		Number of schools
Age of the building or the date of the building construction:	1900 - 1945	10
	1946 - 1979	65
	1980 - 1989	7
	After 1990	1
Type of construction materials:	concrete slab	20
	hollow brick	1
	brick	51
	mixed	11
Floors number:	ground-floor	0
	1-storey	9
	2-storey	52
	3-storey (and more)	22
Shape of the building:	Regular	32
	Irregular	7
	L shaped	27
	U shaped	10
	T shaped	3
	C shaped	2
	H shaped	1
	E shaped	1
Schools without thermo-modernization		57
Schools after thermo-modernization		26

Specification		Number of schools
Schools that require thermo-modernization:	Thermo-modernization planned in 2017	9
	Thermo-modernization planned in 2018	9
	Thermo-modernization planned in 2019	6
Renovation needs*:	Thermo-insulation of walls	59
	Replacement of windows	46
	Fixing the roof	57
	Repair of facades	57
	Replacement of sanitary installation	42
	Replacement of electric installation	69
	Replacement of lighting	54
	Interiors renovation	69
	Replacement of furniture	68
	Ventilation cleaning/repair	44
	Chimneys	3
	Foundation insulation	1
	Lightning protection	1
	Dehumidifying of basements	1
Heating type:	Municipal	71
	Gas	8
	Gas and oil	1
	Oil	3
Ventilation type**:	Gravity	83
	Mechanical	20
	Air Conditioning	1
Location:	High intensity of traffic	27
	Medium intensity of traffic	33
	Low intensity of traffic	23

* more than one answer could be chosen
** more than one answer: mechanical ventilation in the kitchen or sports part, and air conditioning in the sports part

The report on the state of primary schools buildings in Lodz indicates a bad technical state of the buildings; more than a half of the buildings require a thorough renovation including thermo-insulation of walls, replacement of windows, roof and facades fixing, replacement of sanitary, electric installations, replacement of lighting, renovation of interiors and replacement of furniture. Detailed needs are shown in Figure 2. The need for ventilation cleaning or repairing, which has been reported by 50% of the schools included in the report, is particularly alarming. Improperly working ventilation results in the increase of harmful agents concentration present in the indoor air, mainly CO_2 that the pupils themselves are a source of. Exposure to a high concentration of CO_2 in humans induces problems with concentration and negatively affects well-being. It has also negative health effects (among others: headache or mucosal irritation). Therefore, one should pay particular attention to raising awareness of schools management and institutions that run and manage schools of the problem of an inappropriately working or clogged ventilation.

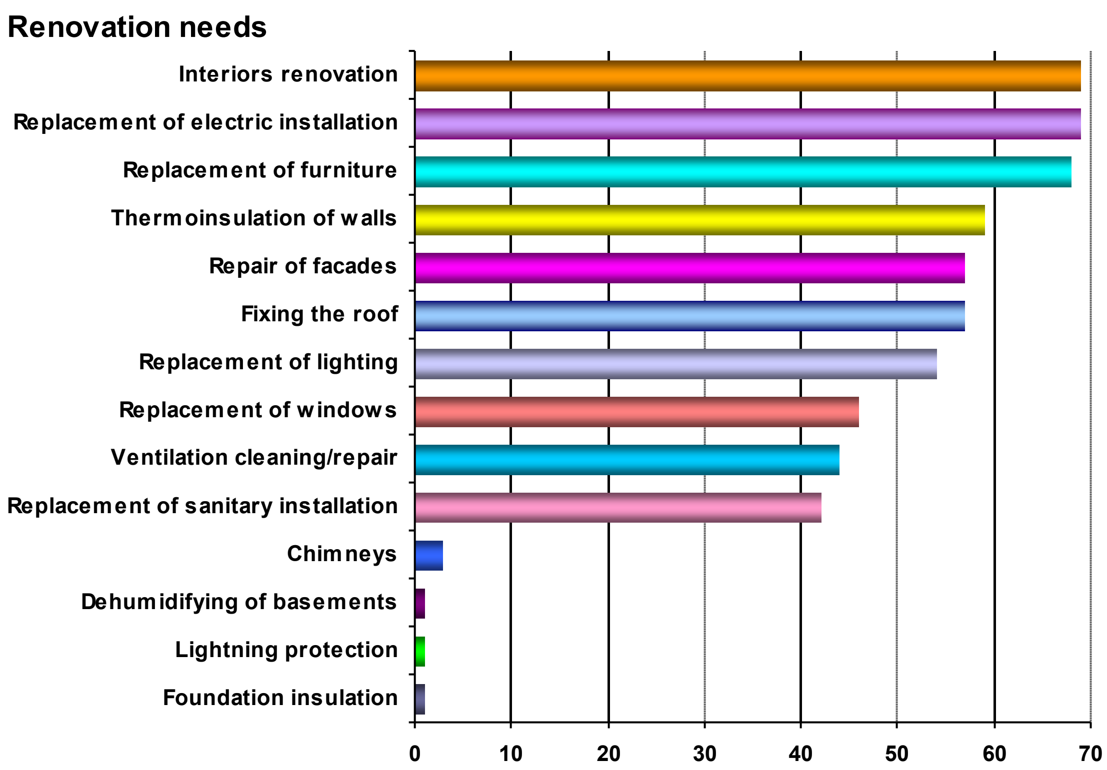

Figure 2. Renovation needs in public schools in Lodz in the school year 2016/2017 according to school directors.

2.4 Major characteristics and problems regarding maintenance of the buildings which might affect the indoor air quality.

Situation concerning the need for replacement of windows is similarly alarming. Old, damaged windows are often impossible to open and make proper airing of the classrooms impossible, which when combined with the previously discussed inappropriately working air ducts, increases the problem of long-term exposure of children to the elevated levels of CO_2 in schools.

According to the information provided by the public primary schools in Lodz, nearly all the school buildings are asbestos free. One school is an exception – according to the information provided by the school, it has some asbestos in the part of the roof. Exposure to asbestos fibers is associated with respiratory diseases including mesothelioma.

The surveyed schools did not have any information if plumbing installations in their buildings contained lead. Lead can leak from the pipe into the drinking water and might cause adverse health effects even at low concentration levels. Lead is considered a highly toxic metal that may induce serious health hazards, especially in children, such as: elevated blood pressure or hearing problems. Lead is particularly dangerous to children because their growing bodies absorb more lead than adults' bodies do, and their brains and nervous systems are more prone to the damaging effects of lead. In accordance with the applying legislation, the use of lead containing pipes is forbidden in Poland, therefore, one may assume that even in old school buildings lead pipes were replaced by safe ones many years ago. Majority of the schools reported the need for interiors renovation and replacement of furniture. Selection of new flooring material and furniture has to be done with care. Several consumer/building products emit volatile organic compounds, which might cause sensory irritation in the eyes and airways, and deterioration of performance. Recently, replacement of old windows by airtight ones in the primary schools could lead to the reduction of energy used for heating; however, concentration of the indoor air pollutants (e.g., volatile organic compounds, carbon dioxide) might be higher due to the lower air exchange rates.

Primary schools in Lodz, which were described in this document, are located in various parts of the city with various intensity of road traffic and thus, diverse levels of air pollutants and noise in the direct neighborhood of each school.

Taking into consideration all the described varieties, one should conclude that in the schools of Lodz that represent primary schools in the region of Lodz and in Poland, actions aiming at improvement of the indoor air quality should be definitely taken.

2.5 Legal measures related to the management of schools and indoor environment monitoring

In Poland there is no authority responsible for ensuring adequate indoor air quality (IAQ) in schools. Legal regulations on the quality of indoor environment in school buildings are formulated in a very general way. The main legal act is the Directive of the Minister of National Education and Sport of December 31, 2002 on the health and safety in public and non-public schools and educational units. However, this regulation does not specify detailed technical or organizational requirements that should be used to ensure good quality indoor air in schools. Content of the regulation includes only a general statement that head masters of schools and other educational units are responsible for providing safe and healthy conditions in the schools as well as safe and healthy conditions of participation in the classes organized by the school but taking place outside the premises of the schools.

There is also lack of any formal regulations with regard to supervision of the indoor air quality in schools. A headmaster is obliged to ensure healthy conditions; however, there is lack of reference values for pollutants concentration in the air, as well as there are no institutions that would control fulfilling this obligation. In general, in Poland there is no institution that would supervise indoor air quality in almost all types of environment. Environment of work is the only exception – for this particular environment there are a number of legal regulations and two national inspections that supervise practical fulfillment of such obligations. In theory, these regulations also apply in schools, which in fact are workplaces. However, in practice, based on this regulations, measurements of harmful agents present in the indoor air of school classes are hardly ever taken.

One of the main purposes of the vulnerability assessment was to review the existing policies, i.e. officially adopted documents on the indoor environment. Based on the type of policy, legally binding standards or regulations, the legally non-binding recommendations or guidelines as well as action plans or programs are distinguished. Furthermore, policies exist at different levels such as international, national or sub-national (regional) levels. International bodies have developed several regulations and guidelines on selected air pollutants outdoors; however, there are still no regulations covering concentration of air pollutants indoors. In 2010, the World Health Organization (WHO) published a book ("WHO guidelines for indoor air quality: selected pollutants") in which some common indoor air pollutants are reviewed and guidelines are recommended.

Besides these international bodies, big effort is made to establish the indoor air quality guidelines at national or at sub-national levels in several countries all over the world. WHO collected relevant information by the "Environment and health policy action questionnaire" from the member states and the results of the work were published in 2014 as "School environment. Policy and current standards".

It is well-known that the temperature and relative humidity in the classrooms are a matter of human comfort. Inappropriate air parameters have negative influence on well-being of teachers and pupils that spend their time there. Too low relative humidity of air, especially during the heating season, results in dryness in the nose and throat and leads to eyes irritation. Whereas, a too high air temperature (especially when combined with an increased concentration of CO_2) may induce breathlessness and tiredness.

Legal regulations oblige to maintain the following temperatures in a school building, in the heating season:

- rooms for learning: at least +18 ° C (*Directive of the MEiS of December 31, 2002 on the safety and health in public and non-public schools and educational units*),
- cloakrooms, corridors, staircases, gyms: +16° C,
- undressing rooms, showers: +24° C.

In case of not meeting the criterion of minimal temperature, the headmaster suspends classes for an unspecified period of time.

There are national regulations related to ventilation in schools but generally they are formulated as 'School premises ensure appropriate lighting, ventilation and heating' (Directive of the Minister of Education and Sport of December 31, 2002 on the safety and health in public and non-public schools and educational units). In Poland in 2008 European Standard EN 13779:2007 Ventilation for non-residential buildings – Performance of requirements for ventilation and room-conditioning systems (Polish Standards PN-EN 13779:2008) was introduced.

Strict regulations are in force in Poland so as to protect non-smokers from tobacco smoke.

The Act of November 9, 1995 on the health protection against consequences of tobacco and tobacco products smoking strictly bans smoking tobacco products, including novelty tobacco products and e-cigarettes, on the premises of organizational units of educational system, and also outside those premises.

In Poland there are reference values related to harmful biological agents present in the indoor air proposed by Górny RL. In practice, concentrations of biological agents in schools very rarely (even never) are measured and only experts in the field of exposure to biological agents know about it.

In accordance with the legal acts in Poland, the school ground has to be fenced. Regulations define the minimum distance between:

1. buildings and roads - regulated by The Act of March 21 1985 on public roads:

   - highway - 30 m
   - expressway - 20 m
   - the road: national - 10 m, provincial and district - 8 m, municipal - 6 m

2. buildings and parking spaces:

   - to 4 positions including - 7 m
   - from 5 to 60 positions including - 10 m
   - more than 60 positions - 20 m

3. buildings and petrol stations

   - depending on the type of fuel tank – 150 – 20 m

Currently applying legal regulations on the technical state of school buildings:

1. Ordinance of the Minister of Education and Sport of December 31, 2002 on the safety and health in public and non-public schools and educational units (Journal of Acts. No 6, 2003 r., Item 69 as later amended.).
2. Ordinance of the Minister of Health and Social Welfare of March 12, 1996 on acceptable concentrations and intensity of adverse to health agents, secreted by construction materials, equipment and fittings in rooms designed to accommodate people. Polish Monitor No. 19 of 1996. Item. 231.
3. Ordinance of the Minister of Labour and Social Policy of September 26, 1997 on general safety and health (consolidated text Journal of acts No. 169 of 2003, Item. 1650).

4. The Act of June 7, 2001 on public water supply and public wastewater removal (Journal of Acts No. 72 of 2001., Item 747, as amended later)
5. Ordinance of the Minister of Infrastructure of April 12, 2002 on the technical conditions to be met by buildings and their location (Journal of Acts No. 75 of 2002., Item 690 with subsequent amendments).
6. Ordinance of the Minister of the Environment of June 14, 2007 on acceptable noise levels in the environment (Journal of Acts No 120 of 2007., Item 826 with subsequent amendments).
7. PN-EN 13779:2008 Ventilation for non-residential buildings – Performance requirements for ventilation and room-conditioning systems
8. The Act of November 9, 1995 on health protection against consequences of tobacco and tobacco products use (Journal of Acts 1996 No. 10, Item. 55 with subsequent amendments).
9. DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE EUROPEAN COUNCIL 2010/31/ EU of May 19, 2010. on the energy characteristics of buildings
10. DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE EUROPEAN COUNCIL 2012/27/UE of October 25, 2012 on energy efficiency, amending Directives 2009/125 / EC and 2010/30 / EU and repealing Directives 2004/8 / EC and 2006/32 / EC.
11. Ordinance of the Minister of Infrastructure of April 12, 2002 on the technical conditions to be met by buildings and their location (Journal of Acts. No 6, 2003 r., Item 69 as later amended.).
12. The Act of March 21, 1985 on public roads (Journal of Acts. No. 14 of 1985, Item. 60).
13. Ordinance of the Minister of Economy of November 21, 2005 on the technical conditions that should met bases and liquid fuel stations, far-reaching transfer pipelines for the transport of crude oil and petroleum products and their location (Journal of Acts No. 243, 2005 Item. 2063).

2.6 Results of the indoor air quality field campaigns carried out in the school buildings in Poland

In Poland, there was an urgent need for studies of the indoor air quality in educational institutions. Till now, only few measurements have been conducted in some schools/kindergartens/nurseries in selected regions or cities. Among them there was only one research related to the indoor air in schools of international significance that was conducted in Poland (SINPHONIE). According to the information published by WHO („School environment. Policy and current standards", 2014), one of the highest in Europe levels of concentration of benzene and formaldehyde was indicated in the indoor air of school buildings that were examined within the SINPHONIE project in Poland, in Silesia Region. Median of the average weekly levels of formaldehyde was 12 μg/m^3 (range from 1 to 66 μg/m^3). The maximum concentration and the highest country-level median value were detected in Romania, the second highest levels were reported in Poland. The WHO guideline for formaldehyde (100 μg/m^3) was not exceeded in any of the schools.

The median level of benzene was 2 μg/m^3 (ranging from below the method detection limit to 38 μg/m^3). The maximum value and the highest country-level median were reported in Poland. Benzene is a carcinogen with no safe level. The schools covered by the measurements under the SINPHONIE project were located in Silesia, which is the most polluted region in Poland. High levels of the outdoor air pollutants could have a strong influence on increasing the indoor air pollutants concentrations in the examined schools.

A national project that was conducted three years ago in NIOM could be another possible source of such results; however, now the results are not yet published and due to the Copyrights we cannot use them in the InAirQ project (authors are not in the project team).

In the literature there are only few reports on the results of measurements of harmful agents in the air in primary schools in Poland. The list of publications that were found in the PubMed database is presented in Table 5.

Table 5. Results of national studies concerning the indoor air quality in educational institutions in Poland based on the PubMed database.

No	References	Type of educational institutions, localisation	Harmful agents
1	Połednik B. Particulate matter and student exposure in school classrooms in Lublin, Poland. Environ Res. 2013 Jan;120:134-9. doi: 10.1016/j.envres.2012.09.006. Połednik B. Aerosol particle concentrations and indoor air parameters in school classrooms. Management of Indoor Air Quality.2011, 31-38. Połednik B. Variations in particle concentrations and indoor air parameters in classrooms in the heating and summer season. Archives of Environmental Protection. 2013, 39(4),15-28. Połednik B., Dudzińska M.R., Ventilation Control Based on the CO_2 and Aerosol Concentration and the perceived Air Quality Measurements – a Case Study. Archives Environ. Prot. 2010. 36(4), 67-80. Połednik B., Dudzińska M.R., The	junior high schools, Lublin	The highest concentration in [μg/m^3] was shown in classrooms during the heating season: * in the presence of students ** without presence of students Benzene 1.4 – 6.5* Chlorobenzene 0.4 – 29.8** 1,4-dichlorobenzene 2.7 – 18.5** Ethylobenzene 2.7 – 18.5** Formaldehyde 9.0 – 28.4** Xsylene m+p+o 8.7 – 77.9** Styrene 0 - 9.9** Toluene 231.5 – 46.8** Trichloroethene 0.6 – 27.0** PM (TSP) 280.3±57.0* PN Particle Number (9.1±2.7) x $10^3 cm^3$ PM_1 86 – 166* *(selected classroom, the highest results)* $PM_{2.5}$ 88 – 167* *(selected classroom, the highest results)* PM10 163 – 538* *(selected classroom, the highest results)*

No	References	Type of educational institutions, localisation	Harmful agents
	impact of the room occupation and the indoor air parameters on the aerosol particle concentration in classrooms. Indoor Air 2011, Austin TX. Połednik B., M. Dudzińska, A. Raczkowski: The influence of occupation on aerosol and CO_2 concentration in classroom, [in:] Indoor Air 2008, The 11th International Conference on Indoor Air Quality and Climate, Conference Proceedings, Paper ID: 546, Copenhagen 2008. Połednik B. Zanieczyszczenia a jakość powietrza wewnętrznego w wybranych pomieszczeniach. Monografie - Polska Akademia Nauk. Komitet Inżynierii Środowiska. 2013 [Pollution and indoor air quality in selected areas. Monographs - Polish Academy of Sciences. Committee of Environmental Engineering].		*TSP - Total Suspended Particle* *PN - Particle Number* *PM - Particle Matter*
2	Mainka A., Zajusz-Zubek E., Kaczmarek K. PM2.5 in Urban and Rural Nursery Schools in Upper Silesia, Poland: Trace Elements Analysis. Int. J. Environ. Res. Public Health 2015, 12, 7990-8008; doi:10.3390/ijerph120707990	nursery schools, Gliwice	$PM_{2.5}$ 53.09 to 96.6 [$\mu g/m^3$] *(winter and spring)* In $PM_{2.5}$ samples were analyzed: As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se and Zn. An anthropogenic origin revealed most trace elements; however, the most enriched elements in indoor $PM_{2.5}$ were Cd, Se, Sb, Zn and—additionally—Cr in spring.
3	Műllerová M, Kozak K, Kovács T, Smetanová I, Csordás A, Grzadziel D, Holý K, Mazur J, Moravcsík A, Neznal M, Neznal M. Indoor radon survey in Visegrad countries. Appl Radiat Isot. 2016 Apr;110:124-8. doi: 10.1016/j.apradiso.2016.01.010.	schools and kindergartens, Lodz, Lublin, Krakow	Radon: - kindergartens: 611 - 673 [Bq/m^3] - schools: > 300 [Bq/m^3]

The above shown data suggests low quality of indoor air in Polish schools. One should pay particular attention to the fact that there is an urgent need for measurement of harmful agents that are present in the indoor air in schools in Poland.

2.7 Quality of ambient air in Lodz and importance of the indoor air quality in schools

In Poland monitoring of outdoor air is carried out by the Chief Inspectorate of Environmental Protection. Monitoring stations are located in urban (traffic, industrial or background), suburban (traffic, industrial or background) and rural (background or industrial) areas. The Chief Inspectorate of Environmental Protection publishes, on its website, detailed results of measurements taken in the existing network of measurement points and information on the current state of air pollution (levels exceeding normative values) for Poland.

When comparing the Region of Lodz and Lodz city it needs to be emphasized that the biggest differences between the mean values, both monthly as well as annual, concern nitric oxide. Both NO_2 as well as NO_X present in the atmospheric air in the city of Lodz are in higher concentrations than in the rest of the region. It is caused by a high intensity of traffic in the city agglomeration. Poland lies in a moderate zone with mixed continental and oceanic climates influences, with cold winter and warm summer. Accordingly, concentration of several air pollutants (e.g., PM_{10} mass concentration, O_3, CO) shows seasonal variation. During the winter period, levels of almost all the measured agents often exceeded the 24-h limit values, simultaneously exceeding alarming values. The annual mean values for $PM_{2.5}$ measured in 2016 in Lodz exceeded the year limit value set by the European Commission.

Atmospheric air, and along with it all the pollutants present in it (chemical and biological) get into the school buildings through windows, doors and air ducts. Moreover, according to MEN, based on the declarations of schools headmasters, it seems that in 90% of the schools PE classes at least once a week take place in school gyms and school playing fields. Therefore, atmospheric air quality in the surroundings of the schools constitutes one of the most important factors that pose hazard to the health of children who attend the schools.

Meteorological conditions during the heating season have a decisive impact on the air quality in Poland. Temperature and the number of days with strong frosts determine the demand for thermal energy. Anthropogenic emissions, which consist of: industrial energy (combustion processes in the energy production and transformation sector), individual heating of buildings and road transport constitute the main source of outdoor air pollution in the region of Lodz. In urban areas a surface emission, coming from the residential heating and the motor transport, is the largest source of air pollution.

Description of the outdoor air in Lodz and region was prepared based on the ‘Report on State of Environment in Lodzkie Region in 2016’. According to this publication, low values of sulfur dioxide concentrations indicate that pollution does not pose a threat to human health. In the case of nitrogen dioxide, the admissible average annual value was reported only for Lodz city and the largest cities in the region. Also average annual concentrations of benzene posed no greater threat to human health. The probability of exceeding the limit value for benzene and the reference value for toluene, ethylbenzene and xylene is very low. Particulate matter constitutes the most important group of air pollution in Poland. Half of the inhabitants of Lodzkie Region live in areas where the permissible PM_{10} concentration level is exceeded.

Concentration of PM_{10} in urban areas undergoes cyclical fluctuations (annual, weekly and daily). The daily fluctuations in the concentration of particulate matter are the highest in the winter period, with the increased low emission. The values of the 1-hour concentration of PM_{10} in Lodz may reach temporarily as much as several hundred $\mu g/m^3$.

Among air pollutants, small suspended particulate matter $PM_{2.5}$ (average annual level of 25 $\mu g/m^3$) pose the greatest threat to the human health. The average annual $PM_{2.5}$ concentration in Lodz in 2016 was 26.6 $\mu g/m^3$. Based on the results of measurements it should be stated that the level of concentration of heavy metals in PM10 does not exceed the permissible level of lead and target levels of nickel, cadmium and arsenic. Emission of heavy metals in the region of Lodz is not a major threat due to a lack of highly developed metallurgical industry in the region. In the case of benzo(a)pyrene, it significantly exceeded admissible values at all the measuring points in the region. Areas where the level of benzo(a)pyrene was exceeded included a range of more than half of the region of Lodz.

2.8 SWOT Analysis

Improvement of the Indoor Air Quality in the school environment in Poland

Identified Strengths, Weaknesses, Opportunities and Threats in Polish schools prepared according to the joint methodology.

	Internal analysis	
	STRENGTHS What has a positive impact on the school environment regarding IAQ?	**WEAKNESSES** What has a negative impact on the school environment regarding IAQ?
SWOT analysis tool	1. Involvement of management, technical personnel and teachers, so that, in practice, all possible ways to improve air quality are used. 2. The school chooses detergents used for cleaning with taking into account their potential adverse impact on children health. 3. Municipal heating (the vast majority of schools). 4. Direct contact with the parents of the students.	1. Low awareness of the indoor air quality. 2. Age of school buildings. Majority of the schools were built over the years 1949 - 1979. 3. Overcrowding of classes. By law there can be max. 25 pupils per class but in practice in 7% of classes there are more than 30 pupils. 4. Lack of proper equipment to check the airflow value in the ventilation ducts. 5. Purchases of furniture and other interior furnishings for classrooms made by the students' parents (e.g. new school lockers, cabinet with shelves for students, tables for students, floor panels). 6. Own heating, boiler room on the school ground (few schools). 7. Lack of the air-conditioning system in classrooms. Air-conditioning systems are installed usually in the kitchen part. There are only few schools with the air-conditioning system in the other parts of the building (e.g. classrooms).

External analysis	**OPPORTUNITIES** What are the opportunities to improve the IAQ in the school environment? 1. Post-inspection recommendations of the State Sanitary Inspection (Department of Hygiene of Children and Youth). 2. Guidance and recommendations developed within the frame of projects aimed at improving the indoor air quality in schools (e.g. prepared in the SINPHONIE project – Attachment 1). 3. Common access to the publication on the air quality, results of measurements of the quality of outdoor and indoor air, impact of air pollution on human health, including children, and methods to reduce the levels of airborne pollution. 4. Ongoing process of thermo-modernization of the schools.	**Opportunity-Strength (OS) Strategies** How can we use Strengths to take advantage of Opportunities? 1. Use of guidance and recommendations developed within the projects aimed at improving the indoor air quality in schools. 2. Proper selection of materials and technological processes used in the thermo-modernizations of the schools. 3. Repairing / cleaning ventilation ducts during the thermo-modernization process. 4. Adjusting activity of children depending on the outside air quality. 5. Observation of the incidence of respiratory diseases listed in the literature as associated with air pollution among pupils and undertaking activities in the case of increased morbidity among school children (e.g. in selected classes).	**Opportunity-Weakness (OW) Strategies** How can we overcome Weaknesses by taking advantage of Opportunities? 1. Frequent ventilation of classes (opening the windows). 2. Exert an influence on the choice of furniture and other finishing materials purchased by parents (e.g. according to the recommendations developed in the indoor air quality projects or relevant publications). 3. Conducting literature review and disseminating selected publications among school personnel to raise awareness of air quality.

THREATS	Threat-Strength (TS) Strategies	Threat-Weakness (TW) Strategies
What are the threats that can negatively influence the IAQ in the school environment? 1. Lack of funds for the required repairs and upgrades, including thermo-modernization and installation of a modern heating system, ventilation and air conditioning system. 2. Surroundings of schools (industry, low particulate matter emission). It has been assessed that a low percentage of schools are localized near some kind of industry, much bigger percentage of schools (~ 30%) can be exposed to low particulate matter emission. 3. Heavy traffic (about 30% of schools). 4. Infiltration of the large amounts of particulate matter into the inside school environment from the outside. 5. Legal regulations in force – lack of detailed requirements for ensuring proper air parameters in school classes. 6. Subordination to the local governments (different financial situation in individual municipalities of Poland). 8. Low awareness of indoor air quality among parents.	How can we use Strengths to avoid Threats? 1. Selection of the right time for cleaning / minor repairs. 2. Frequent cleaning and exact removal of layers of dust. 3. Slowing down the traffic at schools (e.g. to apply to the local authorities about the installation of speed bumps on the road in the school surrounding). 4. Applying for the additional funds to the local self-government on the basis of the post-inspection recommendations of the National Sanitary Inspection. 5. Conducting literature review and disseminating selected publications among parents to raise awareness of air quality.	How can we minimize weaknesses and avoid Threats? 1. Raising awareness of the indoor air quality among local authorities, the school staff and parents of students. 2. Inclusion of issues related to the indoor air quality in the curriculum for future teachers (e.g. on universities). 3. Improvement of the involvement of school staff and parents in taking actions towards improvement of the quality of the indoor environment in schools. 4. Preparation of guidelines or recommendations for the local authorities regarding the criteria of schools selection for renovation, including thermo-modernization. 5. Development of formal guidelines for the specification prepared within the framework of procurement for the thermo-modernization of the school buildings. 6. Initiation of the legislative process, under which a draft concerning the indoor air quality in the educational institutions will be prepared.

1. Surveillance of environment and health in schools in Lodz

3.1 Characterization of school buildings by checklists

The project included 26 schools from the region of Lodz. In all the schools a questionnaire study on the state of the buildings was conducted. Information on the buildings was provided by the school heads or administrative managers acting on their behalf. Nearly half of the schools (12 schools, 46%) were located in the city center, 7 schools (27%) were located in residential areas and the remaining 7 schools (27%) in the suburbs or in the country. In 5 cases (19%) the school buildings were built before 1955, the remaining ones come from the years 1956-1988 (21 schools, 81%). The buildings were mostly made of brick (14 schools, 54%) or brick and concrete (10 schools, 38%), in the other two buildings, apart from bricks and concrete, the wood was used.

Among the schools included in the project, 9 of them (almost 35%) were located near the streets with high or very high traffic. The same number of the schools (9, 35%) determined intensity of traffic in their proximity as medium, while the remaining 8 (30%) as low. Majority of the schools (23.88%) were surrounded by greenery.

Only one school as a whole was equipped with mechanical ventilation (4%), in 10 schools (38%) mechanical ventilation functioned only in some parts of the building (most frequently in the kitchen), whereas in the remaining cases (14 schools, 54%) functioned only natural ventilation.

In the last 5 years only 14 school buildings (54%) were renovated. Additional sources of pollution located in the direct neighbourhood of the schools were: car park and a busy street (13.50%), a busy street (6.50%), a car park (4.15%) or detached houses heated with coal (3.12%).

School directors were asked to make a subjective assessment of the air quality inside the school building on a scale from 0 to 6, where 0 means a very poor quality, and 6 - very good. Only in the case of one school the indoor air quality was assessed as very good, in 19 schools (73%) the indoor air was assessed as good or quite good (mark 5 or 4), and in the case of 6 schools the indoor air quality was assessed as adequate/sufficient.

An analogical scale was applied in the case of subjective assessment of the quality of atmospheric air surrounding the schools. According to the answers of the school directors the quality of atmospheric air surrounding the schools in the majority of cases (14 schools, 54%) was assessed as adequate or low, in the case of 11 schools (42%) it was assessed as quite good or good, and only in one case it was assessed as very good.

3.2 Characterization of classrooms by checklists

Additionally, a questionnaire study concerning detailed characteristics of twelve classrooms, which were selected for air quality monitoring was performed as part of a measurement campaign. The questionnaires were filled in by teachers working in the monitored classrooms. According to the obtained information, the majority of classrooms (75%) were bigger than 41 m^2, while the remaining ones were classrooms with a surface of 23.5 m^2, 34.5m^2 and 36m^2. In the smallest classrooms a student had only 1.4 – 1.9 m^2 of the surface. Taking into consideration the cubic capacity, on average per student there were 6.3 m^3 - 9.6 m^3, and in the smallest rooms - 4.1 m^3 - 5.9 m^3.

In the examined classrooms the average surface of windows amounted to 10.1 m^2 (4.5m^2 – 16 m^2). In the case of 4 classrooms (33% of the schools) the windows faced a street. Fewer than a half of the teachers (5 classrooms, 42% of the study subjects) declared that they opened windows during each break, in 5 classrooms (42%) windows were opened 2-3 times a day, whereas in 2 (17%) only once a day. Window frames in all the examined schools were made of PCV.

Cleaning of the classrooms almost in all the schools (except for 2) was performed after the end of the lessons. Mops, sweeping brushes and vacuum cleaners were used for cleaning. In the majority of schools (10 schools, 83%) during the process of cleaning the windows were opened.

Nine classrooms (75%) had parquet on the floor, in the remaining ones panels were used. The walls and ceiling in most of the schools (8 classrooms, 67%) were painted with water-soluble paints. The students' tables/desks were mostly made of plywood (9 rooms, 75%). Only in case of one school a classroom was equipped with a board for markers, in the other schools there were traditional chalk boards. Irritant preparations (e.g. glue) were used in the majority of schools and were kept on shelves or in ordinary cabinets, but windows were usually opened while using them.

In almost all the classrooms there were some plants (11 classrooms, 92%) in a number of 5 up to 10 flowerpots.

According to the teachers, in the majority of classrooms during the heating season the perceived temperature was too high, and the sun's rays fell directly on the students' desks. Only in the case of one school a distinct smell of mustiness was noticeable, which indicated presence of fungi in the building. Almost all the classrooms were assessed by the teachers as well or very well lit, both with natural and artificial light.

A subjective assessment of the indoor air performed by the teachers only in one case indicated a medium quality of air, while in the remaining schools it was assessed as good or very good.

The analysis of presence of additional potential sources of pollution in the classrooms showed that only in one classroom there was a printer and air freshener. At the same time, information on the external sources of pollution indicated that in the case of 9 classrooms there was a car park within a distance of 50 meters from the windows (75% of the schools), and that in 4 cases (33%) it was a busy street. Only in 6 schools (50%) there was some green space on the school pitch, plastic was present in the same number of schools, there was sand in 3 schools (25%) and asphalt in 2 schools (17%).

3.3 Assessment of indoor air quality based on monitoring campaign

Children of school age are spending more and more time indoors, sometimes even up to 90% of time per 24 hours. Therefore, the indoor air quality plays a crucial role for their state of health. Physical parameters monitoring as well as measurement of harmful chemical and biological agents are necessary actions aiming at determination of the health risk of students. Some parameters may affect the comfort of students (nuisance agents), whereas other may induce breathing disorders and diseases (harmful agents). Due to the wide scope of pollutants potentially present in the air, a proper choice of relevant parameters is of vital importance. In a situation, when there are no legal regulations in this field, it is recommended to use guidelines of the World Health Organization. In accordance with these guidelines the following parameters are usually examined:

- physical parameters: temperature, relative humidity, air exchange indicator;
- biological air pollutants: bacteria, fungi;
- chemical air pollutants: volatile organic compounds, aldehydes, particulates (PM_{10} and $PM_{2.5}$), carbon dioxide, radon.

Due to seasonal air quality variability, the studies in Poland are carried out during a heating season, when windows are usually closed and because of which pollutants are not removed outside and accumulate in the indoor air. Indoor air quality monitoring should be performed simultaneously with measurements of the same agents in the atmospheric air in the surroundings of an examined building. Comparison of those studies results allows confirmation or rejection of atmospheric air as a source of the examined pollutants.

Air monitoring performed in 12 primary schools from Lodz included in the project consisted in examination of physical paramteres, particulate matter, chemical parameters and radon.

Examinations were carried out in a selected classroom of the third graders during classes performed over one week (from Monday to Friday). Air sampling was performed simultaneously in the indoor and outdoor (atmospheric) air.

The following were assessed:

Physical parameters along with CO_2 concentration

The temperature [°C], relative humidity [%] and carbon dioxide concentration [ppm] in the air were monitored using Green Eye monitors that automatically registered those parameters within 2-minute intervals.

The speed of air flow/exchange [m/s] at the outlet of the ventilation system was measured with the Testo435 meter, and then taking into account the area of the ventilation grilles [m^2], the air exchange ratio in cubic meters of air delivered to the room within one hour [m^3/h] and in cubic meters of air delivered to the room were calculated within an hour per one person [m^3/h / person].

$PM_{2.5}$

$PM_{2,5}$ samples were collected using the filtration method by means of sets: air aspirator with low noise level (GilAir5), additionally located in silencing boxes.

Volatile organic compounds and aldehydes

The air samples were collected using the Radiello passive method (tubes with adsorbing gel for the examined compounds). In the samples concentration of the following compounds was determined: benzene, toluene, xylene, ethylbenzene, trichlorethylene, tetrachloroethylene, a-pinene, limonene, 2-ethylhexanol, styrene, formaldehyde, acetaldehyde, propionaldehyde, benzoic aldehyde, hexanal.

Radon

The samples were collected in the school buildings using the passive sampling method. The collector was placed in a school building for a period of three months (from the beginning of December to the end of February).

The results of monitoring carried out in the schools indicated a rather low quality of the indoor air. The study showed that the temperature in the examined schools fit in the range of 14.2°C - 24.7°C (MIN-MAX). According to the expert recommendations, the optimum temperature for mental work is 21°C. In 4 of the surveyed schools (33% of the schools) the average temperature for the whole week reached or exceeded 22°C. Detailed results are presented in Table 6.

Table 6. The results of temperature monitoring in the examined schools (values for the whole measurement week in each of the schools).

School code	Temperature [°C]		
	Min	Max	AM (week)
PL_03	16,8	20,3	19,2
PL_06	17,9	22,4	20,8
PL_13	21,0	24,2	23,1
PL_19	18,2	24,4	21,7
PL_20	18,3	23,8	21,2
PL_21	19,4	24,7	22,0
PL_22	20,3	24,1	22,6
PL_24	14,2	23,5	21,5
PL_25	16,6	21,7	20,0
PL_26	18,6	22,1	20,5
PL_27	20,0	24,7	22,3
PL_28	19,4	23,7	21,5

Monitoring of relative air humidity in the schools included in the study from Lodz showed that the air was too dry and remained below or close to the lower boundary of the comfort level for humans. The level of comfort for relative air humidity fits in the range from 40 to 60%. The scope of relative humidity of air in the examined schools remained at the level of 15.6% - 56.5% (MIN - MAX). In 10 of 12 examined schools (more than 80% of the schools) the mean weekly value was at the level below 40%, including two schools (almost 17% of the schools) with the level below 30%. Detailed results are presented in table 7.

Table 7. The results of monitoring of relative humidity of air in the examined schools (values for the whole measurement week in each of the schools).

School code	Relative humidity [%]		
	Min	Max	Mean (week)
PL_03	15,6	40,2	30,6
PL_06	21,1	51,6	37,7
PL_13	23,3	40,0	33,0
PL_19	20,6	38,8	28,5
PL_20	29,8	46,4	39,3
PL_21	19,2	35,7	27,5
PL_22	23,0	44,0	34,7
PL_24	25,4	49,9	34,8
PL_25	31,1	50,6	44,1
PL_26	35,5	56,5	47,8
PL_27	30,5	49,1	38,4
PL_28	29,3	50,8	39,9

Measurement of carbon dioxide concentration indoors is a significant parameter as it constitutes an indicator of room air ventilation. Too high a concentration of CO_2 indicates insufficient ventilation. Moreover, in accordance with the recommendations the value of CO_2 concentration in the offices should not exceed 1000 ppm (*parts per million*) [Indoor Air 2015;25:105–114]. In the examined schools the range of CO_2 concentrations was at the level of 411 - 4305 ppm (MIN – MAX). Detailed data are presented in table 8. Mean weekly concentrations for the examined schools remained mostly at the level below 2000 ppm. However, when analyzing maximum daily concentrations and the detailed results of monitoring one has to be aware of the fact that the mean concentrations are not reliable since the measurements included breaks between the lessons. Real CO_2 concentrations reported during the lessons exceeded considerably the recommended reference values. In half of the schools maximum values of CO_2 exceeded 3000 ppm.

Table 8. The results of carbon dioxide concentration monitoring in the air of the examined schools (values for the whole measurement week in each of the schools).

School code	Carbon dioxide concentration [ppm]		
	Min	Max	Mean (week)
PL_03	537	**3609**	1904
PL_06	429	**4234**	2030
PL_13	449	2343	1458
PL_19	411	2607	1009
PL_20	471	2218	1220
PL_21	593	1934	1303
PL_22	417	2442	1129
PL_24	443	2597	1095
PL_25	686	**3428**	1831
PL_26	559	**4305**	2332
PL_27	430	**3979**	1398
PL_28	490	**3329**	1776

Another parameter essential for children's health is the indicator of classrooms ventilation. According to the recommendations of the Polish norm *(PN-83/B-03430 and PN-83/B-03430/Az3:2000 Ventilation in residential buildings of a collective residence and public utility. Requirements.)* the amount of air delivered to the buildings of public utility is expressed in m^3 delivered during an hour per person [m^3/h/person]. According to this norm, rooms for permanent or temporary stay of people should ensure inflow of at least 20 m^3/h of external air for each person in this room. For nurseries and kindergartens intended for children, the external air flow can be lowered to 15 m^3/h for each child. Taking into account that children in the classrooms included in the study were older than the kids in nurseries and kindergartens, air flow should be within 15-20 m^3/h, and surely should exceed 15 m^3/h. Indicators of ventilation of the examined classrooms are presented in table 9. Analysis of the obtained results indicates that in the majority of schools indicators of air flow should be considered insufficient.

Table 9. Indicators of ventilation of classrooms in the examined schools.

School code	Type of ventilation	Number of ventilation ducts in classroom	Air flow rate [m^3/h/person][A]	
			Monday	Friday
PL_20	natural	1,0	12,2	11,9
PL_24	natural	2,0	5,6	3,0
PL_27	natural	5,0	5,0	4,1
PL_28	natural	2,0	9,6	9,9
PL_19	natural	5,0	13,1	11,7
PL_25	natural	1,0	8,4	4,5
PL_26	natural	4,0	14,0	12,8
PL_13	natural	3,0	12,3	14,8
PL_21	natural	1,0	6,9	8,3
PL_03	natural	4,0	19,1	19,6
PL_06	natural	1,0	1,8	1,6
PL_22	natural	2,0	20,4	22,2

A -the calculation included the number of kids in each classroom and the teacher

In the examined schools concentrations of volatile organic compounds and aldehydes were also measured. For the purpose of the study compounds that pose an essential health risk were chosen, including, inter alia benzene and formaldehyde.

Benzene has genotoxic (carcinogenic) effect. It is impossible to recommend its safe level of exposure. It is a cause of acute myeloid leukemia (sufficient evidence of a causal relationship has been already demonstrated). The toxic risk from inhaled benzene is the same in the outdoor and indoor air. The figure 3 presents a comparison of concentrations of benzene in the indoor air of the examined schools and in the surroundings of their buildings. Analysis of the data showed that benzene concentration in the indoor air of the examined classrooms was at a similar level or higher in comparison with the atmospheric air surroundings the buildings.

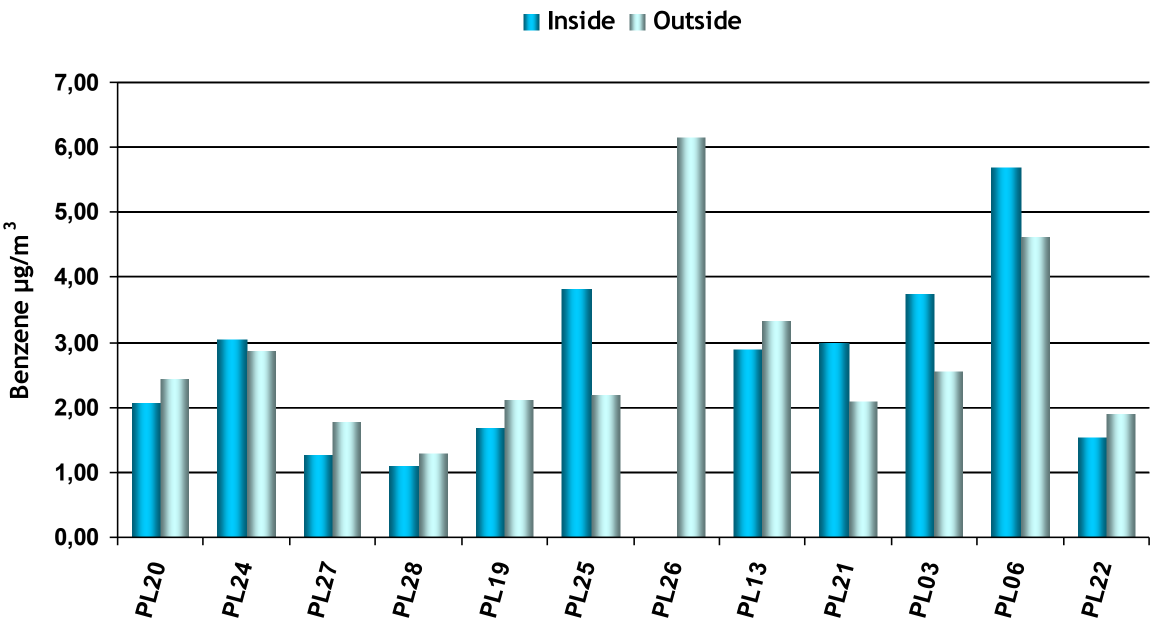

Figure 3. Benzene concentration in the indoor air of the examined schools and in the surroundings of the buildings.

Formaldehyde is commonly present in the indoor air, where its main source are chemical reactions of volatile organic compounds with ozone. Additionally, in school environment formaldehyde is emitted by:

- combustion processes (combustion, heating, cooking, candles, incense);
- building and finishing materials, furniture and wooden, formaldehyde based products containing resins, i.e. chipboard, plywood and medium density fibreboard; insulating materials, textiles; DIY products (paints, wallpapers, adhesives, varnishes);
- cleaning products (detergents, disinfectants, softeners, carpet cleaners and footwear products);
- electronic equipment (computers and photocopiers);
- other consumer products (insecticides, paper products).

It has been proved that formaldehyde has irritating effect in humans, it reduces lungs functions, induces nasopharynx cancer and acute myelogenous leukemia. The World Health Organization has determined a limit for concentration in the air, as a 30-minute average at the level of 100 mg / m3. Formaldehyde emission concerns new products and it may last several months, especially in the conditions of high relative humidity and high temperature in rooms. Formaldehyde concentration in the examined schools and in their surroundings is presented in figure 4.

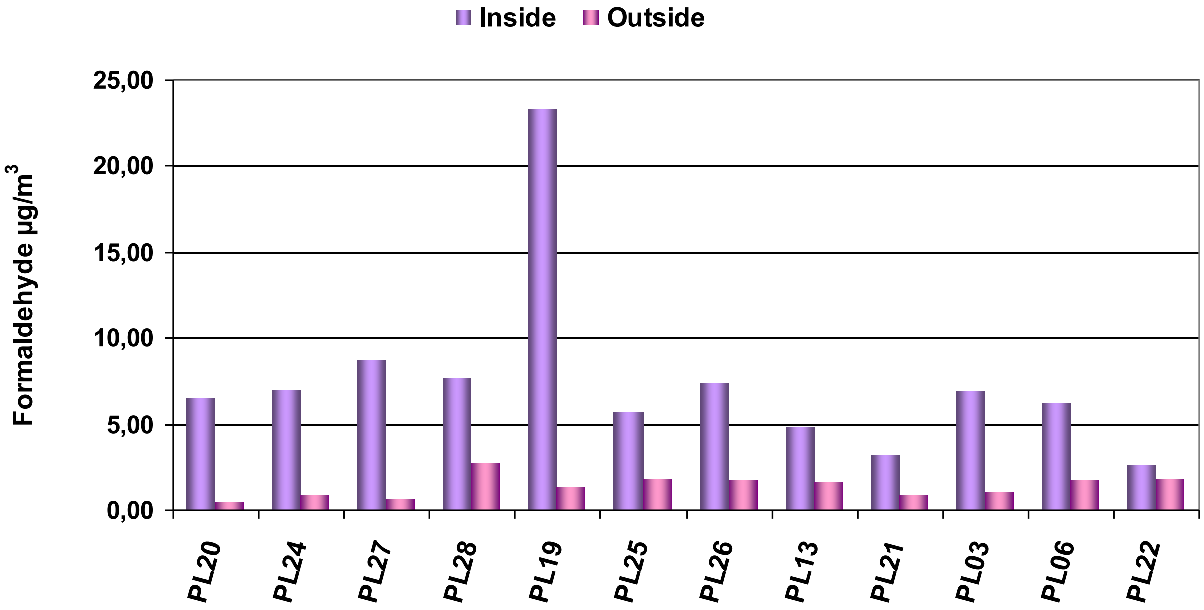

Figure 4. The concentration of trichloroethylene in the indoor air of the examined schools and in the surroundings of their buildings.

Trichlorethylene is another harmful to health volatile organic compound, which has genotoxic (carcinogenic) effect on the liver, kidneys, the bile and lymphatic system (it causes non-Hodgkin's lymphoma). The risk of cancer increases along with the increase of concentration of trichlorethylene in the air. In the examined schools concentration of trichlorethylene was higher in the indoor air of the examined classrooms in comparison with its level in the atmospheric air in the surroundings of the buildings (figure 5).

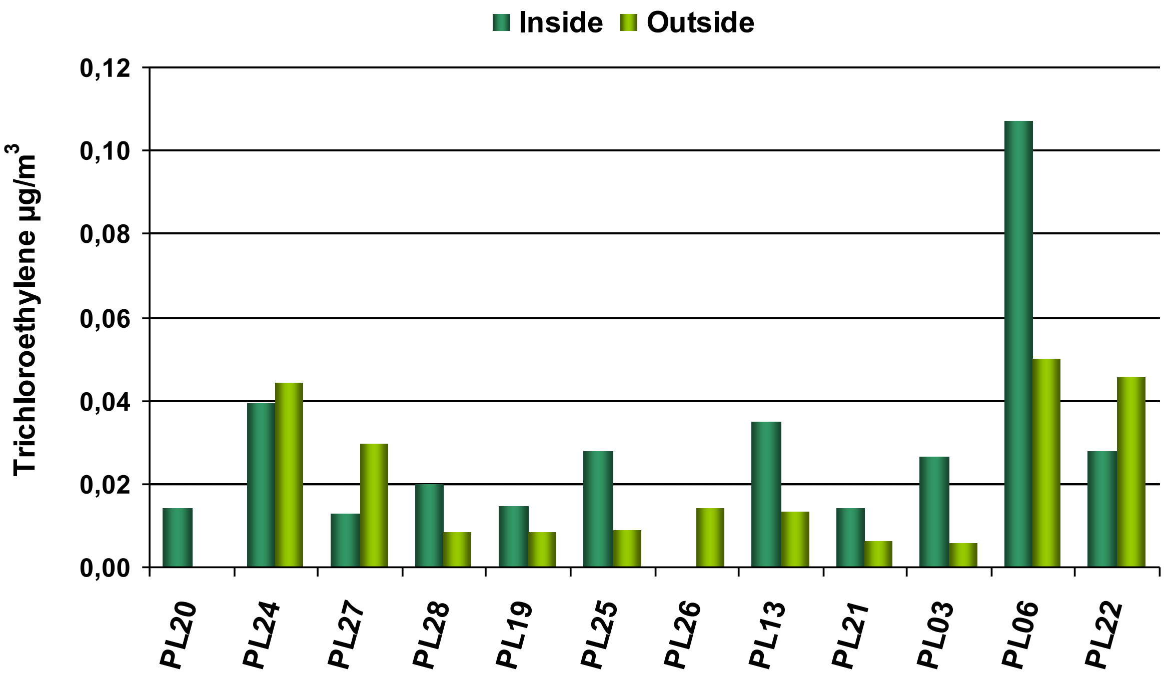

Figure 5. Trichlorethylene concentration in the indoor air of the examined schools and in the surroundings of the buildings.

According to the works and recommendations of the World Health Organization, the examined volatile organic compounds have a negative health effect, including carcinogenic effect. Table 10 presents concentrations of VOCs, including aldehydes in the indoor air of the examined schools as well as in their surroundings with the reference values. The analysis clearly indicates higher VOCs concentrations in the indoor air when compared to the atmospheric air.

Table 10. Mean VOCs concentrations, including aldehydes in the surroundings of the studied school buildings in Lodz (N=12).

Agents	R(f)C[a]	Indoor air			Outdoor air		
		AM	min	max	AM	min	max
		[µg/m³]					
benzene	30	2,7	1,1	5,7	2,8	1,3	6,1
toluene	5000	6,9	1,1	19,3	2,0	0,4	5,0
xylenes	100	3,9	0,0	13,8	0,7	0,0	2,0

Agents	R(f)C[a]	Indoor air			Outdoor air		
		AM	min	max	AM	min	max
		[µg/m^3]					
ethylobenzene	1000	1,2	0,0	4,6	0,2	0,0	0,6
trichloroethylene	2	0,0	0,0	0,1	0,0	0,0	0,0
tetrachloroethylene	40	0,3	0,0	1,0	0,2	0,1	0,8
acetaldehyd	9	4,1	1,3	8,0	1,0	0,3	1,6
formaldehyde	bd[c]	7,5	2,6	23,4	1,4	0,5	2,8
α-pinene	bd[d]	7,7	0,0	64,5	0,6	0,0	4,1
limonene	bd[d]	5,2	0,0	16,5	0,1	0,0	0,5
2-ethyloheksanol	bd[d]	0,2	0,0	2,3	0,0	0,0	0,0
styrene	bd[d]	0,4	0,0	1,8	0,1	0,0	0,2
propionaldehyd	bd[d]	1,0	0,1	2,9	0,5	0,1	1,2
benzaldehyd	bd[d]	0,5	0,0	0,8	0,2	0,0	0,6
hexanal	bd[d]	9,4	3,3	31,8	0,8	0,2	2,3

[a] R(f)C – a reference value according to the IRIS (Integrated Risk Information System) database, below which no negative health effects are present in case of exposure to a given substance via inhalation;

[b] values: mean (AM), minimum (min) and maximum (max) determined in all the 12 schools included in the project;

bd[c] no data via inhalation.

bd[d] – no data in IRIS database;

In accordance with the recommendations of the World Health Organization in case of inhalation exposure to volatile organic compounds, apart from the level of exposure to each substance individually, their total concentration is essential. When the sum of concentrations of all VOCs exceeds 100µg/m^3 then we deal with a situation harmful to health. The sum of concentrations of the 15 examined compounds exceeded the reference level only in one of the examined schools (table 11). It is estimated that there are about 500 of all volatile organic compounds, whereas in the examined schools only 15 compounds were examined. It should be noticed that there is a high probability that the sum of all volatile organic compounds significantly exceeds the value considered harmful to human health, especially children. Comparison of VOCs concentration in the indoor air of the examined schools as well as in their surroundings indicates that these values are even up to many times higher inside the classrooms.

Table 11. The sum of concentrations of all the studied VOCs in the schools from Lodz included in the project.

School code	Sum of the investigated VOCs [μg/m^3]	
	Indoor	Outdoor
PL_20	47,6	12,5
PL_24	42,7	10,2
PL_27	62,8	6,8
PL_28	28,4	8,9
PL_19	71,4	6,4
PL_25	140	7,3
PL_26	28,7*	18,9
PL_13	36,9	13,8
PL_21	16,3	7,6
PL_03	47,8	9
PL_06	47,6	14,8
PL_22	20,6	9,6

The measurements also included concentration of $PM_{2.5}$ mass, which belongs to the most important indicators of air quality. The particulate matter is a carrier of pollutants in the air, and $PM_{2.5}$ is a mixture of solid particles and liquid with a diameter less than 2.5 μm. Small particles enter the respiratory system, where they pass through the gas exchange vesicles to the bloodstream. $PM_{2.5}$ may also contain organic compounds (e.g. polycyclic aromatic hydrocarbons), heavy metals, dioxins and mold spores. The main sources of particles $PM_{2.5}$ inside of school environment are combustion processes of fuel and transport. Particles $PM_{2.5}$ is harmful to humans. Particles with very small sizes easily get into alveoli and blood circulation, exacerbating the symptoms of cardiovascular and respiratory diseases (including asthma, arrhythmias). They can also cause conjunctivitis. The smallest particles can even cross the blood-brain barrier, inducing negative effects in the nervous system, especially in children.

Table 12 presents comparison between concentrations of $PM_{2.5}$ mass in the indoor air of the examined schools and in their surroundings. $PM_{2.5}$ concentration in the atmospheric air surrounding the examined schools exceeded the admissible value of 25 μg/m^3 only in two cases (average 24-hour concentration). Whereas in the case of the indoor air the highest concentration reached the level of 21 μg/m^3.

Table 12. $PM_{2.5}$ mass concentration in the indoor air of the examined schools as well as in their surroundings (atmospheric air) (N=12).

PM2.5		Schools in Lodz		
		AM	min	max
		[μg/m³]		
Air	indoor	11,2**	3,0	21,0
	outdoor	17,9***	5,0	37,0

* values: mean (AM), minimum (min) and maximum (max) determined in the schools included in the project;
** mean value for seven schools;
*** mean value for nine schools.

Radon is a radioactive gas whose products of decay combine with particulate matter present in the air. In the environment, radon is naturally present, it is formed as a result of disintegration of radium present in soil and water. Radon is harmful. Products of its decay inhaled by people emit radiation that is carcinogenic (causes lung cancer). The risk of a disease is directly proportional to the level of radon concentration in the inhaled air and the period of exposure to this gas. In accordance with the regulations in force of the European Union (Council Directive 2013/59 / EURATOM), the health risk is significantly higher in case of radon concentration in the indoor air exceeding 100 Bq/m^3 (in case of long exposure), but the admissible national levels are set at 300 Bq/m^3 (average annual concentration). Among the examined schools, only in case of one school radon concentration was close to the admissible value (275 Bq/m^3) (table 13).

Table 13. Radon concentration in the studied schools.

School code	Radon [Bq/m³]
PL_03	31
PL_06	99
PL_13	34
PL_19	55
PL_20	45
PL_21	275
PL_22	66
PL_24	45

School code	Radon [Bq/m^3]
PL_25	21
PL_26	34
PL_27	39
PL_28	55

3.4 Health risk evaluation

Health Index with reference to the indoor air quality (Indoor Health Index) for each of the schools included in the project was calculated based on the actual values of selected nuisance and harmful agents measured in the examined schools during the measurement campaign. The calculation of Indoor Health Index is based on various threshold values for selected chemical agents and physical parameters determined by their health effects in individuals exposed via inhalation (recommendations of the WHO and/or EC and/or scientific papers). The Indoor Health Index was calculated based on a common methodology developed specially for the needs of the InAirQ project (table 14 and table 15).

Table 14. Calculation methodology for the Indoor Health Index with reference to the indoor air quality.

Category	Benzene [µg/m^3]	Formaldehyde [µg/m^3]	$PM_{2.5}$ [µg/m^3]
Healthy	<1.7	<10	<10
Moderate	1.7 - 4.99	10 - 19.9	10 - 24.9
Unhealthy	5 - 7.5	20 - 50	25 - 49.9
Very unhealthy	7.51 - 10	51 - 100	50 - 75
Dangerous	>10	>100	>75

Table 15. Calculation methodology for the Indoor Comfort Index with reference to the indoor air quality.

Category	RH [%]	T [°C]	CO_2 [ppm]
Healthy	43<RH< 67	18.5<T<25.5	<1200
Moderate	37<RH<43 67<RH<73	17.5<T<18.5	1200 - 1800
Unhealthy	RH<37 RH>73	T<17.5 T>25.5	>1800

In accordance with the provided criteria each school was classified into one of the categories of the Indoor Health Index and of the Indoor Comfort Index. In table 16 each school was described including both indices as well as location and the type of a building as factors with the most significant impact on the state of air quality.

Table 16. Description of indoor environment quality in schools under measurement campaign in Lodz.

School code	Indoor environment quality
PL_03	School is located in the residential area of Lodz, close to the a high traffic road. The school building was built from brick, concrete and wood, in the end of the fifties of the 20th century. The indoor air quality was in the moderate category based on the indoor health index. The main air pollutant was benzene. The outdoor value for benzene concentration was slightly lower but on the similar level. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and was classified in the unhealthy range.
PL_06	School is located in the city centre of Lodz, in the area with a moderate traffic road. The school building was built from brick, in the second half of the 20th century. The indoor air quality was in the unhealthy category based on the indoor health index. The main indoor air pollutant was benzene. It should be noted that the main outdoor air pollutant was the PM2.5 mass concentration, the benzene concentration was on similar level but slightly lower that in the indoor air. Considering the comfort parameters, should be noted that the CO2 concentration was in the unhealthy range; the CO2 concentration in the classroom was high.
PL_13	School is located in the residential area of Lodz, with a moderate traffic road nearby. The school building was built from brick, in the mid-fifties of the 20th century. The indoor air quality was in the moderate category based on the indoor health index. The

School code	Indoor environment quality
	main air pollutant was benzene. It should be noted that the outdoor value for the benzene concentration was also high (even slightly higher), thus the inappropriate indoor air quality was caused mainly by the outdoor air pollution. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and was classified in the unhealthy range.
PL_19	School is located in the suburban, residential area of Lodz, with a moderate traffic road nearby. The school building was built from brick and concrete, at the end of the eighties of the 20th century. The indoor air quality was in the unhealthy category based on the indoor health index. The main air pollutant was formaldehyde. It should be noted that the outdoor value for the formaldehyde concentration was low, thus the inappropriate indoor air quality was caused mainly by the indoor air pollution. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and was classified in the unhealthy range.
PL_20	School is located close to the city centre of Lodz, with a high traffic road nearby. The school building was built from brick, at the beginning of the 20th century. The indoor air quality was in the moderate category based on the indoor health index. The main indoor air pollutants was benzene and the PM2.5 mass concentration. It should be noted that the main outdoor air pollutant was the PM2.5 mass concentration and also the benzene concentration was slightly higher than in the indoor air, thus the inappropriate indoor air quality was caused mainly by the outdoor air pollution. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and was classified in the moderate range.
PL_21	School is located is located in the residential area of Lodz, with a moderate traffic road nearby. The school building was built from brick, at the beginning of the 20th century. The indoor air quality was in the moderate category based on the indoor health index. The main air pollutant was benzene. The outdoor value for benzene concentration was slightly lower but on the similar level. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and was classified in the unhealthy range.
PL_22	School is located close to the city centre of Lodz, with a very high traffic road nearby. The school building was built from brick, in the mid-fifties of the 20th century. The indoor air quality was in the healthy category based on the indoor health index. It should be noted that main outdoor air pollutants was on similar level as in the indoor air. However, one of the comfort parameters was in the unhealthy range; the relative humidity in the classroom was low.
PL_24	School is located close to the city centre of Lodz, in the area with a low density of the traffic road. The school building was built from brick and concrete, in the end of the fifties of the 20th century. The indoor air quality was in the moderate category based on the indoor health index. The main air pollutant was benzene. The outdoor value for benzene concentration was slightly lower but on the similar level. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and was classified in the unhealthy range.
PL_25	School is located in the suburban area of Lodz, with a moderate traffic road nearby. The school building was built from brick, in the first half of the 20th century. The indoor air

School code	Indoor environment quality
	quality was in the moderate category based on the indoor health index. The main air pollutant was benzene. It should be noted that the outdoor value for the benzene concentration was much lower, thus the inappropriate indoor air quality was caused mainly by the indoor air pollution. Considering the comfort parameters, should be noted that the relative humidity in the classroom was law and the CO2 concentration was high, thus the school was classified in the unhealthy range.
PL_26	School is located in the suburban area of Lodz, with a moderate traffic road nearby. The school building was built from brick, in the end of the fifties of the 20th century. The indoor air quality was in the healthy category based on the indoor health index. The outdoor value for benzene concentration was high, thus potentially should be considered as the main source of the indoor air pollution. Considering the comfort parameters, should be noted that the CO2 concentration was high, thus the school was classified in the unhealthy range.
PL_27	School is located in the residential area of Lodz, with a moderate traffic road nearby. The school building was built from brick and concrete, at the end of the eighties of the 20th century. The main indoor air pollutants was PM2.5 mass concentration (moderate category). It should be noted that the main outdoor air pollutant was the PM2.5 mass concentration but the outdoor PM2.5 mass concentration was slightly lower then in the indoor air. Considering the comfort parameters, should be noted that the relative humidity was law and the CO2 concentration was high, thus the school was classified in the moderate range.
PL_28	School is located in the residential area of Lodz, with a low traffic road nearby. The school building was built from brick, at the beginning of the sixties of the 20th century. The indoor air quality was in the healthy category based on the indoor health index. The outdoor value for the PM2.5 mass concentration was moderate high and should be considered as the potential source of the indoor air pollution. Considering the comfort parameters, should be noted that the relative humidity was law and the CO2 concentration was high, thus the school was classified in the moderate range.

Table 17 contains numerical list of the schools included in the measurement campaign depending on the value of the Health Index and the Comfort Index. Taking into consideration The Health Index majority of the schools (almost 60%) fit in the Moderate category. At the same time in case of the Comfort Index as many as 75% of the schools were classified as Unhealthy

Table 17. The Health Index and Comfort Index in schools under measurements campaign in Lodz.

Type of index	Category	Number of schools	
		No	%
Indoor Health Index	Healthy	3	25.0
	Moderate	7	58.3
	Unhealthy	2	16.7
Comfort Index	Moderate	3	25.0
	Unhealthy	9	75.0

Measurements taken as part of the measurement campaign in the schools from Lodz indicate a low quality of air, especially with reference to the physical parameters and CO_2 concentration.

Moreover, the measurement campaign included a questionnaire study concerning the health of children entitled *A questionnaire on the home environment and health of students in terms of the incidence of respiratory problems and allergies*. The questionnaire was filled in, with previous consent, by parents of the students learning in the classroom that were examined. In total, the study included 178 children, of whom 6% (11 children) had bronchial asthma diagnosed. However, according to the information provided by the parents only one kid had an attack of asthma at school and it was not associated with the quality of air (the incident took place during cooking classes). Ailments that were present in fewer than 5% of the examined children every day were, as follows: rash on the skin of hands or arms, eczema, pruritus of hands or arms. In addition, single children had a daily rhinitis / discharge in the nose, sore throat and difficulty in breathing. Only in few cases did the complaints give way during breaks from classes at school (winter break, summer holidays).

4. Action Plan

4.1 Aim of the Action Plan

The main aim of the action plan prepared in Poland is to improve the poor air quality caused by inappropriate ventilation of the classrooms in the school buildings and as a result to build up the children's health.

4.2 Source of finances

Most of schools in Poland are maintained by municipalities. Currently in Poland, regulations on the indoor air quality do not exist, which might be the reason for the lack of funds for this purpose. The change of this state, implementation of relevant regulations will result in the necessity to reserve funds in the budget of local authorities for the purpose of air quality improvement. However, in the current situation, it is only possible to use low-cost or no cost actions.

4.3 Expert assemblies and forums

The subject of the indoor air quality in schools so far has been skipped in Poland. As part of the project, Environmental Quality Forum has been established to which all local organizations (educational, health, environmental, social area e.g. scout organizations) and the most important national organization, i.e. the Ministry of Health were called. Due to the undertaken subject significance it is worth continuing these meetings as meetings of a working group preparing modifications in national and local regulations. Such meetings motivate representatives of local authorities to pay attention to the quality of indoor air in schools and to take up specific actions, which is particularly important in a situation of lack of legal regulations in this field.

4.4 Trainings/courses and potential building

In Poland, in general outdoor and indoor air quality is very poor. The most relevant reason for this state is low emission from central heating and hot water preparation in individual buildings in which coal is commonly used as a basic fuel. The coal combustion process causes emissions of particulate matter and different gaseous pollutants directly into the outdoor air. The enormous number of the old type coal incineration furnaces is responsible for a very high level of air pollution in Poland.

There are two main reasons. The first is economy (poverty and heating by coal) and the second is the lack of awareness of the human health effects of air pollution. In the case of the outdoor air pollution awareness is campaigned by mass media but the indoor air pollution escapes people's notice. The action plan in this field is to raise awareness of different target groups by education/trainings/ seminars organized in cooperation with local authorities and using materials/presentations prepared under the projects (including the InAirQ). It is very important to conduct scientific literature reviews periodically and to select articles taking into account their importance in terms of human and children health, and to disseminate them among school personnel to raise their awareness of air quality.

Increasing awareness of school heads/teachers/technical personnel will result in the increase in their involvement in taking up actions for the sake of the indoor air quality improvement.

Subject of the indoor air quality should be introduced to the core curriculum of teachers' education. Airing classrooms during classes with children is the most basic action towards ensuring suitable air quality and any negligence at this level results in the necessity to take actions requiring more funds and commitment on the part of the management and school maintenance institutions.

What is more, institutions responsible for thermo-modernization should be trained how to select proper materials and technological processes used in the case of thermo-modernization of a school. Those institutions should also implement clear and transparent procedures concerning schools selection for thermo-modernization as well as other renovations.

The awareness raising tasks can be carried out at a regional level by academic / scientific institutions at the request of local /regional authorities.

The target groups: local/regional/national authorities, architects, building engineers, building supervisors, school directors, teachers, technical staff, students/pupils and their families.

4.5 Legal regulations and local/regional guidelines

Currently, in Poland there are no detailed legal regulations in the field of the indoor air quality in schools. The process should be started with preparing a project of such regulations. However, before that begins, actions consisting in formal acceptance of guidelines elaborated as part of the projects (inter alia the InAirQ project) by local and regional self-governments authorities should be taken up. Recommendations in such a situation are given a status of Guidelines, and thanks to that management institutions are obliged to use them to an extent their funds allow. The guidelines should first of all include reference values for nuisance agents (physical parameters and CO_2 concentration) and harmful agents (chemical and biological air pollutants). Moreover, the guidelines should indicate recommended methods for monitoring and measurement of the indoor air, as well as institutions that perform such studies. The last part of the guidelines should include types of actions that improve air quality.

4.6 Institutions responsible for supervising the Indoor Air Quality

In Poland there is a system of supervision of hygiene of kids and teenagers, which is a duty of an appropriate department of the State Sanitary Inspection. However, such controls carried out in educational units so far has not included the indoor air quality assessment. Actions aiming at introduction of the indoor air quality assessment to the permanent tasks of this inspection should be taken. As part of the InAirQ project such actions have already been taken. Personnel of children hygiene departments from the whole voivodeship of Lodz (voivodeship sanitary and epidemiological station and all county sanitary and epidemiological stations) were trained in the field of the indoor air quality in schools (sources of pollution, causes of bad ventilation, health effects in children, ways to improve the indoor air quality). Analogical trainings should be carried out in the whole country by academic/scientific institutions commissioned by the Chief Sanitary Inspectorate or the Ministry of Health.

4.7 Background activities

It is recommended that in schools in which after thermo-modernization the decline of the indoor air quality is observed, as first the following should be undertaken:

1. Action of gathering all possible data about the school building's characteristics and activities of its occupants.
2. Identifying indoor and outdoor pollutant sources and, if possible, also their strength.
3. Measurements and, if possible, monitoring of indoor air pollutants.
4. Checking the subjective assessment of the indoor air quality by teachers and students/pupils.

4.8 Essential activities

If background activities indicate problems with IAQ in the next step actions aiming at improvement of the IAQ should be undertaken:

1. Ventilation rate has to be checked. If the ventilation is poor:
    a. ventilation tracts should be cleaned or reamed out or it should be checked if they are not blocked by furniture;
    b. mechanical ventilation (or hybrid ventilation) could be installed; however then the outdoor air quality should be taken into account. In the case of a high level of outdoor air contamination there is the need for air filtration (e.g. carbon or HEPA filters) and the level of additional noise caused by operations of these systems;
    c. CO_2 alarm should be installed in each classroom as part of the indoor air quality problem;
    d. detailed procedures of ventilation and airing of the classrooms by teachers and cleaners should be prepared, implemented and executed;
    e. installation of trickle vents could be crucial to the proper air circulation inside a classroom. It is important to select proper trickle vent. In the case of schools with relative humidity on a very low level trickle vents automatically controlled by the pressure should be installed. Trickle vents start opening along with the increase of the pressure difference between the inside and outside air. Installation of the trickle vents automatically controlled by the level of relative humidity in the indoor air can be ineffective.

2. If there is no possibility to finance actions described in point 1a – 1e, a possible solution is to minimize the number of students/pupils in a classroom in which the low indoor air quality is diagnosed.
3. Equipment which emits volatile organic compounds and particles during operation (e.g. copiers, printers) should be used in a separate room outside the classrooms.
4. Cleaning should be done according to specially developed procedures with clear formulated:
   - frequency (each day),
   - time of day (after the end of the classes),
   - equipment (mops and cloths for dusting from microfiber)
   - cleaning products (prohibitions of irritant products, sprays only if they are absolutely necessary).
5. Floor should be made from solvent-free, low-emission materials with a certificate and should stay clear without textile covering.
6. Furniture has to be made from low-emission materials with a certificate on using in schools (children friendly).
7. Art works in classes should be undertaken only under control of a teacher and with controlled ventilation or airing. Art materials (paints, sticks, markers etc.) have to be stored in hermetic cabinets /drawers / boxes.
8. All possible sources of indoor pollutants should be removed to a separate room or encapsulated in a proper way (hermetic box, laminated surfaces) or replaced by the new ones (e.g. furniture, painting surfaces of wall, decorations, boards).
9. Classes should be equipped with species of plants recommended for absorbing PM and chemical pollutants from the indoor environment. It is important to elaborate plants cleaning instructions (designate school staff/students/pupils who will clean the plants and establish minimal frequency of cleaning).
10. Activities of children should be modified depending on the indoor air quality. During intensification of the atmospheric air pollution children activities taking place outside the school should be stopped or reduced to a minimum.
11. The area surrounding a school should have as much greenery as possible.

12. If there is such a possibility a car park should be located in some distance from the classrooms windows. In a situation where there is no such a possibility specially prepared procedures of airing classrooms (the windows should be opened not in the peak parking hours) should be prepared, implemented and executed.
13. Schools directors should observe the incidence of respiratory diseases among students / pupils listed in the literature as those associated with the air pollution and undertake proper actions in the case of increased morbidity among school children (e.g. in selected classes).
14. In schools in which there is a high level of radon or it is suspected on the basis of a proper map, actions recommended by the WHO should be taken. The World Health Organization, WHO recommends taking actions that reduce the level of radon in buildings, where its concentration exceeds 100 Bq/m3. Among the available, low-cost methods of reducing radon concentration in buildings there are:
    - improvement of natural ventilation of air,
    - airing classrooms in the morning before the lessons start,
    - increased ventilation under the floor, which prevents penetration of radon from the basement into utility rooms,
    - sealing floors and walls (e.g. sticking visible cracks and scratches),
    - educating users of the rooms in the field of natural ventilation (airing necessity).

4.9 Economic estimation

Admittedly, undertaking the proposed activities (including ventilation ducts, installation of additional mechanical or hybrid ventilation, installation of ventilators in the window trickle vents, purchase of air quality monitoring devices) is connected with incurring certain costs by municipalities and local / regional self-governments maintaining schools. Nevertheless, taking into consideration growing costs of treating children with the symptoms on the side of the upper respiratory tract and allergies in the whole country, such activities are economically justified.

Excessive concentration of CO_2 results in reduction or even makes proper concentration and learning the material processed during the lessons impossible. Therefore, an additional issue is the immeasurable profit in a form of improved effectiveness of education of children and the youth obtained as a result of improved learning conditions via reduction of CO_2 concentrations in the classrooms.

4.10 Feasibility assessment and timing of implementation

The proposed plan of actions is feasible with engagement of all institutions and individuals associated with the school environment. Its feasibility will be ensured by taking actions in a specific order:

1. Raising awareness in the engaged parties (education/courses/trainings/media actions).
2. Indicating individuals and institutions responsible for improvement of the indoor air quality in educational units and supervision of this issues.
3. Defining current problems and preparing plans of actions at the school/local/regional and national levels.
4. Indicating sources and determination of the budget at the school/local/regional level.
5. Taking up direct actions in accordance with the prepared plan, first focusing on low-cost or no cost actions. If they do not bring about assumed results, taking up technical actions. In case of the observed increased morbidity among children in a specific group (e.g. school, wing of the building, classroom) one should immediately ask the institution responsible for the school for allocation of funds allowing all possible actions to be taken to reduce the negative health effects in children.